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CIRADS

Sponsor:
ADVANCED RESEARCH
PROJECTS AGENCY

PROCEEDINGS (U)

Volume I
Part 1

Published by
Infrared Physics Laboratory
Willow Run Laboratories
Institute of Science and Technology
The University of Michigan

14, 15, 16 June 1966
Arlington, Virginia

NOTICES
Unclassified

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CIRADS PROCEEDINGS (U)

VOLUME I, Part 1

Meeting of 14, 15, and 16 June 1966
ARLINGTON, VIRGINIA

PROJECT AGILE

Sponsored by
ADVANCED RESEARCH PROJECTS AGENCY

Published by
Infrared Physics Laboratory
WILLOW RUN LABORATORIES
THE UNIVERSITY OF MICHIGAN
under CONTRACT SD-91
with
ADVANCED RESEARCH PROJECTS AGENCY

SECRET

PREFACE
Unclassified

CIRADS (Counterinsurgency Research and Development Symposia) were organized to provide a forum for the exchange of technical information in the area of counterinsurgency research and development The operational activities undertaken by the Department of Defense to provide overseas internal defense assistance to the developing nations are broad indeed; these include civic action, psychological operations, paramilitary and military training, provision of military equipment, and actual participation in anti-guerrilla warfare. The scope of supporting research and development is as broad as these operations. Therefore, CIRADS are concerned with subject matter ranging from the technology of reconnaissance and weapons through tactical and strategic analyses to research in the biomedical and social sciences.

The last five years have seen an enormous growth of research and development effort in these many areas. This growth has been spurred largely by the growing war in Viet Nam and by an increasing awareness of such problems elsewhere in the world. The Department of Defense research and development during this period has concentrated on highly specialized items designed for use in Viet Nam as well as on efforts with more general application. These efforts are now sufficiently developed to permit them to be defined as integrated research and development activities including many technical disciplines, with a focus on the overseas internal defense problem. The purpose of CIRADS is to help provide this focus.

The CIRADS Proceedings is the written record of the papers presented at the meeting, and of other papers accepted for publication only rather than for oral presentation. The publication is handled for ARPA by BAMIRAC (Ballistic Missile Radiation Analysis Center), a facility of the Infrared Physics Laboratory, Willow Run Laboratories, Institute of Science and Technology at The University of Michigan. BAMIRAC, and is supported by ARPA under Contract SD-91.

This first volume of the CIRADS Proceedings comprises papers that were presented at or prepared for the first meeting. The meeting was held at the Institute for Defense Analyses, Arlington, Virginia, on 14, 15, and 16 June 1966. The program for the meeting is reproduced on the following pages; last-minute changes are noted there.

Part 1 contains papers classified through Secret. All classified papers in Part 1 have been approved for release to ABC (Australian-British-Canadian) Nationals cooperating with the United States under the TTCP Subgroup H-Counterinsurgency Programs. Part 2 contains papers not releasable to foreign nationals.

ABSTRACT
Unclassified

CIRADS Proceedings, Volume I, comprises papers presented at or prepared for the first meeting of the Counterinsurgency Research and Development Symposia, held at Arlington, Virginia, on 14, 15, and 16 June 1966, under the sponsorship of the Advanced Research Projects Agency of the Department of Defense, Project AGILE. Papers prepared for but not presented at the meeting are included.

The purpose of the meeting was to provide a forum for the exchange of technical information in the area of counterinsurgency research and development. The subject matter ranges from the technology of reconnaissance and weapons through tactical and strategic analyses to research in the biomedical and social sciences.

Part 1 contains papers classified through Secret. All classified papers in Part 1 have been approved for release to ABC (Australian-British-Canadian) Nationals cooperating with the United States under the TTCP Subgroup R-Counterinsurgency Programs.

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[redacted]
Institute for Defense Analyses
Arlington, Virginia

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Institute for Defense Analyses

CIRADS PROGRAM

TUESDAY
14 June 1966

9:00-9:30 **Introductory Remarks**
Dr. Charles M. Herzfeld, Director
Advanced Research Projects Agency
Washington, D. C.

9:30-10:00 **Scope of Counterinsurgency R&D and** [redacted] CIRADS Chairman
Institute for Defense Analyses
Arlington, Va.

Session 1
RECONNAISSANCE

10:00-10:05 [redacted] Session Chairman
Institute for Defense Analyses
Arlington, Va.

10:05-10:45 1 Reconnaissance to Support Counterinsurgency Operations
J. A. Stringham, Griffis Air Force Base
Rome, N. Y.

10:45-11:15 Break

11:15-12:00 2 Reconnaissance in Viet Nam
Colonel D. Anderson, USAF, Office of the Deputy Chief of Staff, Research and Development, Washington, D. C.

12:00-12:40 3 Aerial Reconnaissance in Counterinsurgency
[redacted] McDonnell Aircraft Corp.,
St. Louis, Mo.

12:40 END OF SESSION

Session 2
APPLICATIONS OF AVIATION

2:00-2:05 [redacted] Session Chairman
Research Analysis Corp., McLean, Va.

2:05-2:45 4 Counterinsurgency Aircraft Requirements
Brig. General A. Evans, USAF, Director of Development and Assistant for Counterinsurgency, Office of the Deputy Chief of Staff, Research and Development, Washington, D. C.*

2:45-3:25 5 Army Uses of Aviation in Counterinsurgency
Brig. General R. R. Williams, USA, Director of Army Aviation, Office of the Assistant Chief of Staff for Force Development, Washington, D. C.

3:25-3:45 Break

3:45-4:25 6 Cost Effectiveness Analysis of Counterinsurgency Aircraft
[redacted] Institute for Defense Analyses, Arlington, Va.

4:25-5:05 7 STOL and V/STOL Transport Aircraft in Support of Counterinsurgency Operations
[redacted] McDonnell Aircraft Corp.,
St. Louis, Mo.

5:05 END OF SESSION

*Paper delivered by Col. P. E. Hooper.

WEDNESDAY
15 June 1966

Session 3
GROUND OPERATIONS

9:00-9:05 [redacted] Session Chairman
Litton Data Systems, Van Nuys, Calif.

9:05-9:45 **8** Ambush Detection—A Survey
F. K. Kaprelian, Technical Director
U. S. Army Limited War Laboratory
Aberdeen Proving Ground, Md.

9:45-10:25 **9** Defense Against Underwater Swimmer Attack
S. B. Marley, R. W. Denton, U. S. Navy Mine Defense Laboratory, Panama City, Fla.

10:25-10:45 Break

10:45-11:25 **10** Tests and Measures for Mobility
[redacted] Institute for Defense Analyses, Arlington, Va.

11:25-12:05 **11** Tropical Radio Propagation Research Program
[redacted] Jansky & Bailey Division
Atlantic Research Corp., Alexandria, Va.

12:05-12:45 **12** Securing a Petroleum Complex Against the Threat of Insurgent Sabotage: A Systems Approach
[redacted] Defense Research Corporation, Santa Barbara, Calif.

12:45 END OF SESSION

Session 4
RESEARCH AND ANALYSIS - I

2:00-2:05 [redacted] Session Chairman
Life Insurance Agency Management Association, Hartford, Conn. (formerly Director, Behavioral and Social Sciences, ODDR&E)

2:05-2:45 **13** Social Science Applications to Counter-insurgency: Problems and Prospects
[redacted] Stanford University, Palo Alto, Calif.

2:45-3:10 **14** New Perspectives in Training and Assessment of Overseas Personnel
[redacted] Human Resources Research Office, The George Washington University, Washington, D. C.

3:10-3:35 **15** Research in Training for Advisory Roles in Other Cultures
P. H. King, 6570th Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio

3:35-3:55 Break

3:55-4:25 **16** Some Relations Between Urban and Rural Insurgents
[redacted] Defense Research Corp., Santa Barbara, Calif.

4:25-4:55 **17** Essentials of Communist Insurgent Strategy: Organization and Concept of Operations
[redacted] The American University, Washington, D. C.

4:55 END OF SESSION

THURSDAY
16 June 1966

Session 5
RESEARCH AND ANALYSIS - II

9:00-9:05 [redacted] Session Chairman
Advanced Research Projects Agency
Washington, D. C.

9:05-9:45 **18** Insurgency in an African Country
R. N. Hazelwood, Chief Scientist, United States Strike Command, MacDill Air Force Base, Fla.

9:45-10:25 **19** Conceptual Analysis of the Malayan [redacted] Historical Evaluation and Research Organization, Washington, D. C.

10:25-10:45 Break

10:45-11:25 **20** Counterinsurgency Systems Research in Thailand
[redacted] Stanford Research Institute [redacted] Park, Calif.

11:25-12:05 **21** [redacted] RAND Corp., Santa Monica, Calif.

12:05 END OF SESSION

Session 6
SPECIFIC APPLICATIONS OF TECHNOLOGY

2:00-2:05 [redacted] Session Chairman
[redacted] of Michigan, Ann Arbor, Mich.

2:05-2:45 **22** Close Air Support Avionics for Counter-insurgency Applications
[redacted] Institute for Defense [redacted] Arlington, Va.

2:45-3:05 **23** Contrail Suppression
S. J. Birstein, Air Force Cambridge Research Laboratories, Bedford, Mass.

3:05-3:30 **24** Operation of Implanted-Sensor Systems in [redacted] Calif.

3:30-3:50 **25** Testing the Rubidium Vapor Magnetometer [redacted] Royal Australian Air Force, Military Research & Development Center, Bangkok, Thailand

3:50-4:05 Break

4:05-4:45 **26** Performing Research in an Active Counter-insurgency Environment
Brig. General J. Boles, Deputy Commanding General, USA Test and Evaluation Command, Aberdeen Proving Ground, Md. (formerly Director, Joint Research and Test Activity, Viet Nam)

4:45-5:00 [redacted] Director, Project AGILE, Advanced Research Projects Agency, Washington, D. C.

5:00 END OF MEETING

The following papers will be published in the Proceedings but will not be presented at the meeting.

27 Infrared Detection of Heat Sources Obscured by Tropical Rain Forest Vegetation
[redacted] The University of Michigan, Ann Arbor, Michigan
J. Rinker, U. S. Army Cold Regions Research and Engineering Laboratory, Hanover, N. H.

28 Error Analysis and Data Requirements for Models of Pre-Revolutionary Conditions
[redacted] bt Associates, Inc., Cambridge, Mass.

29 Resonant-Region, Phase Comparison Radar for Detection of Objects in Clutter
C. J. Sletten, P. Blacksmith, C. E. Ellis, Air Force Cambridge Research Laboratories, Bedford, Mass.

30 Monitoring the Physical Status of Guards by Means of Biosignal Telemetry
[redacted] RAND Corp., Santa Monica, Calif.

31 Status and Trends of Laser Line Scan Sensors for Night Reconnaissance
N. L. Rowe, Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio

32 The Visual Reconnaissance Program in South Viet Nam
[redacted] RAND Corp., Santa Monica, Calif.

33 A Counterinsurgency Communications Simulation
[redacted] Defense Research Corp., Santa Barbara, Calif.

34 Toward a Model of Revolutionary Political Recruitment
[redacted] Abt Associates, Inc., Cambridge, Mass.

35 Potential Scope of Application of the ARL Separator for Turbine Powered Vehicles
R. Poplawski, Aerospace Research Laboratories, Wright-Patterson Air Force Base, Ohio

36 A Mathematical Framework for the Dynamic Insurgent Society
[redacted] Defense Research Corp., Santa Barbara, Calif.

37 A Conducting-Slab Model for Electromagnetic Propagation Within a Jungle Medium
[redacted] efense Research Corp., Santa Barbara, Calif.

CONTENTS*
Unclassified

* All paper titles are unclassified.

INTRODUCTORY REMARKS* (U)
Confidential

Dr. Charles M. Herzfeld, Director
Advanced Research Projects Agency
Washington, D. C.

I'd like to welcome all of you to this meeting, which is the first of its kind, we believe, and we hope the first one of a long series.

Let me make a few comments about why there is a problem in the research community with respect to counterinsurgency. If we look at the history of research on defense problems, at least in this country, we immediately get the impression that, for the last twenty years or so, most of the real thinking (both by the military and by civilians), on war, on technology for war, and on strategy, has been concentrated on problems of strategic war. This trend started soon after World War II and was no doubt influenced by a number of factors and dominated by two features. The first was the introduction of nuclear weapons, which changed the dimension of war in a number of ways. The second was that strategic war is very much easier than any other kind to understand and to analyze. This is particularly so of a war fought with ballistic missiles, particularly if there are no defenses; and if we are talking about a war with ballistic missiles and thermonuclear weapons and there are no defenses, then Newton's laws plus a little bit of weapons-effects information will see us through every time; that is, simple calculations and simple models provide meaningful answers, a situation which is appealing to scientists and engineers. And indeed, I think it is fair to say that, at this stage of the game, strategic war is rather well understood on the whole. We think we know what we are doing.

But if we look at the world today, it's perfectly clear that the war that's really going on is a quite different kind of war and that in fact the chances for a strategic war have gone down dramatically in the last five to ten years.

What kind of war are we really coping with? Well, the phenomenon in Viet Nam is a most instructive one, and I'll come back to that. There are lower-level conflicts, such as the one in Thailand. There are sub-sub-counterinsurgency situations in parts of Africa and Latin America. In general there is a series of conflicts going on now, and these promise to go on for a long, long time. They are quite different from any of the kinds of wars that most of us have thought about; certainly

*Transcribed from tape recording.

they are quite different from the wars that most of the people in the R&D community have thought about. So the question that arises is how should we think about the R&D problems posed by these new kinds of wars.

First of all, I think it is evident that our ability to do R&D and to apply it is one of the advantages we have in this kind of conflict. In particular, our ability to understand human societies in detail is one of the unparalleled advantages we have. It is simply a fact that American social science is deeper, more advanced, more powerful than in any other country in the world. On the other hand, we have some handicaps in R&D. We continually think of making things the way we make them for satellites, the way we make them for ICBM's. And the notion of building very simply and crudely doesn't appeal to many engineers in this country. One can't get either rich or famous by building something which is simple, rugged, and would last forever. This attitude is a very serious handicap, which in various quarters of this country's R&D communities is beginning to be overcome, but by no means everywhere and by no means to a great enough extent.

The second feature of this kind of conflict which we must face is that it is enormously more complicated than the strategic conflicts we have thought about in the past. It is simply not enough to deal only with Newton's laws and with a little bit of weapons-effects information. We know perfectly well, I think, that counterinsurgency is a very involved mixture of human problems, of historical matters, of geology, of weather, of political problems — all kinds of things in addition to the straightforward military problems of finding people and killing them. The military problems are clearly not the only, and may not even be the most important, feature of counterinsurgency operations. This kind of war depends heavily on the details of the situation. For example, those of us who have had the chance to look at the war in South Viet Nam in some detail know that there are many wars going on in Southeast Asia, and that these wars are quite different from each other. Our air war in North Viet Nam is quite different from our air war in South Viet Nam. Our land operations in the highlands of South Viet Nam are quite different from the land operations of the Delta, with different technologies, different human kinds of problems, and so on. Of course they have some things in common, and some of these will be explored at this meeting.

I've been particularly struck in trying to think about counterinsurgency-type wars by one particular fact: whereas in thinking about strategic war and its strategies you can make real impact with a one-dimensional ladder of escalation in the manner of Herman Kahn (where you can measure violence in one dimension), on the contrary, in counterinsurgency it is quite clear that you cannot get anywhere with a model which is this simple, just because many factors other than military violence are involved — political power, economic power, psychological force, and so on. I have sometimes thought that what we ought to do is to write down several escalation ladders in parallel, one for military conflict, one for political, one for economic, one for psychological, and perhaps others. These different ladders interact with one another. In other words, if we move up on one ladder this may be the equivalent of moving down on another. For example, it is conceivable that an increase in military violence will in fact amount to a decrease in some other kind of conflict, and so on.

Now there is an interesting factor here: of course Herman Kahn's one-dimensional ladder for strategic war is a great oversimplification, and if we tried to do the job more completely even for strategic war, we would have several ladders describing different kinds of conflicts. However, because the time of strategic war is measured in weeks and the time of counterinsurgency war in years, in counterinsurgency these different kinds of forces interact in a much more visible and in a much more complicated way. I raise this as a problem rather than as a finished thought.

Let me change gears abruptly and talk about something completely different: how are we organized to do research on counterinsurgency? I will address a very narrow fraction of that problem so that I may be able to tell you why it is that we are starting this particular form of symposium, why we believe that it may be worthwhile to do so, and why we have great hopes for it. It is simply a fact, which everyone who has done research in any field appreciates, that every field must have a more-or-less institutionalized way of exchanging information and (equally important) of accumulating information which has been judged to be interesting by some set of standards. Without this, the field will flounder. The early history of science shows this very well, in fact, the early history of any science shows this very clearly. In counterinsurgency R&D we have been frustrated for a number of years, and I personally have been frustrated for something like three years, by the absence of regular technical meetings and publications, which allow the accumulation of results of importance.

I was reminded by this of the state of affairs which existed in another technical community in which some of us are involved — ballistic missile defense, where for a number of years we also had no formal means of gathering to exchange information. The community, though very large, was very amorphous and had no regular focus. A regular meeting evolved over several years, starting out as an advisory committee, and it wound up being a regular scientific meeting, the so-called AMRAC meeting. AMRAC proves that it is possible to invent a mechanism whereby the people who contribute to the field get together regularly in a good scientific meeting and are able to present classified results, are able to discuss them critically, and in particular are able to accumulate a printed record of the papers. Well, a number of us decided to try something similar in counterinsurgency R&D and finally, after a year and a half of talking and planning, we are opening today the first meeting of its kind for counterinsurgency R&D.

It seems to me that this is an extremely important step forward. It seems to me that this is a sign that counterinsurgency R&D has reached a significant level of maturity. From the point of view of the consumer of R&D rather than the producer, we have a right to expect from all of you a much more careful, better organized, and more concerted approach to the problems at hand. From now on you do have a forum where you can bring your papers, where you can give them, where you can have them criticized by each other, where you can present them before a lively and large technical audience. It is quite clear that this meeting is an experiment. But if history is any teacher at all, I'm quite convinced that this experiment will succeed.

With respect to the subjects we are discussing, I can say that this is quite easily the broadest military R&D field that I have ever run across. The subjects range from narrow weapons effects of conventional weapons like hand grenades in the jungle, all the way to communications theory, sociology, anthropology, economics, political science, and what have you. I think we must be prepared in future meetings as we are in this one to accept papers which cover the whole range. Obviously this means that we cannot treat all aspects of the problem equally well all the time. I think it does mean that we must take care that no major aspect of the field is overlooked for long. This is a very serious responsibility for the people who are planning these meetings, and it is a responsibility which I think they have discharged in a brilliant way in this particular meeting.

I don't know how often this meeting ought to be convened. We are thinking tentatively of once a year. It may turn out that by the end of the summer or even by the end of this meeting we will all be convinced that that's much too soon or not often enough, that this kind of meeting ought to be held twice a year or every five years. We are quite open minded on this score, and would like very much to have your reactions to these questions: (A) Was it worthwhile? (B) What can we do to improve it? (C) How soon should we meet again? (D) What great papers have been overlooked by the excellent program committee? That too happens in this kind of business.

Let me conclude then by saying again how glad I am that you are here, how very grateful I am to the many people who have made this meeting possible, in particular the Program Committee under Sy Deitchman's chairmanship. I think there is no question that, in a meeting like this, the Program Committee has an absolutely crucial role to play. It is the group which makes sure that interesting, important, controversial matters come to the floor, that trivial, uninteresting, or wrong matters do not; that pseudo-results are relegated to the place where pseudo-results belong (maybe the "round" file); but on the other hand, that important results are highlighted and sharpened as much as possible. In addition we must thank the Arrangements Committee, which was headed by Tom Couper of The University of Michigan. Also, I think all of us owe a great deal of thanks to Fred Koether of ARPA, who made the security arrangements.

Thank you very much for being here. It's good to see you. Let's go.

SCOPE OF COUNTERINSURGENCY R&D AND CIRADS* (U)
Confidential

[redacted] CIRADS Chairman
Institute for Defense Analyses
Arlington, Virginia

Before the planned program starts I would like to repeat Dr. Herzfeld's welcome, and to welcome you all to the IDA building and the IDA auditorium. We've tried to put together a program that you will find interesting, and having the scope Dr. Herzfeld outlined. Before we begin, I would like to describe more of the specifics of the R&D problem, and how R&D in this area is accomplished in the Defense Department. It's a very complex organization, and we should start from a frame of reference where everybody has the same information. I'd like also to make a few comments on the scope and organization of this symposium.

Why do we have special requirements for counterinsurgency research and development? Why is it different from other R&D? I think Fig. 1 makes fairly clear the conditions under which

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SPECIAL REQUIREMENTS IN COIN

DERIVE FROM:

1. UNDERDEVELOPED AREAS
2. DIFFICULT TERRAIN
3. UNFAMILIAR CULTURES
4. LOW INDIGENOUS TECHNOLOGICAL CAPABILITY
5. "PRIMITIVE" ENEMY: HIGHLY MOTIVATED; SIMPLY EQUIPPED AND ORGANIZED
6. CONFLICT REVOLVES AROUND NON-COMBATANT POPULATION
7. U.S. PREDOMINANTLY IN ADVISORY RATHER THAN COMBAT ROLE

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FIGURE 1

*Transcribed from tape recording.

counterinsurgencies in which the United States is involved most often take place, and that we're getting into problem areas that perhaps we hadn't particularly thought about for many years. I would like to call special attention to the last two points on Fig. 1. Item 6 should not be forgotten: that most often we're fighting a war for people; we are not fighting a war of army against army. Item 7, that the United States is predominately in an advisory role, might seem rather strange when we read the news from Viet Nam. But the Viet Nam conflict started that way, and that part of the war does continue. We have seen it overlaid by conventional limited war of rather large proportions. But the important part of the Viet Nam war still revolves around these last two items, even though the research and development that affects it spans all the problems of the many aspects of the war.

Now what problem areas are important? If we consider that a communist-instigated and -supported war of subversion really has three phases to it, we can then single out in parallel with those phases the problems that we need to worry about. (See Fig. 2.) To begin with, one must defend the institutions of government, its installations, economic facilities, etc., against the depredations of a guerilla insurgent attack. One must also attack the insurgents so that they cannot operate freely. But then, also, one must work with the population. For an insurgency to a rise, there must be grievances within the population; the people must be attracted to the insurgent side and away from the government. Their condition has to be transformed so that they would rather support the government than the insurgents. This requires attention to the economic, social, and political problems that are a key part of this kind of war.

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MAJOR PROBLEM AREAS

1. IMPROVE ABILITY OF DOD TO SHARE IN NON-PURELY-MILITARY ASPECTS OF CI
   - A. CIVIC ACTION
   - B. INTERNAL SECURITY (POLICE)
   - C. PSYCHOLOGICAL OPERATIONS
2. IMPROVE ABILITY TO: FURNISH AREA-ORIENTED, LANGUAGE TRAINED TROOPS ; ESTABLISH EFFECTIVE ADVISOR-COUNTERPART RELATIONS
3. IMPROVE ABILITY TO FIND AND IDENTIFY INSURGENTS AND THEIR SUPPLIES
4. IMPROVE ABILITY TO DEFEAT INSURGENTS' TACTICAL MAINSTAYS:
   - A. AMBUSH AND SURPRISE ATTACK
   - B. ACROSS-BORDER INFILTRATION
   - C. COAST AND INLAND WATERWAY OP'NS
   - D. NIGHT OPERATIONS
5. IMPROVE PRECISION AND CONTROL OF AIR-GROUND OP'NS
   - A. MORE EFFECTIVE
   - B. LESS COLLATERAL DAMAGE TO POPULATION

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FIGURE 2

There are many agencies in addition to the DoD involved in counterinsurgency warfare. The DoD's responsibilities overlap those of the civilian agencies and also shade into more or less conventional tactical warfare. The spectrum of problems pretty much follows this spectrum of activities. Our agents are involved with the civil as well as the military population. Since we furnish advisors and since the job the United States can do is as good as the people we send to do it, we must worry about what types of advisors are sent and how well they are trained for solving the problems they meet. A key technical problem arises from the fact that an insurgent survives by hiding; he is not to be found when someone wants to find him. Next, he has certain tactical mainstays. It's because of these that a numerically inferior force, one that has, by almost any standards, armaments inferior to those of the defender, can defeat a superior force. These tactics are not easy to overcome because of the surprise that characterizes them and the ability of the insurgent to pick the place of his attack. Further, we have seen in Viet Nam that air operations can have a very important part in counterinsurgency, but that they must be very carefully controlled, if they're to have the desired effects and not be counterproductive.

I think it can be shown that most of the problems that face the DoD— those that can be solved with the help of research and development—can be related to one or another of these problem areas. However, the DoD doesn't quite work on the problems in this order. (See Fig. 3.) The program is really divided into a number of technical areas. The first one listed, "Reconnaissance, surveillance, intelligence, command, control," is very often thought about in terms of the separate entities. We find, however, that in a counterinsurgency war if these are not very closely integrated it is difficult for efforts in any one of these areas to be effective by themselves. Night operations

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TECHNICAL AREAS

1. RECCE, SURVEILLANCE, INTELLIGENCE, COMMAND/CONTROL
2. NIGHT OPERATIONS
3. CROSS-COUNTRY MOBILITY, EXTREME TERRAIN
4. INCAPACITATING WEAPONS
5. AIR-GROUND WEAPON DELIVERY SYSTEMS
   - TARGET ACQUISITION
   - COORDINATION (AIR-GROUND)
   - ACCURATE WEAPON DELIVERY
   - SPECIALIZED WEAPONS
6. MEDICAL AND LIFE SCIENCES
   - EXOTIC DISEASES
   - PUBLIC HEALTH IN UNDERDEVELOPED AREAS
   - ACCLIMATIZATION
7. OTHER NON-MATERIEL RESEARCH
   - POLITICAL AND COIN STRUCTURAL STUDIES
   - PERSUASION AND MOTIVATION RESEARCH
   - OPERATIONS AND ECONOMIC RESEARCH
   - SELECTION AND TRAINING RESEARCH
8. OTHER FIREPOWER
9. OTHER MOBILITY AND LOGISTICS
10. COMMUNICATIONS

~~CONFIDENTIAL~~

FIGURE 3

are closely related to the reconnaissance and surveillance problem, but also pose some operational problems of their own. Not the least of these problems is overdependence by troops on gadgetry for seeing by night, instead of dependence on adequate training for night operations. The incapaciting-weapon problem is, as you know, rather deeply involved in many aspects of policy. The obligation of the research and development people is to make sure that a capability is "on the shelf" and ready for use if policy calls for it.

A special problem occurs in the area of aircraft attack systems. Even though it's not necessarily easy to design good weapons, it seems to be easier for people to think of work to do in the weapons area than in the other areas. If we look at the overall research and development program we find that by far most of the effort and money is devoted to weapons. Much less is devoted to the other three areas: target acquisition, communications, and fire control; and these areas need very much more work. Some further things will be said about this problem at this meeting.

Now, a final comment about nonmaterial research (the other technical areas listed need no further elucidation). That refers to the four separate areas of effort listed on the figure. They interact, and this is worth keeping in mind. As a general matter, one must collect projects into programs, and such groupings are necessary even at this conference. But the important thing to remember is that most of the problem areas interact with each other and must be treated together at some point. We'll be hearing something about work in most of these technical areas in the next three days.

Let's look for a moment at how the counterinsurgency R&D area is organized for management within DoD. (See Fig. 4.) This is very complicated, and I'll have to be brief. The research and

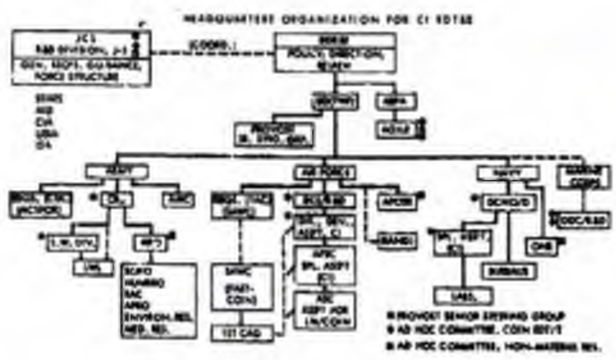


FIGURE 4

development direction starts with the Director of Defense Research and Engineering, and lines of coordination are not always shown: there must be coordination with the Joint Chiefs and also with all of the other agencies listed. The line of authority to the military departments goes through the Deputy Director for Tactical Warfare Programs. In addition, the Advanced Research Projects Agency supports Project AGILE, whose work covers the entire spectrum of problems. Although it's hard to show here, it should be made clear that there is close coordination between ARPA and the military departments, between ARPA and the whole DDR&E "shop," and also among the military departments.

Below this level there are a number of threads to be traced, in each of the military departments. The first is the requirements track: it must answer the question, "What do we need?" Then there is the hardware development track; in most cases there is a separate coordinating or directing agency for specialized research and development on counterinsurgency problems. Under the Chief of Research and Development of the Army, for example, this responsibility resides in the Special Warfare Division, which also has cognizance over the U. S. Army Limited Warfare Laboratory. In the Air Force, the agency is at Wright Field, and also, through the Operating Forces to the Special Air Warfare Forces, there is a specialized laboratory where urgent short-term developments can be undertaken. The Navy works through its laboratories and bureaus, again with a Special Assistant to make sure that this very diversified program is tied together. In addition to all this, separate tracks exist in each Service for what may be called "software": operations research, environmental research, and social sciences research.

Now, these efforts are coordinated at many levels of management. For Viet Nam, there is the PROVOST Senior Steering Group, which is made up as shown by the asterisks in Fig. 4. PROVOST as some of you know, is an administrative scheme for expediting the research and development that supports operations in Viet Nam. Requirements can be expressed very quickly; if the Military Assistance Command in Viet Nam says it needs something, then a requirement is established. The military departments and ARPA use supplemental appropriations, emergency funds, or special project funds to apply money against these requirements without delay for the usual budget cycle. At the next lower management level, the people who have special responsibility for tying together the diverse research and development efforts meet as an ad hoc committee on counterinsurgency R&D, to act on problems that involve coordination between the Services, among the Services, ARPA, DDR&E, etc. Similarily, there is a mechanism of this kind on the software side.

This is not yet the whole picture. Since we are primarily concerned with research and development that has to do with the military efforts of foreign countries, we also need connections in the foreign countries for research and development there. This relates particularly to field research, to tests and evaluation of equipment designed to operate in special environments, and especially to the need for "requirements" input from the field—it's unreasonable to expect people sitting in Washington to know what the problems are in the backwoods of countries like Thailand or Iran. Figure 5 shows that there has also been a rather complex organization built up to handle this aspect of counterinsurgency R&D.

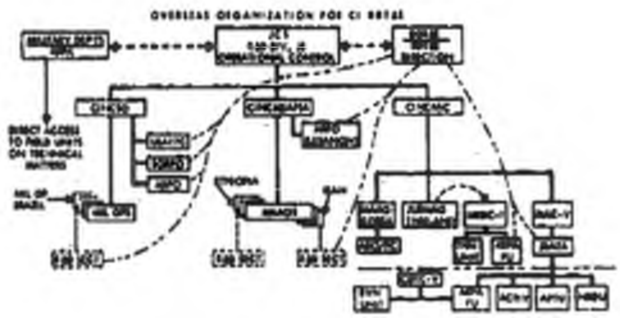


FIGURE 5

Since field R&D groups are attached to operating organizations, the line of command really goes through the Joint Staff, but (as shown) the research and development community has direct connections with the field. The organizational elements exist under the cognizance of the Commanders in Chief of the three main geographical areas of concern: Latin America; Africa, the Middle East, and South Asia; and the Pacific. In Panama, under Commander in Chief, Southern Command, there is the U. S. Army Tropic Test Center, the SORO* Field Office, and the ARPA Field Office, all concerned with coordinating research in Latin America. For the Middle East-Africa-South Asia area there is an ARPA Field Office in Lebanon which has a similar concern in its area. As an experiment, research and development sections were established last year in three of the Military Assistance Advisory Groups: Brazil, Ethiopia, and Iran. The purpose of these sections is to see that specific specialized requirements are expressed; to give full-time attention to field research and development efforts in their areas; to make sure there is follow-through and good coordination in the field. If successful, this sort of arrangement may well spread further. Next there is an Army Research Office field office attached to the MAAG in Korea; it is concerned primarily with troop and personnel problems.

In Southeast Asia the organization shown in Fig. 5 has seen the greatest elaboration simply because that's where the conflict has been hottest. In Thailand, working in coordination with the Military Assistance Advisory Group and the Embassy, is ARPA's Military Research and Development Center, which has both American and Thai units (we'll be hearing more about their work later

*Special Operations Research Office, American University (supported by the U. S. Army).

in this meeting). In Viet Nam, under the Military Assistance Command and reporting directly to General Westmoreland, is the Joint Research and Test Activity, commanded by a Brigadier General who receives guidance and instruction from two sources: the Joint Chiefs on operational and combat developments matters, and DDR&E on R&D matters. He has under his command a Naval R&D unit, an Air Force Test Unit, the Army Concept Team in Viet Nam, and the ARPA field unit; the latter, again, is part of a Joint Combat Development and Test Center that includes a Viet Namese unit.

The R&D task in Viet Nam is essentially one of test and evaluation. We find also some operations research, some social science, and some combat development efforts — testing and evaluating tactical and command concepts.

This symposium is organized somewhat in parallel to the problem areas as I've outlined them. Each session is designed to cover some separate aspect of the problem; and the interrelationships among the various problems will be shown to some degree in the session called "Research and Analysis - II," where we will be exposed to some counterinsurgency problems from a very broad point of view. Work in all the problem areas I listed will not be covered completely at this meeting; their scope is too broad for the time available. The Program Committee tried to select at least one paper in each problem area and each technical area. Some of these areas are not represented, but an attempt was made for this first CIRADS meeting to provide a good cross sectionof the work. There is some very good work going on that has not been reported, and we will hear about this at future meetings.

You will also find that, even though we tried to organize the sessions in an orderly manner, there is some scrambling of subjects. For example, in the session on systems, there is one paper that deals to great extent with a reconnaissance problem; the reconnaissance session will contain a lot about uses of aviation; etc. This is simply an indication of the complexity of the subject and the degree of overlap among the many areas. It's worth remembering that, although we give names to the various areas that we're concerned with, there are really no hard-and-fast boundaries.

Many good papers were submitted to the Program Committee, and in view of the very short time available to authors to prepare and submit the papers, I think all the authors are to be congradulated. There were some papers that didn't quite fit into the program as it was arranged by subject matter, or for which there simply wasn't enough time. If these appeared to the Program Committee to be very important they were selected for inclusion in these Proceedings.

I'd like to comment on the relevance of some of the detailed work in rather narrow technological areas. This will be talked about in the last session, and it highlights something rather characteristic of the counterinsurgency R&D area. By itself the work could be applied to almost any type of war; it assumes relevance because it's being performed to meet a counterinsurgency problem. We know from having answered all the requests for invitations to this meeting that this is a very diverse audience and that many people have very specific areas of interest or specialization. The work reported in some of the sessions will be far outside these areas; but we certainly hope that all of you will stay for and enjoy all of the sessions, because cross-fertilization and transfer of information among those with varying interests is one of the main purposes of CIRADS. The symposium is intended to broaden the general understanding of the entire counterinsurgency research and development area, since narrow specialization alone cannot help us meet all the problems in this area.

Finally a comment on research and development in Viet Nam: it's fair to say that the interest in counterinsurgency research and development has grown in parallel with the growth of the war in Viet Nam. There has been an attempt, in many respects successful and in some respects not, to meet many of the problems in the theatre with research, development, test, and evaluation on the spot. This has been a sort of bootstrap operation having many unique problems, difficulties, and fascinations. We thought it would be appropriate to close the meeting by getting everybody's feet back on the ground through some exposure to the realities of R&D efforts co-located with an active war. General Boles, who was responsible for that activity for the last two and a half years, will close the meeting by discussing some of the problems he got into there.

Thank you for your attention.

INTRODUCTION OF CIRADS BANQUET SPEAKER*

Charles M. Herzfeld
Advanced Research Projects Agency
Washington, D. C.

Ladies and gentlemen: this is indeed a very special occasion for all of us. I am keenly aware of my responsibility in insisting that so many people who are terribly busy come together for a meeting like this when there are already so many meetings.

This morning, when I opened this meeting, I said that solving certain of the strategic problems was easy. Now my boss (b)(6) [redacted] who is not with us tonight because he is trying to solve some of these "easy" problems, keeps saying that one of the problems of American R&D is that "you guys don't know that there is a war on." To some extent I think he is right; but obviously many of you do, and many of you have just come back from the war. It is clear, however, that many, many Americans in the military R&D business treat the counterinsurgency problem, which is the only live war that we have at the moment, as if it didn't exist, as if it were something that is only being fought in scientific journals, at budget sessions, at committee meetings. But it's not that way. I have just come back from South Viet Nam, and let me assure you that it is more serious than that. What's to be done? Well, my boss says, "Why can't we get everybody on three shifts a day?" Well, why indeed not? It is perhaps a mistake to talk about eight-month, eighteen-month, two-year, three-and-a-half-year programs if one could go on three shifts a day. Let's think about that a little bit. I suggest we all do. We are thinking about it, believe me, and I suggest very much that you do. Things are going to change, I hope, with respect to this in the next few months, and let me tell you very frankly that the pressure on industry, the pressure on government laboratories, the pressure on all of us, is going to increase very much, to do our jobs better, faster, more intelligently, and above all more effectively.

This is all by way of preamble. However, it does lead into the point I want to make in introducing our speaker. We are very lucky to have for our speaker a man who is fighting a war that is not in the country you usually read about but in a country that is just as much at war. Let me tell you some things about him, which I dare say most of you do not know.

First of all, he has been heavily decorated by his government for gallantry in air combat. He was educated in a variety of places in his native country, and also at the U. S. Military Academy at West Point, where he was graduated in 1937 in the upper third of his class. He was commissioned

*Transcribed from tape recording.

second lieutenant in the Royal Thai Air Force in the next year. He went to a number of other schools such as Kelly Field, where he was graduated in 1938 as a pursuit pilot. He then went on to other schools in England, returned to Thailand at a time which must have been a very difficult one in his country's history, became an active fighter pilot in his Air Force, then became chief instructor at a Thai flying school during the war where he assisted considerably in the various underground activities in favor of the Allied cause. He became an instructor in the Royal Thai Military Academy and had a large number of other appointments in his highly distinguished career. He attended the U. S. Air Force Air Command and Staff College in 1962. He was a Director of Intelligence in the Royal Thai Air Force. Finally, and for us most important, in 1965 he became the Commanding General of the Military Research and Development Center. MRDC is a remarkable institution. There are not very many like it. It is an institution that is "combined and "joint"; and for those of you who haven't read the JCS Manual of Definitions, that means there are several countries involved: his own, ours, the United Kingdom, and Australia. MRDC is joint in the sense that the Air Force, Army, Navy, and Marines of his country and of ours operate jointly. It is a research organization which has departments in electronics, in operations analysis, and many other subjects. It is a military organization in the sense that many, though not all, of the staff are military officers and that all of the problems, or very nearly all, are directly involved with the defense of his country and the defense of our alliance there.

It is therefore an exceptional pleasure and an exceptional privilege for me to introduce our speaker. I believe it is an exceptional honor for all of us to have with us (b)(6) [redacted] (b)(6) [redacted] of the Royal Thai Air Force.

ADDRESS TO CIRADS BANQUET*

(b)(6) [redacted] Royal Thai Air Force
Commanding General, MRDC
Bangkok, Thailand

Dr. Herzfeld, gentlemen, and two ladies:† I feel highly honored and most delighted to present a few facts and to express my own opinions to the distinguished audience present tonight. As you have heard, Dr. Herzfeld has praised me very highly. I wish to take this opportunity to express my deepest gratitude to all American taxpayers because you have given me a free education at the U. S. Military Academy at West Point. And not only that: you were kind enough to further my flying training at Randolph and Kelly Fields. You were so nice that you did not even make me pay for crashing one of your airplanes there.

*Transcribed from tape recording.

†CIRADS is organized mainly for men. Since these two ladies were courageous enough to attend, the speaker was advised to address them last just to make it obvious.

1.

Let me tell you about that little incident. When I was in the advanced stage of the Pursuit Section in 1938, at 7:30 on the evening of March 12, just before dark, the instructor ordered me to night fly a BT-8. Those of you who are pilots (in the old days or even now) realize that a BT-8 was a Sikorsky version of an underpowered fighter (two seats with an undercarriage, not folding). It had a special characteristic of being very maneuverable, but it also ground looped very easily. It was the custom then that, when cadets or any officer ground looped, he had to buy a case of beer for the crew chief. It is not the intrinsic value of the case of beer, but it is the pride of the pursuit pilot not to ground loop. To make the story short: as I came in for a landing, I was way above the water tower at Kelly Field, which is now called Lackland Field. As I approached the last leg, my mind was exercising the power of Buddhist concentration not to ground loop; and I forgot to look down at how close I was to the hangar. My right landing gear hit hard on the far side of the roof. With a bang I was knocked unconscious. My right eye was wounded by the broken glass of my goggles, and the airplane ricocheted up some 50 feet. As the nose of the airplane was heavier, it fell down first. Being unconscious, of course I did not turn off the ignition as I had been instructed. The plane landed flat on the cement tennis court. The instructor ran to pick me up and put me in the hospital. But the main point is that Hangar 13 then was not a hangar for airplanes, but was used as a gymnasium, and that night it was used for a basketball meet. There were a few ladies in the ladies' room. They were, of course, performing their own business. At the first bang they were interrupted suddenly (maybe they thought I was trying to peek at them or something). Now you see what happened. Then at the second bang, when the airplane came down, they ran back and I was told four days later that those ladies had to go home and take a bath. Again, apologies to the ladies present. It was a true fact; I did not know all this until I was out of the hospital. The newspaper played it up with a headline: "Death Cheated When a Siamese Lieutenant Officer Pilot Had Crashed and Was Still Alive." For the next few days flowers and other gifts were sent, wishing me speedy recovery.

I think I have wandered too much away from my subject. May I again apologize to this distinguished audience to bear listening to what they already know, because it is necessary to present you with a little picture of Thailand before going on to the main part of my speech.

By now, since many of you have read about fighting in Viet Nam, I believe you know where Thailand is. See the map shown in Fig. 1. It is west of Viet Nam in the Indo-China peninsula. It is a country of 200,000 square miles or about two-thirds of Texas, with a population of about 30 million. Development in Bangkok, the capital, is just like in Washington or New York, so I need not tell you in detail about it. I'll endeavor to show you undeveloped rural sections instead.

An outstanding feature of Thailand is the floating market. You see, Bangkok used to be called the Venice of the East. Everywhere in Thailand there are canals. They are the cheapest means of transportation, so when men produce any material they put it on a boat, and float it down a canal for selling. Figure 2 is a picture of the floating market.

FIGURE 1

FIGURE 2

We are a Buddhist country. Buddhism in Thailand came originally from India, as you know, and Buddhism taught us to be at peace, to mediate, to concentrate, and to try to find out our own faults so as to be able to reach happiness. Buddhism is not involved in politics. We present food to the priests so that they meditate more. It is the religion with a philosophy of teaching.

Just before I came to this dinner a distinguished member of the audience asked me about some of the Commandments. I am very happy to inform you that one of the Commandments in Buddhism is "Thou shalt not kill." No matter what form of life it may be, if you are a good Buddhist, you must not kill even if you see a snake: your spread kindness and the power of meditation to it; I was told that then the snake would not bite you. Whether or not this is so, I shall maintain the Commandment "Thou shalt not kill." If you commit suicide, you are an even worse Buddhist and are committing more sins. Also, you are sinful if you direct others to kill. Believing in reincarnation, we shall not blame others if something goes wrong with us Buddhists. So we shall not mix any politics with our religion, Buddhism.

To go on telling you of our happy life in Thailand, I'll say we enjoy both freedom and independence. Speaking of independence, we are also grateful to the United States. Up to World War I we still had to be under extraterritorial rights; that is, we had to try foreign subjects in the consular courts, and the Americans were the first nation to give up this system so as to let us enjoy full freedom.

Dancing is one of the gayest practices in all of Thailand. See Fig. 3. There are various movements which are full of twisting of the body and wrist.

FIGURE 3

Another extraordinary sport of Thailand is Thai boxing (Fig. 4). Many of you have seen this; those who have not — if you should go to Thailand I invite you to see it because it is a form of defending yourself against an opponent in which you can use every part of your body — elbows, knees, head, and fists, but not teeth. There is also sword fighting for self-defense.

FIGURE 4

Back around 397 years ago we had a little trouble with our neighbor, Burma. They were then more powerful, so they often attacked us and burned our capital city of Ayuthia. I bring this up because you will need to know that we fought back the Burmese just as often. The King used elephants to fight, something like tanks. If any of you have seen "The King and I," you will recall that King Mongkut wrote to President Lincoln offering elephants to fight in the Civil War. This is an actual event, although President Lincoln refused. In Thailand we did use them. There were "Ngow fights"* on elephants' backs between our King and the Crown Prince of Burma. We won that war and became so strong that the Burmese did not dare to bother us for more than 167 years thereafter. Figure 5 shows some of the elephants.

When we speak of the King, I wish to emphasize further that Thailand is a constitutional monarchy, headed by a king. The King is not only the head of state; he is respectfully worshiped by us all. This is especially so of the present King Bhumipol.

May I remind you that a few years ago, when the King and Queen visited this country, the King addressed a joint session of the Congress. The first thing he said was that, when His Majesty arrived in America, he did not consider it as a visit but a homecoming, because he was born in

*Ngow is a sword about 6 feet long.

FIGURE 5

Boston. This King is most democratic, if I may say so; he inherited the democratic principles of his birthplace. He spends most of his money for charity, helping the people who may be flooded during a catastrophe, giving scholarships for students to study abroad. He went so far as to experiment at his compound in the palace with growing rice, and that rice is used at the plowing festival in May for the farmer to re-sow as a good omen when he grows his own rice. The King also plants all kinds of trees around his palace. The University of Agriculture in Thailand sends students to do research on special types of trees which only the King has, and the student must get permission from His Majesty first before using his trees. The King also runs a dairy farm as a model because he wants to encourage production of more milk. All these activities have caused the King to be most popular and most loved. I feel that His Majesty is one of the most important factors in preventing us from falling to Communism. The King and Queen (see Fig. 6) devote most of their time to looking after other people. Their Majesties went around to visit fishing villages, to offer help. Figure 7 shows a royal barge which the King rides once a year to take necessary materials to the priests at the end of the period of the Buddhist Lent. In the old days we used the barge for fighting in the Navy as well.

Looking at the map, you see that Viet Nam is on the east of Thailand. We have 30 million people, even though the Northeast has mostly people of Laotian origin, who intermarry with Laotians in Laos and move back and forth across the Mekong River, our northeast boundary. In the dry season they can walk across the river. Before I go on to discuss Communism, may I show you the

FIGURE 6

FIGURE 7

people of the Northeast—just to let you know how they are different from the people of Bangkok or the center of Thailand. The Northeast is not yet developed. Farms are less fertilized, and have not enough water. There are fewer roads, although we used up a great deal of budget money for this development. Even with that money we still do not have enough roads leading to all remote villages.

The capital income is about a little over a hundred dollars per year. The farmers produce rice, then after that they have leisure. Even now the government is trying to introduce double cropping so they will be more occupied and less free. Still there is not much to do during the summer time. This is the area where we find the most Communish insurgency, and Communist insurgency is the main topic of my speech.

Who are these Communist insurgents? We learned about them from the members of the Communist Party who surrendered to us and who were captured and investigated. We found out that the Viet Cong, the Pathet Lao, and the Communist Chinese have infiltrated into Thailand. These are the hard-core Communists coming into our country. In addition there are a few Thai politicians who lost power and went over to try to make friends, to try to get any form of help to gain back their old positions. How do they organize? They come in and form cells. They will visit a village, and their propaganda says that right now the Thai Government is selling or giving the country to the Americans. We are now an American colony, they say, consequently, let's join this group and liberate our country so that we can be free by changing the government's present form to another. They don't call it Communism; they call it something else. And this activity has gone on and on.

Let me go back a little. Some years ago when French Indo-China was under French rule, many of the Viet Namese settled down in Vientien, a large city in Laos, to earn their living, after they started fighting to gain their independence. Some peaceful ones moved across the river and stayed in Northeast Thailand. We call these people Viet Namese refuges. We have over 40,000 of them. A large number of them were even born in Thailand. They can speak Thai just like natives. We sent a few back to Hanoi for repatriation if they wanted to go, and now evidence shows that some of them have come back to be hard-core Communists. In particular, a girl 21 years old now is the head of a Communist hard-core group of about 20 stationed about 20 kilometers from the airfield Lerng-Nok-Tar, which the British were kind enough to help build for us. Let me tell you a little more about this 21-year-old Viet Namese girl leading this Communist cell. She has two guns, and this particular girl will shoot both at you. She runs away from the suppression unit and shoots backward over her shoulder. Further north we have another similar girl about 32 years old.

I say all this to inform you that the insurgency in Thailand is accelerated by outside help. Some young men who are free in the summer are recruited and persuaded to go to Hanoi to be trained. They are promised that once they get back they will be paid about $25 a month. That's a lot of money for those farmers, one-fourth of their yearly earnings. One of them that I know about went to Hanoi. The training school is some 20 or 30 miles from Hanoi, just inside of the sanctuary boundary where you cannot bomb. He heard the bombing but he never was bombed. He said there were 120 people from Thailand, 20 of whom were women. The first six months he was trained to be loyal to his party, to be loyal to the upper echelon. They avoided the word "Communist." They were taught to say just that they were to liberate Thailand. One strange thing: these men are not allowed to look at a girl student in a personal manner or in the love mood. They can talk to the girls about serious matters like how to revolutionize Thailand. No love affair could take place at all. They were taught to confess. After so many days passed they had to confess what they did. After eight months in school the man I'm talking about graduated and returned home. He found the promises made in training school were not kept, so he surrendered to our authorities. That's how we got to know all these facts.

Figure 8 is a map of villages already fallen to Communist aggression. The dots represent villages. There are a total of about 43,000 villages in the whole of Thailand, many of which, especially in the Northeast, have been subjected to infiltration. The Communist training camp shown in Fig. 9 was captured and occupied by our police. The Communists used such facilities to train what they called woods soldiers, meaning hard-core Communist soldiers who were trained in the woods with weapons issued to each one. They also trained village soldiers, who were more or less the labor force of the Communist cause. Also they had the villagers who were sympathetic to the Communist cause or who did not know any better or who just simply followed when they were forced to do so. Figure 10 is a picture of medicine we captured, and of food supplies. You see, sometimes the insurgents could not come to their village to get food, because we sent our security patrol to that village, so the villagers, in groups of ten to twenty, had to prepare themselves to be in the jungle or in the training area with preserved foods to face the eventuality of combat. Figure 11 shows the food supply, and Fig. 12 shows some of the weapons we captured, including a pistol. There is an M-2, I believe, also a submachine gun that looks like a sten gun (Fig. 13), but I think it was made in China.

Figure 14, a picture of a dead Communist, will prove to you that there existed Chinese Communists; if you look at the picture on his chest you will see that he is Chinese. It is not a very beautiful sight but it is a fact. And Fig. 15 I would like to say more about. The dead man is a Viet Namese, head of a group of cells, who had two Thai as his followers. He ordered the two Thai to the village to get his food for him while he was asleep. The Thai had been brainwashed and believed they would get what was promised; but they never found it at all, so they shot him. Then the Thai Communists surrendered to us; that's how we got this picture and learned the details.

As part of the insurgency it is also rumored that there were helicopters landing in Thailand providing their cell units with whatever they needed. Through our captives we found that some of the heads of this unit are quite civilized. They even drink tomato juice (we found the cans), and some of them even have ladies' sanitation.

FIGURE 8

FIGURE 9

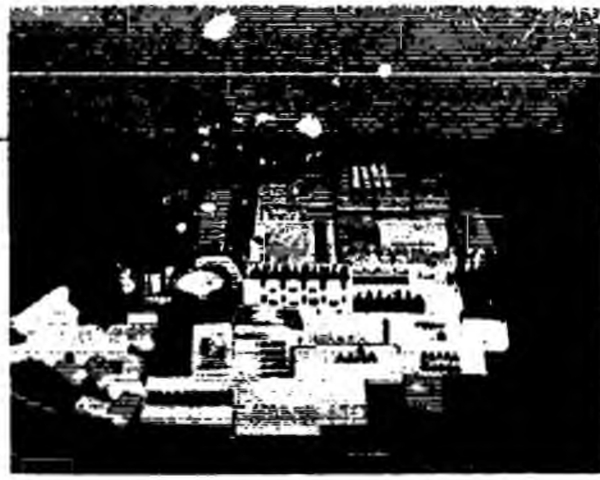


FIGURE 10

FIGURE 11

FIGURE 12

FIGURE 13

FIGURE 14

FIGURE 15

I shall summarize by saying that all this will inform you that Communists have infiltrated the Northeast. What does the government do about it? We are trying to counter in two ways: passive and active. The passive method is trying to develop the country, and the Ministry of Interior went so far as to try what we call accelerated rural development in cooperation with the USOM, but it's too slow. Therefore the government is trying another system, which we call National Security Command, a passive measure which we feel will be more effective. We call for full cooperation and combine the input of all government agencies engaged in countering Communist activities. This coordination must be keynoted by a more effective system of delegating responsibility and authority. The concept of the National Security Command, the passive action, is counterpsychological warfare, and includes technical improvement of Thai roads, radio broadcasts, visiting rural people, mobile development units, and identification card projects. Each individual person must be identified. The project calls for training the hill tribes and the rural people of the border area. Besides using the mobile units, we are also using the youth project and adult education. What we try to do is to improve the standard of living so that we can win people's minds.

The National Security Command prepares plans for countering Communist activity by passive or active operations directed by the policy board. The government agency concerned is supervised only so that the operation may be carried out effectively. The most effective method we are using is the Mobile Development Unit. It is operated by the military people because of time, and its object is to approach the rural people face to face to win their minds, to persuade and motivate them to maintain their loyalty and honesty to the Thai Government and make them proud of their Thai nationality as Thai people. The objectives of MDV are shown in Fig. 16.

OBJECTIVE OF MDU

Approach rural people face-to-face to win their minds, to persuade and motivate them to maintain their loyalty and honesty to the thai Government and make them feel proud of their nationality as THAI people

FIGURE 16

Figure 17 is a listing of the mission of the Mobile Development Unit. As I said, its mission is collective action for rural people, to promote their standard of living. In order to achieve the objectives, we determine their needs, improve their projects, and then collect information, which is the most important. Now some of the achievements of the Mobile Development Unit are to rearrange houses of the village so as to widen roads, to rebuild living quarters, schools, and temples, to improve or provide places where they can pasture their cattle, often kept in cellars, to set up health stations, to bore efficient wells, to construct public community centers, to improve public welfare, to promote agricultural activities, to provide playgrounds for children, and above all, to set up TV antennas as high as 250 feet, or radio antennas, and to provide television and radio sets. The results show that rural area people reflect favorable attitudes to the central government and to the MDU personnel. We won the minds of the rural people. They felt that they belonged to Thailand, to the central government, and they felt that they were not left unattended.

MISSION OF MDU

1. Conduct Civic Action and rural development to promote people's standard of living in order to attain the objective.
2. Determine their needs to be improved for long range project of Development.
3. Collect informations for National Security.

FIGURE 17

Let me say a few words about the youth program. We invited one or two boys to Bangkok from each remote village, altogether about 200 of them, ranging in age from 10 to 12 years. We presented them to the King, gave them a banquet, showed them what a country or what the developed city of Bangkok looks like. These youths, after they went back home, realized that a well-developed city is full of modern conveniences. They felt that they belonged to Thailand; they were Thai. They no longer fall for Communist agitation or propaganda. They would then tell us where the Communists had a meeting place, and who brought food to the Communist cell outside the village. These led to many arrests and successful destructions, and that is the main function of our passive program.

So much for the passive method. Let us look at the active suppression. We are now creating what we call Civil Police Military units so as to be able to counter the Communist activity, which is increasing. I shall read a report from a newspaper, which I cut and brought with me. The CPM unit is now concentrating on the suppression of Communist terrorism in Sawang-Dan-Din in the Warich-Pum District in Sakon Nakorn Province. Several terrorist gangs have been broken up, and many members of the gang killed or arrested. The newest engagement in which the CPM units have been convincingly displayed has made the leaders of the terrorists issue orders to avoid clashes with the units. The Communist terrorists were being trained by Pathet Lao instructors, who are now increasing their activity by having more instructors come from Viet Nam as well as from Communist China. The terrorists became overly aggressive because of the support they received from Communists outside Thailand. The slaughter of the teachers, I repeat, the slaughter of the teachers, and the village chiefs is a real Communist plot.

Since the establishment of the CPM units, much satisfactory work has been carried out. One unit has been working southward throughout the infested area. It has clashed several times with terrorist gangs and routed them, capturing and killing the important leaders. The use of helicopters for transport purposes has greatly increased the efficiency of the unit.

As you will see, Fig. 18 show we have seven CPM units, headed by the governor of the province. They are the civil units. But there is a special one called CPM 1, headed by a military colonel, because that particular unit has to take care of a more Communist-infested area. And that's where the Viet Namese girl of 21 years old was found.

Now here are some statistics on Communist casualties to the end of May 1966, in Thailand:

1521 surrendered to the authorities (1490 from the Northeast)
509 arrested by the Government officials (480 from the Northeast)
86 killed in fighting (65 from the Northeast)
67 contacts with our suppression units
40 ambushes by the Communists on our forces
23 police soldiers of Government forces killed in action
15 wounded police and soldiers
21 civilians killed by terrorists
7 civilians wounded

One of our Bangkok beauties wanted to show her sympathy, so she went up to visit the wounded soldiers fighting for the freedom of Thailand. She spoke softly: "Corporal, where were you hurt?"

FIGURE 18

And the corporal would say, "My arm was shot." She bent over and kissed the arm. Then she walked over to a sergeant who was dying to see her, and said "Where were you hurt?" He said "Oh my beauty, I was bitten by a Communist on my lips." Do you think she would bend down and kiss his lips? I wasn't told.

Now, I want to speak of one more important activity before I come to my conclusion, and that is about the Military Research and Development Center, of which I am the commander, as Dr. Herzfeld has already said. It is a unique Thai-Allied operation. We have, of course, Americans as the main influence, and we have the UK officers, and four Australians (I think two or three are in the audience). It is a joint operation. We try our best to research and develop so as to make our fighting units of the armed forces most efficient, to defend our country. Whatever information we collect, we share, and through the complete cooperation of Dr. Herzfeld and General Timmes, I dare say, we get very good officers and men to work with us. We have combat equipments, which we are very proud of, and we have developed dry rice, which is, I think, called Minute Rice in America. This is a good ration for fighting the guerillas because to prepare it you just pour hot water over it. Even curry, which is a popular Thai dish, is dehydrated, and, after you add hot water, it is ready to serve. So you can fight and eat at the same time. These are examples of MRDC developments.

There are many other projects in the fields of communications, mobility, and surveillance. I would like to emphasize surveillance because there are many of the surveillance people in the audience. For example, The University of Michigan infrared scanner will help us find where the Communists do their cooking. We take a picture of the fire in the forest where they are supposed to be and then we can locate them more easily or more exactly. Then we have environment jungle survival, and we have research analysis, and the air division. As I said before, I am grateful to Dr. Herzfeld and General Timmes for sending the good scientists and officers to work for me at MRDC; and they are working very hard. If you don't believe me, look at [redacted] He worked so hard that he lost weight. Not only that, look at [redacted] He worked so hard that he lost his hair.

My main point is that there exists Communist insurgency in Thailand, and that the Thai Government is trying hard to counter the insurgency, by passive and active methods. We are doing our best. Of course, I want to assure you, it is not as dangerous as I make it sound. Bangkok is still quite safe, so safe that [redacted] has sent [redacted] to Bangkok. So you are all invited to visit; it is still quite safe, but of course, in the Northeast we still have ambushes, and shooting as well.

Before I end my speech, I wish to read you a little newspaper article that I brought for Dr. Herzfeld. It is a report on the visit of [redacted] and Dr. Herzfeld to [redacted] and also the leader of all the counterinsurgency in Thailand. Here it is:

DAWEE TELLS U. S. COUNTERPART OF
LAG IN U. S. AID DELIVERY

Military assistance to Thailand from the United States, despite the agreement on the program reached, is far too slow and may even be too late to cope with the situation that will arise, Air Chief Marshal Dawee Chulsap reportedly told Mr. William Foster, Deputy Chief of the U. S. Defense Department, yesterday.

Highly reliable sources said that Marshal Dawee, Deputy Minister of Defense, and Chief of Staff of Supreme Command, told Mr. Foster that if Thailand should fall to the Communists the U. S. will have to spend several thousand million dollars to liberate Thailand and the rest of Southeast Asia.

Mr. Foster in his turn was reported to have asked Marshal Dawee the reasons for the delays in executing the aid agreement. He noted down Marshal Dawee's explanations and expressed his surprise that there are delays of not less than six months in the execution of the agreement, the sources said.

Mr. Foster assured Marshal Dawee that the U. S. realizes the importance of Thailand as a bastion of the Free World and promised that he would do his best to accelerate the execution of the agreement.

Earlier the two discussed the war in South Vietnam and the Communist terrorist activity in Thailand in the context of the general situation in Southeast Asia.

In conclusion, may I assure you that I, personally, am grateful for all your help, way back from the beginning of my education. This is the first time in many years that I have been able to deliver an expression of my gratitude to such a distinguished audience. Such aid is very beneficial; whatever help you give us is put to good use. With your support and with your acceleration of the needed materials I am sure we can hold Southeast Asia as a bastion of the Free World.

Thank you.

Session 1

RECONNAISSANCE

Session Chairman:

(b)(6) [redacted]

J. ALFRED STRINGHAM

Mr. Stringham was born in Shuntefu, China, on 27 October 1934, of American missionary parents. He graduated from Syracuse University in June 1957 with a BS degree (cum laude) and joined the Air Force's Rome Air Development Center. Initially he conducted analytical studies on the use of reconnaissance imagery for targeting purposes. He currently heads Rome Air Development Center's Interpretation and Analysis Section, which has a major Air Force responsibility for evaluation of reconnaissance sensors and development of exploitation techniques and keys.

RECONNAISSANCE TO SUPPORT COUNTERINSURGENCY OPERATIONS (U)

~~(Confidential)~~

J. Alfred Stringham

Rome Air Development Center
Griffiss AFB, NY

ABSTRACT

~~(Confidential)~~

Reconnaissance is a prime source of intelligence to support counterinsurgency operations. Modern technology has and is providing a vast array of sensor systems that can be applied to the problems of detecting the insurgent or indications of his activities. The problem of judicious application of these systems to various levels of counterinsurgent warfare has been the subject of extensive Rome Air Development Center programs since 1960. This paper discusses a number of sensors and concepts we have evaluated or evolved during this period and presents the significant results and trends that have emerged. Evaluations range from laser scanners, forward looking infrared (FLIR), and foliage penetration radar (FOPEN SLR) flown over simulated targets at Eglin to advanced infrared (IR) and photographic systems flown in Thailand under the ARPA sponsored AWPIRT program. Observations from U. S. experience in South Vietnam are included to substantiate test results.

Several distinct applications of reconnaissance have emerged to date and development of exploitation techniques for these are discussed. First sensors contributing to background information used in conjunction with collateral intelligence from sources such as agent and interrogation reports are considered followed by discussion of those providing detection capability for timely action. The interrelation between these aspects of reconnaissance and timeliness problem is presented.

NOTE: For administrative reasons some of the figures presented during the CIRADS conference have been deleted.

INTRODUCTION

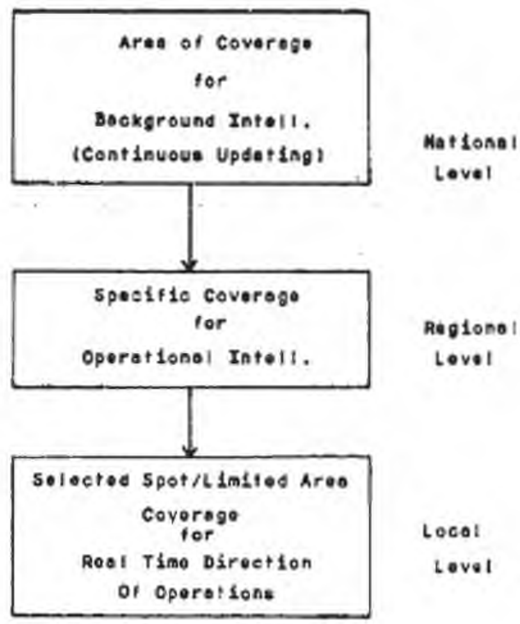
The United States is assisting a number of nations from South America to Southeast Asia in dealing with the problems of insurgent movements. One aspect of this aid is to improve the effectiveness of internal security or military forces in countering insurgent activity ranging from poorly organized quasi bandit groups to highly efficient units armed and supported from external sources. A key element in any successful counterinsurgency operation is accurate and timely intelligence. Aerial reconnaissance is an important source of this information. While modern technology has provided a madrid of sensors with potential for vastly improved detection and identification of insurgent forces, much remains to be done in applying these techniques to practical operations. The current reconnaissance inventory ranges from the human eye to all-weather foliage penetration radar. During the past seven years, Rome Air Development Center has conducted dozens of the evaluation and test programs to determine the potential of many newly developed and existing reconnaissance systems. These tests have been conducted in environments ranging from Camp Drum, New York and Eglin, Florida to Thailand and South Vietnam. Flights have been made under every conceivable weather condition over targets ranging from vehicles and camp fires to personnel and individual weapons. What has emerged is a clearer picture of what can be accomplished through astute application of this technology but there remains a wide margin between theory and practice.

RECONNAISSANCE OPERATIONS

In order to apply aerial reconnaissance to the problem of finding the insurgent, his camps, supplies and works requires careful planning of mission sequence. Figure 1 illustrates three levels of reconnaissance ranging from area coverage for background studies and intelligence to selected spot coverage for real time direction of strike operations. Initially, area coverage is primarily planned and analyzed at the harassed country's national level. This imagery will be used to produce background maps, studies of infiltration routes, location of possible training camps and staging area to likely spots for ambush and sabotage.
In addition, it may be necessary to obtain reconnaissance of

Figure 1

SEQUENCE OF RECON OPERATIONS



neighboring countries to determine infiltration routes and sanctuaries in cases the insurgent movement has external support. The crux of the problem in these operations is that much of the time the insurgent is indistinguishable from his fellow citizens. It is, therefore, necessary to either look for indicators of his activities or observe during active operations. The second phase of our reconnaissance is to provide operational intelligence for military or security forces. Whereas background studies may be days or months old, this information should normally be current within a matter of hours. Acquisition of this reconnaissance covers much more specific areas, isolated on the basis of known insurgent concentrations or planned government operations. In some incidents the information derived from this reconnaissance allows government forces to anticipate projected insurgent operations. For example, photographic detections of intrenchment activity along the highway may be indicative of the forthcoming ambush. This type of reconnaissance allows us to keep an up to date order of battle of the insurgent. The final level covers a very limited area with the intent of finding insurgent actively engaged in operations. Since it is common practice to conduct the operations under the cover of darkness, inclement weather and foliage it is frequently necessary to predetermine action on the basis of detection indicators. Because positive identification from high resolution sensors is not compatible with many phases of insurgent activity, pre-decision to strike on the basis of thermal indicators or changes in deployment of metallic objects may be necessary. Since coverage of this nature has been carefully preplanned it is sometimes possible to isolate the insurgent from normal activity. Movement of water traffic after curfew in parts of South Vietnam is an example of this. Figure 2 summarizes three categories of intelligence and the current and projected sensors expected to provide them. It should be noted that some of the sensors, such as the FOPEN radar system, require a great deal of sophisticated equipment and will not be compatible with U. S. assistance coverty provided underdeveloped nations. In all cases it becomes obvious our success in finding the insurgent is highly dependent on observers or interpreters thoroughly familiar with the area, his tactics and patterns of activities. Figure 3 outlines general characteristics of a number of sensors for mission planning purposes. While we have omitted high resolution photography it is obviously the prime reconnaissance source for background studies. In this case, we can afford to wait for photographically clear days since the in-

Figure 2

PHASES OF THE

RECONNAISSANCE - INTELLIGENCE CYCLE

Function Supported	Data Age	Sensors Operational	Sensors Developmental	Type Information Sought	Remarks
Background Intelligence	48 hrs - 12 mos	Mapping and Reconnaissance Photog Infrared SLR	Improved Photography Including Color New Infrared Scanners	Terrain Cultural Features Trails and Routes Probable Campsites Sanctuaries Operational Planning Data	High resolution detail valuable, stereo photography for relief information. Liberal use of collateral source material.
Operational Intelligence	30 min - 48 hrs	Visual Recon Photog Infrared SLR - (MTI) Night Photo SLR	Laser FOPEN SLR Color and CD Photography	Active Camps - Route sabotage Activity Patterns Fortifications Operational Planning Data Fixed targets such as supply dump strike assessment	Resolution important in establishing confidence for major decisions. SLR and SLR (MTI) primarily activity indicators collateral source material important.
Real Time	0 - 30 min	Visual SLR (MTI) IR Inflight display	Laser FLIR FLR LLLTV FOPEN SLR - Data Link* or inflight display IR Data Link* or Inflight display	Insurgent Units Logistics movements Positions during attack for air and artillary support Ambushes	Problem of Timely information extraction and targeting - *For situations where large A/C (C-130) can survive inflight displays - where high performance A/C required (RF-4C) use of data link

formation we seek will be fairly stable. Looking at the table it is obvious that SLR provides tremendous area coverage quickly and thereby is frequently referred to as a mapping system. However, in fact there are few cases where the mapping detail obtainable from SLR is not much more effectively obtained through high resolution photography. Since rivers, road patterns and cultural features derived from SLR imagery don't vary it is better to wait for photography which adds the additional features of vegetation and detail on route condition, buildings, etc.

The true merit of SLR is as an activity indicator during night and inclement weather conditions. A pair of passes with the APQ-102 SLR system at 35,000 to 50,000 feet can cover several different roads and coastal regions. Comparative coverage may allow detection of route traffic such as trucks and coastal and river vessels down to the size of sampans. This information can be available within two and a half hours from time over target. Another system the Army APS-94 SLR using MTI allows detection of vehicle and water traffic movement on an inflight basis. The FOPEN SLR development will eventually extend the EEI's from trucks and water traffic in the open down to individual weapons hidden under fairly dense foliage. This sensor flown in an aircraft with sufficient space for inflight display using comparative coverage techniques will be a tremendous step in cutting the insurgent's advantage of hidden deployment and surprize attack.

During the last four years, we have conducted and sponsored studies to define how background intelligence and area knowledge will improve both the mission planning and exploitation functions. As was obvious from Figure 3 we have at our disposal a wide range of sensors with associated altitude and area coverage constraints. Figure 4 shows sequential infrared coverage over part of Tay Ninh province in South Vietnam. The imagery in the center sample contained over 20 small fires that went undetected during initial screening. Decision to carefully interprete imagery covering this area was based on it's being a known infiltration route of men and supplies entering from Cambodia. Through the use of photographic coverage and interrogation reports various routes through Tay Ninh province have become fairly well defined. Therefore, it became a matter of looking at key points where Vietcong and logistic units might establish transient rest camps. This illustration shows how background studies can lead to timely intelligence. From the detection of these fires it was estimated a unit of 200 to 300 men was moving

Figure 3

MISSION PLANNING CONSIDERATIONS

SELECTED RECON SENSORS

	λ=MM-METER REGION (SLR)		1-30μ INFRARED (IR)			.3-1.0μ PHOTOGRAPHIC REGION		.4-.8μ VISUAL	
	OP (APQ-102	DEV. (FOPEN II)	OP AAS-18	DEV. RS-10	DEV FLIR	NIGHT FLASH OP	LASER DEV	EYE-BALL OP	LLCTV DEV
COV. (SQ.M) MPH	10,000 @ 500	9,000 @ 500	300-600 @400	400-1,000 @400	50-200 @100-150	20-50 *CAR-TRIDGE LIMITED	100 250 @250	200-300 @100-120	50-100 @100-120
ENVIR CONST.	DAY/NIGHT-CLOUDS RAIN	DAY/NIGHT-CLOUDS RAIN-FOLIAGE	DAY/NIGHT	DAY/NIGHT	DAY/NIGHT	NIGHT	NIGHT	DAY-NIGHT	
ALTITUDE THOUSANDS OF FEET	35 - 50	30 - 45	1 - 3	1 - 5	.5-3	2-4	1-4	.05-5	.5-3
INFORM. DERIVABLE	ROUTE (TRUCKS) WATER TRAFFIC	CAMOU-FLAGES WEAPONS O.B., VEHICLES	THERMAL INDICATORS OF ACTI-VITY (CAMPFIRES	THERMAL INDICATORS OF ACTI-VITY CAMPFIRES, PERSON-NEL HOT GUNS	THERMAL INDICATORS OF INSUR-GENT ACTIVI-TIES (CAMPFIRES) ROUTE AND WATER TRAFFIC	PERSON-NEL, WEAPONS VEHICLES ETC.	PERSON-NEL, WEAPONS VEHICLES		
REAL TIME	NO	EVENTUAL	LIMITED	LIMITED	YES	NO	EVENTUAL	YES	YES

Figure 4

Man. 4952 35870R b
Alt. - 2000'
Date - 17 Nov '64
Time - 1902
Detector - Ge:Hg

Man. 4963 35872R 4
Alt. - 2000'
Date - 18 Nov '64
Time - 2000
Detector - Ge:Hg

Man. 5029 35897R 4
Alt. - 2000'
Date - 28 Nov '64
Time - 1930
Detector - Ge:Hg

A pattern cluster of approximately 20 smoldering fire remains discernable at b. The same area is unoccupied on pre and post flight comparative images a and c. The fires are located near the edge of a forested area in the "Boi Loi" SECRET zone where intelligence reports extensive enemy activity.

<u>Detection Characteristics.</u>

A. Transient

B. Pattern

C. Location

into the province. Since in some areas infiltration rates can also be estimated the next step would be to plan spot FLIR coverage over possible rest sites on the following evening, the aircraft commander being given permission to call in air or artillery strikes.

Figure 5 is an example of detailed area studies specifically oriented to the problem of mission planning. In this case we have broken a region down by those features that will obscure or hamper detection of insurgent activity to various sensors. The intent of this type of analysis is to predict detection probability and increase effectiveness from regions covered. It is obvious the final flight profile will be selected on the basis of both the background intelligence and the physical features effecting sensing of desired information elements. The camps during period of meal preparation are highly susceptible to infrared detection. In some cases, however, extremely dense foliage, multilayer forest canopy and fire discipline will preclude this source of intelligence. Where the insurgent are carrying radar reflective objects such as mortars, rifles and machine guns or using bicycles an ox carts for transportation some degree of detection is anticipated with the foliage penetration radar system. The time of overflight would be planned to coincide with anticipated insurgent deployment compatible with sensor and background characteristics. In the case of infrared detection we would attempt to achieve maximum contrast of thermal indicators. Since infrared and various real time systems cover limited areas careful selection of flight paths is an important prerequisite for success. In the case of SLR systems capable of covering literally thousands of square miles per hour, background analysis of this sort is necessary to draw the interpreter's attention to regions of probable activity. Also our studies have demonstrated that where detection is accomplished on the basis of thermal or radar returns insurgent activity is only distinguishable from normal background in select regions. Fairly large Vietcong units, for example, can be assimilated in villages with relatively undetectable changes in thermal or radar returns. The reaction of villagers to an observation aircraft or changes in their activity pattern may be detected visually by a man thoroughly familiar with the region.

While buildup of area knowledge is critical to exploiting the vast potential of our sensing technology for counterinsurgency operations it has often taken years to accumulate in practice. Although the U. S. has been operating in

5a Map Showing Part of Tay Ninh Province.

PENETRATION PROBABILITY				
BACKGROUND	[illegible]	[illegible]	[illegible]	[illegible]
DENSE FOREST	50%	1	1	1
CLEAR FOREST	10%	2	3	4
BRUSHWOOD	5%	4	4	5
[illegible]	10%	4	6	7
CLEAR	20%	8	9	9
RICE	5%	8	9	9

5b Penetration Overlay Covering Part of Infiltration Route (Values Postulated for Illustration Only).

South Vietnam for a number of years the current state of such information for that country is extremely limited. In the future we hope to be able to provide at least preliminary information of this nature along with initial deployment of our reconnaissance systems, whether they are operated by indigenous forces or our own military organization.

On 1 April 1966 Rome Air Development Center was assigned responsibility for development of Air Force interpretation keys. We plan to develop keys in the future that will aid the reconnaissance cycle from mission planning through interpretation, whether it be in a fixed facility or at an inflight display unit.

RECONNAISSANCE EVALUATIONS

The wide variety of new sensors that can be used in acquiring intelligence to conduct counterinsurgency warfare has resulted in numerous test and evaluation programs. In setting up these efforts we have attempted to establish the elements of information most appropriate for the sensor considered. Therefore, during the course of the field evaluations "targets" have ranged from fairly stable trail patterns to highly perishable objects like personnel and moving vehicles.

In order to achieve realistic results, situations are simulated by deploying targets in environments closely approaching those expected operationally. One or several aircraft carrying the sensors to be evaluated systematically make passes over the target arrays varying parameters such as altitude, offset, and time of day. In order to conduct significant tests representing repetitive coverage patterns are frequently varied in a realistic sequence. For example, as part of one test at Eglin we set up a series of frozen target arrays that represent various stages of Vietcong ambush preparation. Each array is held fixed until we have acquired the desired test imagery and then redeployed into the next step.

A number of our evaluation programs have collected physical data such as weather observations and radiometric measurements to allow detailed analysis of why targets were or weren't imaged and appear as they did. We have found these measurements most useful in evaluating reconnaissance systems highly sensitive to background variations, such as infrared scanners.

The final element of our evaluation is normally "blindfold" tests with interpreters unfamiliar with the area or targets. These tests result in percentage of targets detected, identified, and number of false alarms. Frequently this data is compiled as a function of altitude or other collection parameters. Acquiring an adequate number of skilled interpreters to serve as subjects is always a problem since a fairly large sample is required to assure we are evaluating sensing variations not interpreters.

The first serious program directed toward problems of counterinsurgency reconnaissance was TROPICAN, accomplished during the fall of 1962. This was a program to evaluate a number of sensors (IR, SLR, and multiband spectral photography) through flights over the Guajataca Forest of Puerto Rico. This was one of the few programs that included major effort toward evaluating the type of background detail derivable from various types of reconnaissance imagery. A portion of the Guajataca Forest was imaged extensively and ground checked for such details as trails, campsites, and observation points. In addition, more perishable targets (campfires, etc.) representative of operational intelligence were covered. The effort demonstrated the potential of night infrared reconnaissance in detecting camouflaged thermal activity and applications of color, camouflage detection, and spectrally filtered photography for terrain detail supporting area studies.

As a result of the TROPICAN program the Advanced Research Projects Agency (ARPA) sponsored an extensive effort to develop multispectral infrared and photographic reconnaissance techniques through flights over target arrays in various parts of Thailand. Flights for this program, known as AMPIRT, covered simulated guerrilla activities in background ranging from heavy forest to a canal site. An Air Force C-47 was equipped with two infrared scanners and seventeen cameras. Twelve of the cameras were matched 70mm systems allowing simultaneous collection of narrow band spectrally filtered photography along with color films. Another bank of four 70mm cameras and a panoramic system turned in the direction of flight allowed systematic variations in scale and aspect angle. The photographic part of the AMPIRT program was accomplished by Cornell Aeronautical Laboratory and the infrared portion by the University of Michigan.

Figure 6, shows preliminary results of Rome Air Development Center tests using the AMPIRT imagery to compare color and black and white photography in detection and identification of small targets. One of the tests included comparison of stereo and non-stereo for these functions. As can be readily seen there is a significant advantage in favor of color. While the targets used during this test were representative of operational or real time intelligence needs, a major advantage would be in deriving background intelligence. Although for these targets there was no significant difference between stereo and non-stereo, we believe there will be for such functions as determining trail patterns and probable campsites.

From the infrared aspects of AMPIRT we determined significant operational intelligence can be derived on targets down to the size of personnel and animals. While "blindfold" tests have not been accomplished to date, preliminary results indicate spatial resolution is a critical parameter. For detecting and in some cases identifying the necessary elements of informations we believe resolutions of one milliradian or better are required. Another aspect being investigated further as a result of AMPIRT is the use of magnetic tape recording to increase dynamic range of the imagery for selected purposes. Whether the additional complexity of ground display equipment will be justified operationally remains to be determined.

Detailed analysis of both the photographic and infrared imagery collected during AMPIRT is continuing at Cornell Aeronautical Laboratory and the University of Michigan. In addition, Rome Air Development Center will extend the preliminary blindfold tests evaluating color to include infrared alone and in conjunction with background photography.

Since much of the insurgents activity is conducted under cover of darkness a number of our efforts are devoted to evaluating night sensors. During 1964 we completed a series of tests under project RODEO. These flights were made at Eglin over targets ranging from vehicles to mannequins simulating personnel. Figure 7, shows the sensors evaluated during this program. The RODEO effort includes the first LASER scanner. Figures 8 and 9 show detection and identification accuracy summaries based on extensive blindfold tests with twelve experienced interpreters. Considering the LASER flew for the first time during this program the results were extremely encouraging.

Color Vs Panchromatic (Detection Completeness)

Evaluations

	Study I		Study II	Study III
	Stereo	Mono	Mono	Mono
Color (Ektachrome)	19.5%	17.1%	53.6%	55.0%
CD - (H-8443)	-	-	-	53.0%
Plus - X	15.4%	16.4%	33.2%	31.0%

EQUIPMENT CHARACTERISTICS				IMAGE CHARACTERISTICS			
Sensor System	Recording System	Aircraft Used	Illumination of Ground Targets	Scale (A.C. AL ? 1500)	Format	Apparent Quality	Availability of Stereovision
I Developmental Model Strobe (XLS-4)	Vertical, 6" KA-45A Camera, 250 ft. cassette	RB-66	Three strobe lights triggered by camera shutter	1:4000	4-1/2" frame	High contrast sharp imagery	Yes
II Demonstrational Model Strobe (QRC-221)	Vertical, 6" KA-51A Camera, 250 ft. cassette	RF-101C	Four-unit reflector-lamp system triggered by camera shutter	1:3000	4-1/2" frame	Some underexposure and vignetting of imagery	Yes
III Operational Flash Cartridge	Split vert. 12", K-47 Camera	RB-66B	M-112 photo flash cartridge fired by A-5 flash cartridge ejector	1:1500	9" frame	High contrast sharp imagery	Yes
IV Developmental UV	Vertical, 4.15", KA-18A aerial strip camera modified to accept Barnes 6-212 UV lens with 4000A cut-off filter and unfiltered visual transmitting lens	Martin 204	Bank of 12 GE B-H6 mercury vapor lamps	1:4500	5" strip (continuous exposure)	Low contrast	No
V Developmental Line Scan Laser	Electro-optical recording; effective focal length 6"	C-97	Continuous wave He-Ne gas laser with frequency of 6328 A and power output of 100 milliwatts; scanning range 42° orthogonal to flight path	1:3000	4-1/2" strip (line scan)	Low contrast; very grainy at 7X magnification; obvious scan lines	No
VI State-of-the-art IR (Reconofax IV Mark II)	Ge:Hg detector operating in 8-14 micron region; angular resolution of 2 milliradians with scan angle of 110°; lens focal length of 1-1/8"	T-29	N/A	1:15000	2-1/2" strip (line scan)	Inconspicuous scan lines; low contrast for hot targets; high contrast for cold targets	No

Figure 7. Project Rodeo-Sensor Equipment and Image Characteristics

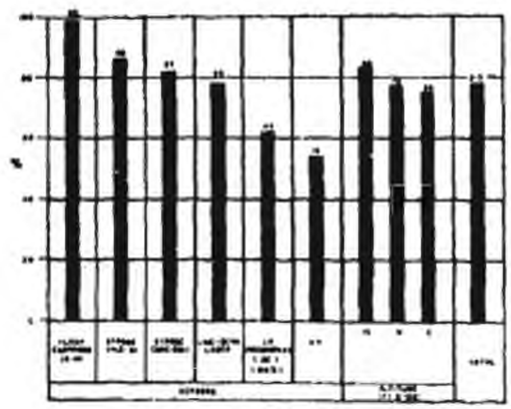


Figure 8. Project Rodeo Detection Accuracy Summary

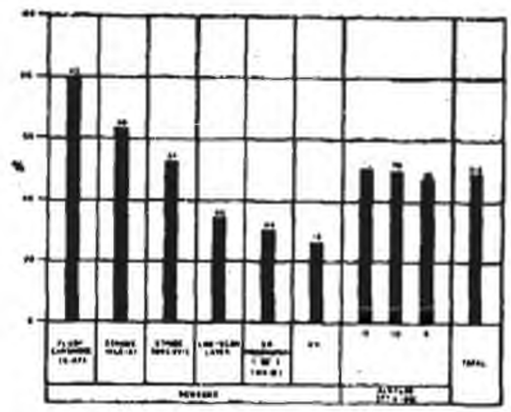


Figure 9. Project Rodeo Identification Accuracy Summary

Another area to which we have devoted extensive effort is the inflight display for near real time intelligence. For example, under the RED SEA I and RED SEA II programs we evaluated two forward looking infrared (FLIR) systems for detection of guerrilla activity. Although these systems demonstrated great promise, further development, particularly to improve spatial resolution was necessary for reliable use at operationally realistic altitudes.

Unquestionably one of the difficult problems from the standpoint of reconnaissance is the insurgents use of heavy foliage to camouflage his activities. For several years we have been working with a low frequency coherent SLR system for this purpose. Experimental flights with the PIPSQUEAK (developed for the Air Force Avionics Laboratory by Conductron) have demonstrated the ability to detect trucks, mortars, and machine guns under fairly heavy vegetation. Until recently the question of false alarms from the SLR imagery, which we believe is usable only through comparative coverage or change detection techniques, was presumed to be a severe limitation. However, Rome Air Development Center blindfold tests just completed indicate detection completeness of 63% with an accuracy of approximately 50%. This means there was approximately one false target for each real one. Considering the LW/SLR penetrates both weather and certain amounts of foliage cover these percentages are highly encouraging although we would expect them to be considerably lower operationally. Interestingly most false targets were reported after the interpreters finished noting the actual ones, a result consistent with tests run by the Army Personnel Research Office on photography.

The follow-on development to PIPSQUEAK is the FOPEN LW/SLR currently being tested over target arrays at Eglin AFB. Problems of debugging the sensor have precluded blindfold tests to date. However, this and follow-on developments should significantly cut into the insurgents use of weather and foliage to mask his activities.

The above slected summaries have been illustrative of the vast amount of experience being accumulated with the intelligence potential of reconnaissance sensor technology. In addition Rome Air Development Center is actively engaged in determining the problems of utilizing these systems operationally. We invite those having appropriate clearances and need-to-know to make use of this wealth of data. Inquiries should be addressed to:

CONCLUSION

Six years of active application of reconnaissance technology to the problems of counterinsurgent warfare finds us making some inroads into the insurgent's refuge of night, inclement weather and camouflage. Infrared operations in South Vietnam have been sufficiently successful (but unforturnately generally known) to result in Vietcong procedures to introduce measures of fire discipline. The next round of information elements currently being defined is based on a steadily increasing knowledge of their tactics and habits combined with vastely improved infrared scanners and recording equipment. By the end of the year we expect the current 4-6 milliradian systems will be supplemented by an order of magnitude improvement in resolution and dynamic range.

The low frequency side looking radars capable of detection of insurgent deploy-ments through a certain amount of foliage is at least a year from operational deployment in spite of increasing use of weather and vegetation to camouflage activities.

Major steps are being taken to improve the quality and timeliness of intelli-gence derived from our existing reconnaissance sensors by improved training and organization of interpreters. Establishment of area specialists skilled in the exploitation of new sensing technology is in its infancy and in South Vietnam the combining of U. S. - Vietnamese interpretation talent to produce background and operational intelligence has just begun.

We are beginning to gain experience in training personnel from under developed allies to operate some advanced forms of reconnaissance sensors such as infrared scanners. How far this can be carried under circumstances where skilled U. S. technicians must remain in the background is an open question. U. S. involvement in South Vietnam has reached a level of technological sophistication that frequently requires the assistance of highly skilled contractor technicians. Application of complex techniques and equipment to situations where our presense is strictly advisory or covert will be limited.

Finally, we find the situation in aerial reconnaissance operations today much the same as existed a decade ago. Our prime source of operational and background intelligence being the camera (admittedly considerably improved) and for near real time the human eyes. Technology has and is producing a vast array of new sensors, but successful development of exploitation techniques and operational doctrine lies ahead. By combining our vast wealth of technological knowledge with our growing reservoir of operational experience the reconnaissance contribution to successful counterinsurgency operations will improve immensely.

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AERIAL RECONNAISSANCE IN COUNTERINSURGENCY (U)

~~(Secret)~~

[redacted]

McDonnell Aircraft Corporation
Saint Louis, Missouri

ABSTRACT
(Unclassified)

The immediate problems confronting us in tactical aerial reconnaissance are examined, particularly as they are embodied in the employment of the RF–4C. The environment of counterinsurgency is defined, and the interactions between this environment and reconnaissance vehicles, equipments, and doctrine are discussed. The principal thesis is that the urgency of the situation demands that an immediate search be initiated for new doctrines and new techniques. Such methods can provide the most immediate improvement in operations and should be given an equally high priority with the longer ranged development of new equipments.

To achieve this goal, it is proposed that the Reconnaissance Intelligence Cycle be viewed as a total system and that the techniques of system analysis and system engineering be applied in the search for solutions. Illustrative examples of the potential success from such an approach are cited from recent McDonnell involvement in South Vietnam.

This presentation will concern itself with tactical aerial reconnaissance in a counterinsurgency environment. These data have been derived from the author's military, industrial and recent Vietnamese operational experience at Tan Son Nhut with the former 2nd Air Division. The information will be primarily directed to the problems of optimizing the application of present reconnaissance systems and secondarily to areas for future development that this experience has highlighted. Problems of counterinsurgency reconnaissance operations in S.E. Asia including reconnaissance sensor effectiveness, targets, training, maps, weather factors, navigation and communications will be discussed. The comments on Southeast Asian activity and reconnaissance in general are primarily based on RF–4C operational employment. The central thesis of this presentation is the extreme urgency of the problem and the need for a new look from a fresh point of view. Revolutionary, exotic devices can, in theory, solve the problems completely, but the war is already underway. Equally to be desired with new hardware, new weapon and reconnaissance systems, are more effective ways of employing the hardware we already have. If new techniques, new procedures can be developed to utilize equipment already in the field, they will be the more welcome because of the inherent speed with which new ideas can be communicated as opposed to the long lead time required to produce new equipment. (U)

It is axiomatic that the nature of the war directly influences the variety of intelligence data that aerial reconnaissance must collect. In the contemporary world, the types of war that are existent or possible vary from what the Communists call "wars of national liberation" which we call insurgencies through larger wars involving a limited area but using the full armamentarium of modern conventional arms and tactics to general or total war. The wars that have been most numerous since WW II have been the insurgencies such as those now going on in S.E. Asia and the recent Congo episode. With so many economic, educational, and political problems manifest among the large group of newly emerging nations, it seems reasonable to expect that these insurgencies will continue to occur and to increase in number. (U)

A prudent nation with world-wide responsibilities must be prepared with reconnaissance vehicles and techniques that can survive and operate effectively throughout the entire spectrum of war in any environment from general war to counter-insurgency. These vehicles must be equipped with reconnaissance sensors that can collect the required intelligence concerning the enemy during such conflicts. Such sensors must be able to operate effectively both day and night, and some must work in bad weather. (U)

One of the simplest, most reliable and effective reconnaissance systems ever devised for the insurgency environment was used against the "pony soldiers" by the American Indians more than 100 years ago. The basic components of this system consisted of a sharp pair of "MARK-1" eyeballs mounted in a low maintenance Indian located on a high piece of ground and equipped with a wet blanket and a smoking fire. This "clear air mass" system, while primitive by today's standards, actually had a number of advantages over today's sophisticated collection/reporting devices. Some of the more obvious advantages were as follows:

a. The Indian chiefs had unlimited confidence in the abilities of their "reconnaissance systems" and did not insist on validating the reported information by seeing it personally. The credibility lag that plagues us today had not yet been thought of.

b. The time lag from initial detection to positive identification of an enemy and the reporting of same was, for all practical purposes, only momentary.

c. Should a malfunction occur within the system, a new "vehicle" was always available as a replacement. By replacing the entire system, both the need for preventative maintenance and highly skilled mechanics was eliminated. (U)

Of course, the problem of distinguishing between the good guys and the bad was not nearly so complex for the Indian as it is for us today. For the hypothetical Indian, the enemy wore blue uniforms, carried long sabers, and looked like John Wayne. (U)

The primary target in Vietnam is precisely the same as that of our 19th century Indian wars, personnel, and secondarily his supplies and facilities. In an insurgency environment, our task is to seek and search or seek and destroy the armed enemy. Far more important than the enemy real estate is the enemy himself. We must find the enemy before we can engage him in battle. This problem is the more complicated because in Vietnam, "Charley" looks exactly the same as the friendly forces. The King of Siam's plaintive lament, "Is a puzzlement," holds equally true today as it did when the fair Anna first introduced him to Western culture. (U)

The economics of the post-WW II-Korea era dictated the production of several different multipurpose reconnaissance aircraft which were developments of bombers and fighters; e.g., RB-66, RF-101, RF-4B, RF-4C, and Mohawk. In each case, the vehicle had been designed originally for some mission other than reconnaissance. That capability was later "adapted" to them with resultant trade-offs that to some extent compromised sensor performance. Until the last year or so, when the evolving requirements of Vietnam became more pressing, reconnaissance systems have primarily been optimized for general war with the capacity for effective reconnaissance in lesser conflicts being secondary. Today, fortunately, there are indications that more attention is being directed toward specialized reconnaissance aircraft built around and for the sensors. (U)

We have spoken briefly about how the aircraft presently being used have evolved; now let us seek some definition of the insurgency environment in which all such reconnaissance aircraft may operate. There are a number of factors influeacing the development of insurgencies and the areas in which they are most likely to occur that have several things in common:

a. The available maps are usually inaccurate both in horizontal positioning and in elevation.

b. The areas of enemy operation are usually densely forested or otherwise covered with heavy vegetation, complicating the problem of gathering intelligence,

c. The available base structure from which reconnaissance aircraft must operate is limited in numbers and required support facilities introducing a great requirement for improvisation and flexibility,

d. The communication network is usually sparse, antiquated, unreliable, and hopelessly overloaded,

e. The weather is usually tropical with the attendant operational flying difficulties and aircraft and sensor maintenance problems, and

f. The areas of likely warfare are almost always several thousand miles away from U.S. bases and usually have poor to nonexistent transportation nets. (U)

S.E. Asia has provided the most vigorous test of tactical aerial reconnaissance since Korea, with the possible exception of the Cuban Crisis of 1962. The targets in South Vietnam have been made more difficult to image with any given sensor by the very nature of guerrilla warfare. An expression of the difficulty of photographing the Viet Cong was recently given by Mr. McNamara when he said, "It is much easier for us to photograph Mars than it is to photograph the Viet Cong." The enemy is normally so diffused among friendly activities that positive target identification as an enemy is very seldom possible from the interpretation of the sensor imagery alone.(U)

Collateral intelligence data must be used in conjunction with the imagery before an evaluation of friend or foe can validly be made; e.g., agent reports, defectors, villagers, time-place relationships, change comparisons, etc. In Laos, the enemy modus operandi is the more confusing in that he utilizes guerrilla techniques as well as those of a more conventional war. The enemy hides his movements and equipment, for example, camouflaging roads and trails in the Laotian "panhandle" along the North Vietnam to South Vietnam supply routes to prevent visual and photo observation. He also operates in areas he controls completely, as in the Plain of Jars area in Northeastern Laos. The extensive air and ground defenses of this area with its airfields, headquarters and supply installations is an example of the relatively open areas and target systems representative of the usual concept of Limited War and only occasionally that of counterinsurgency. (U)

The targets representing the enemy in counterinsurgency are basically the same everywhere. The backgrounds and cover vary, but the targets remain about the same; i.e., small groups of people and their weapons. The locales in which they are found depend on the time of day, the stage of guerrilla warfare in which they are fighting, and the season of the year. The enemy may be found from the deep rain forest to the city streets; from the rice paddy to a sampan along the coast; or in a camouflaged, fortified defensive position with 37 mm AA guns, recoilless rifles, 105 mm pack howitzers, 81 mm mortars, heavy machine guns all surrounded by a mine field. He may be living in the open with full military regalia in the areas he controls such as in much of Laos, or he may fight from concealed pop-up sniper holes which may be connected to an extensive tunnel system. The enemy seldom possesses aircraft, though his "neighbors" sometimes supply him with transports in some areas; e.g., northern Laos, the Congo. Rail and road interdiction type targets are usually limited to those systems which provide the insurgent with his external source of supply. (U)

The tropical rainy season favors the enemy in that it provides him additional cover from our aerial reconnaissance. The enemy can operate more in the daytime and in the open without fear of discovery. (U)

Aerial reconnaissance in Southeast Asia has had its successes, its partial successes and its failures, but the enemy is being found, and he is being attacked, through use of aerial reconnaissance. IR, Side-Looking Radar (SLR), and optical photo sensors are all being used. IR is the primary and most effective sensor being used in South Vietnam because of the way the enemy cooks his food and his lack of discipline when going about it. These cooking fires are found by IR techniques, whether hidden in deep jungle, in the open, or on small sampans on the rivers and canals. Successful air attacks, artillery strikes, and ground sweep and clear missions are made daily, based on IR reconnaissance. (S)

The SLR is used primarily for finding sampans and junks that are breaking curfew on inland waterways and along the coast. A complete SLR mosaic has also been made of South Vietnam and the Laotian "panhandle." The high geometric fidelity (1.8%) of the RF-4C SLR enables SAC B-52 radar bombardiers to find more suitable offset aiming points on these mosaics for bombing the jungle-covered enemy more accurately than present maps allow. IR is regularly used simultaneously with the SLR on coastal curfew surveillance as a means of relating levels of activity along the shore with numbers of watercraft breaking curfew in that area. Such data enable the Navy to better employ overextended meager forces. (S)

Optical photography is being used both day and night for targeting open areas and for bomb damage assessment, but the nocturnal and camouflaged nature of the enemy operations makes the enemy more difficult to find than with IR. (S)

Generally, this is the reconnaissance situation confronting us, and the sensors that are being used. Improvements in our equipment and its application usually come from an examination of the problems that ensue. Let's begin the examination. (U)

The Reconnaissance Intelligence Cycle in S.E. Asia is plagued with a number of problems in current operations. It is reasonable to assume that S.E. Asian conditions are analogous to other counterinsurgency environments. The elapsed time between the initial requests for reconnaissance and the delivery of the data to the requestor at worst requires days and at best too many hours. So "Charley" often goes on his way noticed, but unharmed. This introduces a number of factors, some of which are at least partially solvable by more effective use of people and equipment; i.e., better procedures, better training, more understanding on the part of the reconnaissance requestor of what is possible. Other solutions will require improved sensors, communications, and especially improved techniques. (S)

Due to the unexpected acceleration and expansion of the U.S. commitment in Vietnam last year, the Air Force deployed the 16th RF-4C squadron far ahead of schedule. This early deployment left insufficient time for completion of the planned training cycle for staff, flight crews, and sensor maintenance personnel. Training was futher hampered by the lack of data in the field concerning what intelligence it is possible to derive from IR and SLR sensors, as well as the best ways to fly the sensors to gather the desired intelligence. The Services have been conducting a number of multisensor tests on tactical targets during the last few years, but apparently little of the newly developed data on the uses of IR and SLR have been disseminated to operational units. Industry has also conducted controlled sensor tests both contractually and with company funding. These tests have developed meaningful data on sensor adjustments and flight techniques for more effectively imaging targets, some of which have been communicated to the staffs and units in the field. McDonnell's RF-4C Multisensor Reconnaissance test, Project IRIS, is one example of such a company funded effort. This effort consisted of:

a. A simultaneous multisensor flight test and imagery interpretation program on simulated Vietnamese type tactical targets with outputs in the form of manuals. One manual was for staff planners, one for imagery interpreters, and one for sensor maintenance men.
b. Sending the writer, who devised and conducted the test, to Vietnam with the RF-4C squadron to aid staff planners and squadron personnel whenever possible in planning and accomplishing their missions. (S)

The Air Force, realizing that there was a gap in the knowledge of the sensor maintenance men, purchased a six-month contractual package of McDonnell, Goodyear, and Texas Instruments engineers to go to Vietnam to help maintain the sensors and to conduct OJT. (U)

The combination of these company funded and Air Force contracted programs was a deliberate attempt by a company and a Service to bring more of the state-of-the-art to the man in the field. Now let's look at these problems in more detail, and perhaps they may point us toward some solutions. In the Reconnaissance Intelligence Cycle, the request procedure itself is reasonably simple and effective so long as the requestor understands the capabilities and limitations of the reconnaissance equipment and communications work. It is in responding to a request that the system slows down. The staff planning for filling the requests has suffered from a lack of understanding of what intelligence the IR and SLR sensors could gather, and the best flight profiles required to gather it. This knowledge gap is gradually being filled through experience. It is vitally important that lessons learned from operational field experience be passed on to replacements as the opportunity to acquire this knowledge is extremely limited outside the combat area. (S)

The flight crews of new multisensor reconnaissance aircraft have been hampered by a lack of understanding of, and training for, the best way to fly their aircraft to collect the required intelligence with IR and SLR. (S)

The sensor maintenance personnel apparently have had no chance to learn the inter-relationships of settings of the various component parts of IR and SLR as they affect the manner in which these sensors image the different targets and their varied backgrounds. Unless all of these personnel are trained to use such data to optimize the IR and SLR for the desired intelligence of the targets requested, the chain of effective reconnaissance is broken before it can be used. (S)

There are many knowledgeable men in the various research and development laboratories who are aware of and accept as common knowledge much unpublished data that is completely unknown to the "outside operational world." These data can materially affect the success of operational application of sensors in the field. It seems that too often we wait until a "full report" can be published. An excellent example of such a condition is in the field of IR and SLR. These sensors were designed to operate within specifications ("specs") that it was generally believed would enable them to collect the desired intelligence on tactical targets in various environments. Operational application of the sensors has shown that the "spec" adjustments have frequently prevented, rather than enhanced, successful target imaging. This appears to have been due to an insufficient "latitude" available in the system to encompass all the different target/background conditions that have been encountered. McDonnell, in concert with Goodyear and Texas Instruments, is presently preparing an RF-4C Reconnaissance Sensor Applications Training Program in an attempt to partially alleviate this condition. The program is twofold. The first portion concerns the preparation of a manual which will contain the essence of what we presently know about the best means of collecting and extracting intelligence from the RF-4C IR and SLR imagery. This manual will deal with: mission planning for staffs and crews; imagery interpretation techniques; and sensor adjustments for optimum imaging of the various targets for the maintenance men. The second part of the program will provide a team composed of highly qualified engineers and imagery interpreters. This team will take the data to the field to the staffs and reconnaissance organizations and work directly with them. This is only one small effort. A regular channel must be established by all concerned, through which current data can be passed in layman's language to the staffs, the training organizations and field units on a timely basis. (S)

We must train the people, staff planners, processors, and users alike, more as a total package than in bits and pieces as we presently appear to be doing. We must try to recognize the system implications in the intelligence cycle and engineer the systems accordingly. (U)

Another area where there are problems is that of imagery interpretation. In the optical field, the only immediate problem appears to be adequate numbers of people, equipment, and working space in all but the pan cameras where more training and experience are needed. In the case of IR and SLR, there is an extreme lack of understanding of sensor performance; i.e., the varying factors such as time of day, target and background that affect the imaging of targets, what intelligence can be extracted from the imagery, and the techniques for its extraction. In the Air Force, few service interpreters have had any experience with IR and SLR imagery. The loss in operational capability in the field by rotation to the U.S. is evident in this area as well. (S)

Another side of the coin is what I call the "Credibility Gap" between the Command and Staff Officers and the imagery interpreters. Such gaps are a normal development when new equipment is introduced but is considerably amplified in this case. The images of targets as seen on IR and SLR imagery are not directly interpretable on sight by untrained people, regardless of their rank, as in the case with optical photos. Commanders and their staffs are most reluctant to accept the "interpretations" of a professional in this area if they cannot "see" the target on the imagery themselves. I am reminded of a similar problem in SAC before radar bombing became so commonplace. Until decision makers are willing to base decisions on the professional interpreters' reports, the usefulness of these sensors is greatly reduced. It may be some time before this educational problem that is causing the "credibility gap" is alleviated. (U)

Even if we make the assumption that the requestors, planners, pilots, and interpreters all know their business and can communicate with one another in an acceptable time frame, there are still remaining two other problems of nearly equal magnitude. These are map and reconnaissance vehicle navigational accuracy. It is "distressing" for a pilot to fly to the target coordinates given in a "frag" order, reconnoiter it and return to base, only to learn that the map was wrong, and that he had not actually covered the target. It is even more "disconcerting" if his navigational system indicated he was over the target and he then discovers the navigation system was off by several miles from the coordinates shown on a map which itself was erroneous. If a reconnaissance flight is made in daylight, a pilot can frequently correct both the map and his own navigation by visual reference or by Forward Looking Radar if there are enough landmarks to compare. However, there are many broad expanses of jungle in which there are no distinguishing landmarks, and navigation and map accuracy become all important. (S)

Night flights in counterinsurgency environments are as walking in the Stygian darkness of a deep cave due to the lack of city lights, highway nets with traffic, etc. Since the enemy primarily operates at night, a large number of reconnaissance missions must be flown in that time frame. Navigational accuracy becomes even more important under these conditions because there are almost no visual reference points. (U)

Most reconnaissance flights in the counterinsurgency environment are made at such low altitudes that normal high altitude navigation aids such as TACAN cannot be used in the target area. TACAN can guide you to a let-down point in a Hi-Lo-Hi profile, but is useless in the target area itself. Radio navigation systems such as Loran D can provide the desired positional accuracy, but they require several ground stations spaced over a wide area. These stations must be located in certain geographic relationship to one another and must be protected from the inevitable sneak mortar or recoilless rifle attacks. Improvements in an inertial navigation system might be the most economical from the cost effectiveness standpoint because only the air bases would have to be protected from the sneak attacks instead of several isolated stations which are nearly impossible to defend. An inertial navigation system with a positional accuracy on the order of one nautical mile per hour of flight time or less could provide a dependable, defendable system. If provisions are made for updating the inertial navigation system with a Forward Looking Radar (FLR) in areas where landmarks are visible, even greater accuracies can be achieved. (S)

The problem of map error is one that has always been with us. In a normal, permissive, peaceful environment, maps of acceptable horizontal and vertical accuracy can be made with aerial reconnaissance and ground geodetic control. In a counterinsurgency environment, free access to the necessary ground areas for adequate geodetic control is denied, leaving one with old and incomplete geodetic data, erroneous maps, and a mass of new aerial reconnaissance imagery (photo, IR, SLR). In time, the maps can be updated by assiduous application of all available old data and the carefully plotted operational imagery. All insurgencies which have developed since the word itself became so popular, have progressed at such a rapid rate that the ones who fight haven't the trained people, the time, space or equipment to update existing maps to reflect the real state of affairs. Other agencies in the CONUS could easily perform this task on an ASAP basis, and thus improve the efficiency of all reconnaissance and strike operations. This is the best solution. (U)

An interim solution to the horizontal accuracy problem using current equipment might be to fly mosaics of targets and target areas. Flying mosaics does take more time, and the intelligence on the fleeting enemy may become less valid, but it may offer some help. The relative accuracies of maps have always been established by pilots through trial and error.

The maximum error in the areas covered can be established in a reasonable time. Mosaics can be planned and flown to minimize map errors. One may begin the initial flight line a distance equal to the maximum map error to one side of the desired target or target area and continue the flight lines a like distance on the opposite side of the target area. The probability of obtaining the desired coverage is much greater. If by chance this target area is defended by AA weapons, the multiple flight lines required for a mosaic increase the risk of attrition. Commanders would naturally have to assess the value of the data they might collect in relation to the risks involved. (S)

Up until now we have been discussing positional or horizontal map accuracy as it pertains to the target finding and the reporting problem. When vertical accuracy enters into the picture, the "apple becomes wormy" indeed. In order for one to get the necessary large scale photos needed for COIN targeting from the RF-4C, these targets must be photographed from 2000-2500 feet. This altitude is for night photos with flash cartridges. During the day, flights can be made at higher altitudes with other cameras and still get the intelligence. If the usual COIN targets are to be imaged on IR, one must fly at 1000-2000 feet. SLR can be flown at from 1500 to 5000 feet for MTI, or up to 50,000 feet for mapping only with the same effectiveness against those few COIN targets for which it is suited. When there is no visual reference, pilots must fly at an altitude that will clear all terrain obstacles. This drastically reduces the sensors' operational effectiveness. The reduction is due to obstacles that may force the flight altitude too high for the sensors to image the targets adequately for the required target intelligence to be extracted. The use of forward looking navigational and terrain following radar (FLR) can reduce this problem, but it will not be eliminated until the pilots become so familiar with an area that they can correct their own maps for elevation or horizontal positioning or until the maps are corrected by the appropriate agency. Lack of landmarks for reference points can make FLR nearly useless in those COIN areas covered by broad expanses of jungle. In areas where there may be a landmark from which the pilot may fly a time and distance leg on a given heading to the target or target area, or align himself for his various flight lines, the FLR is a must. (S)

The FLR terrain following mode is an ideal tool for maintaining an optimum altitude for sensor operation in terrain of varying altitudes. In areas where the maps do not accurately report the presence of mountains, valleys and buttes, it is an absolute necessity. The effective use of the FLR in these conditions, however, does require much practice as well as the complete confidence of the crew in the equipment. (U)

Current RF-4C reconnaissance missions in the Laotian "panhandle" are excellent examples of some of the problems of avoiding terrain while maintaining the desired altitude. The night photos and IR are being flown at 3500-4000 feet which is high enough to avoid the tops of the mountains along the flight path. Unfortunately, this altitude has usually been too high for the night photo or IR sensors to effectively image the vehicle traffic on supply routes from North Vietnam very often. As previously stated, for the best intelligence extraction, the night flash photos in such generally jungle covered areas should be flown at not more than 2000-2500 feet altitude and the IR at 1000 to 2000 feet. At these altitudes, if vehicles are imaged, they will appear at such a scale and clarity that their presence and type of activity can be easily determined. The RF-4C pilots tried using the FLR in Southern Laos earlier this year, but found so many uncharted mountains that they spent most of their time in violent maneuvers which exceeded the stabilization limits of the sensors. This resulted in unacceptable imagery. To say the least, a few of these rather violent "exercises" cause one to add a thousand feet or so each for home, mother, wife, and children. The IR imagery secured from the 3500 to 4000 foot altitudes in Laos has been almost useless for anything but plotting the optical photos and for trying to update the maps. For example, the trucks on the supply routes could not be resolved on the narrow tree lined and tree covered "roads" at these operating altitudes. (S)

There is no clear solution to the vertical map accuracy problem except to fly higher until the maps can be updated by local effort or by the map making agency. (U)

To summarize, in order to obtain the desired intelligence, it is necessary to fly at certain minimum altitudes with the various sensors. The low flight altitudes required for sensor effectiveness make for narrow sensor swaths. This necessitates many more flight lines, each of which must overlap with great precision. In South Vietnam, this problem has been especially evident in RF-4C IR reconnaissance. At 2000 feet, the ground sensor swath is only 6900 feet. To cover a 10 nautical mile x 15 nautical mile area requires 11 parallel flight lines if a 20% sidelap is to be provided. Pilots experience great difficulty in flying such a mosaic and leave frequent open spaces between flight lines. Present Air Force techniques call for flying from a known point on a time and distance leg to the beginning of the first flight line. The mosaics are usually flown at 360 knots. At the end of the first line, based on the time flown, the pilot goes into a 45 degree bank in a jet standard rate instrument turn. At the completion of the 180 degrees of turn, he begins his next line four lines over from the first. At the time completion of this line, the pilot then initiates a jet standard rate instrument turn at 55 degrees angle of bank for a 180 degree turn and returns to the flight line beside the first one flown. This "race track" pattern technique works fairly well. It appears to work because of the variables inherent in the pilot's flying technique, some of which cancel each other. This is a no-wind pattern, and there is always some wind. A variation of even ±1 degree in the exact angle of bank results in a ground track error of hundreds of feet. Attempting to begin and end each flight line at exactly the same time also offers some opportunity for error in track spacing. Variations between the rate at which pilots enter into the turns vary the spacing of the flight lines. Pattern accuracy is also sensitive to variations in flight altitude. (S)

In an attempt to alleviate this difficulty, McDonnell is developing a reconnaissance flight path steering computer. This computer will provide pilot steering information on the Bank Steering Bar of the RF-4C Attitude Director Indicator to enable predictably parallel mosaic flight paths to be flown over predesignated areas. The pilot steering information will consist of "turns to" and "steering along" flight paths which are parallel and offset a predetermined distance from the adjacent flight path. (S)

The Computer can provide a capability for flying mosaics of any area up to 40 nautical miles by 40 nautical miles along any desired course angle from 0–360 degrees. The distance between adjacent flight lines can be varied from 0–6 nautical miles. This range of settings can accommodate expected variations in sidelap, flight altitudes as they affect sensor effectiveness, and operational speeds. A light is used to indicate when an aircraft is flying a path in the mosaic and a binary counter will indicate how many of the programmed paths have been flown. The preselected mosaic grid pattern may be changed at any time during the mission to bypass unexpected enemy defenses or weather. (S)

Test results indicate that a major increase in mosaic flight line accuracy for all sensors will be achieved when using this device. (S)

Thus far we have discussed the requesting and collection areas of the intelligence cycle and proposed some solutions to correct problems. We have defined the reconnaissance requestor's need for knowledge of the potentialities of aerial reconnaissance sensors and for an understanding of the problems that beset the collectors. The final critical area of the Reconnaissance Intelligence Cycle is that of reporting. (U)

There has been no intelligence communications net per se in Vietnam. As a result, intelligence is frequently lost to all practical use because the complete reconnaissance cycle takes too long. There are delays in requesting; headquarters staffing; mission planning and accomplishment; interpreting, and reporting. Let us address ourselves now to the problem of communicating the intelligence on the enemy that has been collected. Immediate Photo Interpretation Reports (IPIR's), once composed, are sent by phone in code when lines are available and operable. IPIR's are also sent by TWX, but the available lines for telephone or TWX messages are few and are frequently glutted with traffic. The last means of delivery are by aerial drop and by messenger on the ground, which usually take the longest. In the writer's opinion, a separate and exclusive intelligence net for request and reporting is mandatory if the perishable data on an ever fleeting enemy are to be best employed. (S)

Earlier references in this paper to the fleeting enemy in Vietnam have not been exaggerated. The primary tactical target is people, frequently on the march. If in bivouac when imaged from a reconnaissance flight, the fact that he has possibly been "seen" is stimulus enough for "Charley" to pack up and move. Obviously, the longer the interval between location and identification and a strike, the greater is "Charley's" opportunity to escape. To reduce the time from detection to attack, some positive means of instant identification as friend or foe, and the greatest possible reduction of elapsed time between target acquisition and strike is required if the enemy is to be defeated. At present, the only means of acceptable identification as friend or foe from the air is still the time-place relationship. In Vietnam, two systems are used. One is the "free strike" area. Such areas are so designated by the Vietnamese Province Chiefs based on reports of their intelligence agents that only enemy forces are in a given area. In these areas, strikes may be made by any means at any time whenever targets are found. The second system is the "curfew," and it applies to boats on canals or rivers. Any craft seen moving during curfew hours must by definition be the enemy. (S)

There are two partially operational solutions to the target identification and reporting problems that are being used in Vietnam. These are:

a. A reconnaissance-strike force made up of a reconnaissance aircraft with IR or SLR sensors and in-flight cockpit real time readout, a flare or light aircraft or helicopters, and attack aircraft or helicopters; and

b. Reconnaissance aircraft equipped with an IR sensor, in-flight cockpit readout, and a real time data link of the IR video presentation. (S)

In the free strike or curfew environment, these solutions offer a great reduction in the target acquisition-target intelligence reporting cycle. In the reconnaissance-strike case, the time is reduced to a few minutes. In the data link case, the reporting time is greatly reduced because the imagery can be interpreted in near real time at the requesting agency and appropriate action taken. There are not nearly enough of the in-flight readout-data link equipped aircraft operational in Vietnam to meet the actual needs. (S)

Until true people-finding sensors that can locate humans in any environment and weather and still be carried in aircraft are developed, the aerial reconnaissance job will still have to be done by utilizing present equipment more effectively. (U)

There are several other factors which affect the success of the in-flight readout and data link operational solutions which involve the aircraft navigation system and map accuracies that we mentioned previously. They also include two other factors that have an even greater impact. The impact of these factors can be summed up in two questions:

a. Is there enough time for the air crew including an airborne imagery interpreter to detect, recognize, and report the location of targets on the in-flight readout scope when the aircraft is flying at the operational speeds required by the defensive environment and the urgency of the mission?

b. Can the data link system send the desired imagery directly or through aerial relay to the desired recipients with no degradation of resolution and contrast of the imagery? If present equipments can be improved so as to fulfill the requirements posed by these questions and then installed in pertinent reconnaissance aircraft used in counterinsurgency, a great step forward in operational efficiency will have been made. (S)

In summary, we have:

a. Defined the basic problem areas that are common to all counterinsurgency environments;

b. Examined the status of a current operational reconnaissance aircraft, its sensors and its navigational systems as they are being applied to the reconnaissance tasks;

c. Stressed the need for a total package rather than fragmented training of all personnel from commanders to sensor maintenance men in the application of present SLR and IR sensors to the counterinsurgency intelligence collection problem;

d. Emphasized the need for making better use of present equipments through bringing new developments and knowledge promptly from the laboratories to the field so that combat operations can more expeditiously reflect improvements in the state-of-the-art;

e. Identified the need for building improvements into present equipments for the near term as well as continuing work on more exotic devices which may indeed help to solve the problems but whose availability cannot be immediately anticipated. (S)

The ultimate answers to the aerial reconnaissance problems confronting us in a limited war environment are still somewhat obscure. The solutions suggested in this presentation are interim, operational answers at best. It is the writer's considered recommendation that the entire reconnaissance cycle be subjected to a thorough systems analysis under the sponsorship and direction of the DOD. It isn't simply an Air Force, Navy, or an Army responsibility. Intelligence collection, interpretation and dissemination, especially in the present context, must be viewed as a total integrated system and be analyzed and engineered as such. The talent and the manpower to perform such a total systems analysis exists both within the DOD and within industry. Who does it seems far less important right now than getting it done. (S)

Session 2

APPLICATIONS OF AVIATION

(b)(6)

[redacted]

BRIGADIER GENERAL ANDREW J. EVANS, JR.

Brigadier General Evans was graduated from the United States Military Academy in 1941. After training as a pilot, he was assigned to fighter aircraft units in the United States and the European area during World War II. Since the war General Evans has served on the staff of the Air University; attended the Air Command and Staff School; served on the Joint Staff, Joint Chiefs of Staff; was executive assistant to the Chief of Staff, USAF; attended the Air War College; was Deputy Commander of the 49th Fighter Bomber Wing in Korea; was on the faculty of the Air War College; was Group and Base Commander at Oxnard AFB, Vice Commander of the New York Air Defense Sector, and Commander of the 65th Air Division in Spain, before being assigned to his current tour within the Office of the Deputy Chief of Staff, Research & Development, Hqs. USAF. Currently, as the Director of Development, General Evans is responsible for the development of advanced system and major sub-systems leading to production and procurement and provides technical support for the development aspects of systems and sub-systems already in production and procurement. General Evans also serves as the Special Assistant to the Deputy Chief, COIN. In this capacity General Evans is the Air Staff focal point for all matters pertaining to COIN Research and Development.

APPLICATIONS OF AVIATION

IN COUNTERINSURGENCY (U)
(For Official Use Only)

Brig. General A. J. Evans, Jr.

Hqs United States Air Force
Deputy Chief of Staff, Research and Development
Washington, D.C.

It is my desire today to discuss the basic use of airpower in Counterinsurgency, to emphasize that this intrinsic Air Force capability demands early and continuing Air Force activity in Remote Area conflicts, and to review the manner in which the Air Force addresses the subject today and must continue to do so in the future.

I hope that you will sustain me in my belief that a vigorous R&D effort in the fields of Counterinsurgency is mandatory if we are to meet the challenges to which the uses of aviation can best respond. As my definition of Counterinsurgency I am using that which I believe is generally subscribed to -- both the maintenance of a climate of order and stability under which progress can take place, as well as the restoration of order after open conflict breaks out.

First of all, it is my fundamental belief that the proper application of air power can have a profound effect on the success or failure of Communist insurgency. In considering almost any job associated with COIN - and we can look at many of these later - the inherent advantages that airborne vehicles have over ground vehicles - of course these are such things as mobility, flexibility, speed, etc. are the very factors that are most needed to cope with unrest and insurgency in a developing nation. I suggest that if these advantages are brought into play soon enough, open combat by U. S. ground forces may be forestalled or prevented.

It has always seemed strange to me that while the contribution of air power in nation building is freely recognized for our more advanced nations, for some reason we relegated it to a secondary role in underdeveloped countries. In the case of Vietnam, air power should have been forcefully applied to the military and the civic action problems in 1957 or earlier. But as late as 1964, the general theme was held by most people I talked to that it was a "ground war" and that aviation was not necessary to the pacification of the countryside or control of the Viet Cong. So we cannot fault the use of aviation in Vietnam in the early stages of insurrection, as it wasn't seriously used until open conflict was involved. (Incidentally, I make no distinction between helicopters and fixed wing aircraft, between Air Force and Army, in my subject "Application of Aviation in Counterinsurgency".)

Having made the contention that early application of air power in Vietnam as early as 1957 could have resulted in an effective force to curb the then existing insurrection, I must admit that we were not ready for such a role. One of the obvious prerequisites for this role is a focusing of R&D efforts on the various facets of air power so that when national policy recognizes and calls for early and proper application of aviation support in insurgency situations, then air power is prepared to meet the challenge. That is one of the reasons we are here today. I am, frankly, uncertain whether a U. S. commitment exists to block Communist insurgency wherever it may appear in underdeveloped countries throughout the world. Whatever the extent of the commitment, the military must be postured to meet it. In Vietnam we are learning to apply 1966 technology to a conventional, limited war. The lessons we are learning should be applied, in each of our Services, to developing a capability for countering future insurgency at a level well below the intensity of Vietnam, for it is certain that neither national resolve nor public policy will tolerate containment of Communist insurgency if the price is several more Vietnams in our generation.

In expanding on thoughts concerning the true potential of air power in counterinsurgency, I wish to emphasize some of the potentialities which are unique to aviation and then discuss the basic requirements for their application.

First, what are the potential contributions inherent in aviation and air power that I have in mind? In the earliest stages of preventing insurgency, the use of aviation to establish and maintain contact, and in turn to promote the necessary rapport between the people and their government are obvious. There exists a requirement for political, economic, and sociological intercourse between the government and its people. It was stated with classic simplicity by a Guatemalan officer at the first Inter-American Air Forces Counterinsurgency Symposium. He said:

"Without communication, there is no education;
Without education, there is no patriotism;
Without patriotism, there is no government;
Without government, there is no employment;
Without employment, there is no consumption;
Without consumption, there is no industry;
Without industry, there is no progress;
And without progress, there is no communication."

Without question, the greatest single contribution that aviation can provide in developing countries is in the field of communication. Communication means the sharing of information, by messages, by talk, by radio, by TV -- and then, from Webster, "a way for getting from one place to another." So communication is also travel, and in the areas of the world with which we are concerned, travel by air is not only the desirable way but in some instances the only way. The need to get representatives of a government into remote areas, and the capabilities of aviation to accomplish this, is a key factor in counterinsurgency but the contribution of aviation goes beyond the mere transporting of individuals. The introduction of an airline of communications into a remote country, no matter how austere it may be or how unsophisticated the aircraft, offers new opportunity and new hope to the country. New jobs are created in order to logistically support the operation; weather information, for instance, is required and this in turn is the basis for another system or network in the communication field. A capability or service that has equal application to the agrarian or even pleasurable pursuits of the population are therefore outgrowths of uses of aviation. Medical treatment also is made available to those who were previously isolated from these services.

Many of our communication modes, such as TV, are line-of-sight and here aviation can make a contribution. The use of TV in Vietnam - beamed from airborne transmitters - has been a great boon to the psychological warfare efforts of the government. Many people tend to think of psychological warfare as primarily applicable to active insurgency. Some do not consider that it may be equally effective in preventing an individual with no sense of national identification from becoming an insurgent. In either circumstance, however, a person isolated from his government and remote from the mainstream of his country's activities is a ripe target in the so-called "struggle for the minds of men." Whether he is an active insurgent or a potential insurgent, he can be influenced by communication, and aviation offers a vital contribution in this entire field. Aviation - and here I underscore the peaceful applications of aviation - should, therefore, be employed in the early stages of a struggle within emerging nations, and through its contributions in the field of communications and transportation become a decisive factor in determining the outcome. Most emerging nations lack technical skills, have few teachers, doctors, public health and sanitation officials. Aviation, properly utilized, can multiply these scarce skills and enable one teacher to provide instruction to several otherwise isolated villages -- enable one medical team to serve many communities.

The other capabilities of aviation would normally augment and follow on its contribution to communication and travel - and be required only where the initial applications were not totally successful. If insurgency progressed to the stages of armed insurrection by guerrilla bands, then the applications of air power become those of surveillance of the insurgents, transport or airdrop of troops or supplies and delivery of weapons in support of friendly government forces. Reconnaissance and surveillance, of course, should begin long before the stages of armed insurgency and, used in conjunction with other sources of intelligence, should provide for the immediate show of force or active intervention before an organized guerrilla movement or attack becomes possible. The initiative then becomes ours and the oft quoted ratio of 10 to 1 required to win can be substantially reduced.

We need to focus additional R&D effort in this area and are now doing so. We have made significant strides in the direct approach to surveillance and detection in the past year with accelerated efforts in infrared, foliage penetration radar, low power radio direction finding and radiometry, to name a few. There is no reason to doubt that the technological capabilities of the military and industrial resources which this gathering represents can provide the capabilities that will be needed in future situations.

Once we have the insurgents or guerrillas located, or at least know his main supply routes, encampment areas, and primary support areas, we want to isolate or contain him. There is a real need to seal off sizeable areas preventing or alternately controlling the introduction of personnel and material by the establishment of an aerial blockade. This would be particularly appropriate when striking the source would not be politically acceptable. The use of a ground force barrier may be too expensive in men and material, and could also be unpopular or politically unacceptable. Through the use of aerially delivered area denial weapons, then, air power can be used as a substitute for massive ground deployment. Air movement of a tailored force of our own ground troops into such an encircled or sealed off area could then be accomplished without fear of enemy support from outside forces or of their getting away. Barrier effectiveness would not have to be absolute to be effective. The unpredictability of barrier penetration could create obstacles too great for the insurgent to risk.

We all know that the violator of the law thrives on darkness, nature's most universal and simplest gift to the guerrilla for cover and concealment. We have long recognized the value of lighting up our streets when we wish to prevent crime, and to give the policeman a chance to see the criminal so that he can be countered or killed. In the guerrilla environment we have no lamp posts to hang lights on and no ground vehicles that can operate in his environment. Aviation, therefore, can with the proper R&D emphasis provide the means of lowering the threshold of darkness through LLLTV systems and of exposing him to visible light intensities provided by airborne illumination systems.

Before we leave my identification of potential applications of aviation and discuss the key requirement for the realization of this potential, I would like to mention another possible application of air power. It involves the capability to influence the agricultural efforts of the people, either favorably or adversely. We have engaged, to various degrees, in defoliation and the use of herbicides in Vietnam. We have not concentrated on an operational capability for aerial application of pesticides; and fertilizers to enhance agricultural efforts of the people in emerging countries. However, at the Special Air Warfare Center (Eglin) where a part of their job is to consider the subject of CIVIC ACTION, they define it in part as "the employment of military forces in civilian projects to better the lot of the people." They also recognize the significant psychological influence that could be obtained in forecasting - or threatening, if the situation warrants -- the future welfare of agricultural efforts, and then following up the promises with actual results. On the positive side - improving harvests through the use of fertilizers - this is certainly "bettering the lot of the people" and we are making initial studies, with the Department of Agriculture and ARPA, as to the feasibility of aerial application of fertilizers in underdeveloped countries.

Now, as you have noticed, I've been discussing the capabilities of aviation in counterinsurgency in broad terms without treating the individual subjects in detail. This is intentional in that the areas where aviation can provide enhanced capabilities - such as in reconnaissance and in psychological operations- are specific subjects elsewhere on the symposium agenda. But without the proper aerial vehicles, these capabilities cannot be optimized. So I do think it pertinent to discuss the so-called COIN aircraft or Special Air Warfare aircraft in some detail.

I must preface this treatment, however, with the note that it is an incomplete discussion. The COIN aircraft problem has many facets. Studies, while contributing to our knowledge, do not solve the problem. Considerations of the entire spectrum of conflict leave their mark on the COIN aircraft and its relationship to the other inventory requirements. The final answer is not yet at hand, and I'm only warning you that I am not providing it here today, but merely discussing some of the many factors identified with the subject.

Hopefully we will get the first airplane identified as "COIN", the OV-10A, in 1967. This schedule is not indicative of our early interest in the subject. In reviewing briefly the history of our Special Air Warfare or SAW forces aircraft, I found that we have been considering for some time possible requirements for three types of aircraft - a strike/recce aircraft, a utility aircraft, and a transport aircraft. The U-10 Helio Courier has been the utility aircraft in the SAW forces. Many potential follow-on aircraft have been evaluated by the Special Air Warfare Center, including the Turbo-Porter, the Helio Stallion and the DeHavilland Beaver, all modified with turbine engines. However, a successor has yet to be approved.

The transport aircraft are today C-47's, C-46's and C-123's. In May 1962 we considered a proposal to modify C-123's with jet engines, but the mod was at that time thought to be too costly. Today C-123's are a critically short airlift resource and the requirements in Vietnam will continue to limit the number of aircraft available for SAW forces elsewhere. Although most of our C-123's are now being modified with jet pods, a new SAW transport aircraft is a definite requirement.

A similar situation exists concerning strike/recce aircraft. The original inventory included T-28's, B-26's and later A-1E's. Forty B-26 aircraft were modified to the ON-MARK configuration and those that remain today are in the SAW inventory.

Future requirements for both transport and strike/recce type aircraft are documented in SOR-222 for a family of SAW aircraft. The missions of the light transport include airdrop; medical evacuation; an assault landings; psy ops; crop dusting, seeding and defoliation; flare drops and training of indigenous forces. STOL characteristics are required for operations from semi-prepared fields while accomplishing missions in civic action, psychological warfare, and delivery and supply of Army Special Warfare personnel. The design payload is 4000 lbs for a 250 NM radius mission at 5000 ft. with normal cruise of 200 knots. The basic passenger capacity is 12 fully equipped troops - the equivalent of an Army Special Forces "A" Team.

TOD over a 50 foot obstacle at home base is to be 2000 ft and 1000 ft on take-off at the midpoint field. Landing over a 50 foot obstacle must be equal to or less than the take-off criteria. Take-off and landing performance degradation cannot exceed 20-25% due to high terrain elevation operation -- i.e., up to 10,000 feet. Ferry range is to be 2600 NM without inflight refueling and the aircraft must be capable of night and adverse weather operation. Landing gear should accommodate a minimum sink rate of 12 ft/sec at design gross weight and provide a UCI of 10.

To insure maximum safety and survivability to crew and passengers within the Special Air Warfare environment, the aircraft will have a load factor of 3.8g, self-sealing fuel tanks, armor (against 50 cal), and crew and passenger egress even when main cargo compartment is loaded. Reliability and maintainability requirements and characteristics are to receive special attention to provide the optimum in operational ready rates, reaction time, turn-around time and overall effectiveness.

The Air Force first became really active in COIN matters in 1962. The Special Air Warfare Center was formed in May of that year, and it was in 1962 that the earliest requirement for a COIN aircraft development program was submitted. The program was disapproved because of the DOD view that COIN requirements could be met with existing aircraft, and we began to look for ways to improve existing aircraft. This led to the YAT-28E and the YAT-37D programs, as well as the ON-MARK modified B-26K.

Although the Air Force has been on record since 1962 for a COIN aircraft development program, to replace these aircraft, in all honesty we did not seem initially to have much interest in the so-called LARA, which in its earliest stages got support mostly from the Marine Corps.

There is still some doubt about just what the OV-10A can do, but the Air Force is solidly behind the procurement of an aircraft of this type for the forward air control mission. I think it is fair to say, though, that there is still an open field to discuss what our future COIN aircraft should be.

The philosophy of the Special Air Warfare Center gives us an interesting perspective on the problem. SAWC sponsors the "family of aircraft" concept as an answer to their needs for three functional types: light utility, light transport, and Strike/recce. SAWC recognizes that U. S. policy, no longer valid in Vietnam but presumably applying to future COIN situations, is that we will assist host governments in the maintenance or restoration of internal defense, but we will not do the job for them. This immediately identifies a need for a relatively simple aircraft with dual controls. Since most of the countries involved are newly emerging and developing, their economic stature may not permit independent procurement and initial support of a national aviation program. Their lines of communication are austere or non-existent and the usually rugged geographical terrain places additional emphasis on their need for aviation, but if they are to have it the U.S. must provide most of the monetary assistance. This supports the arguments for an inexpensive airplane in order that we might underwrite indigenous aviation programs with new aircraft. On the other hand, the aircraft we have provided under the MAP program seldom are ideally suited for use in a counterinsurgency role. The older trainers lack capability while jet fighters are certainly too complex for internal security purposes.

Balancing these considerations, SAWC recommends a family of aircraft encompassing the utility, light transport and the strike/recce aircraft, based on a single type with maximum commonality of components, including engines, props, landing gear, accessories, instruments, control surfaces, etc. This is considered by SAWC to be the only possible solution to achieving reduced costs. The benefits of such commonality in developing the capability of a host nation are obvious in terms of logistic support, training requirements and minimum transition requirements from one aircraft class to another for pilots and maintenance personnel alike. It would be beneficial to the USAF for the same reasons, and to the host country psychologically, if the same aircraft were in the USAF inventory.

Not everyone agrees with this approach to meeting our COIN aircraft requirements. It concentrates upon commonality for easier logistic support, and simplicity for use by the less technically advanced emerging nations. In regard to the latter, we have the apparent dilemma of requiring new scientific advances in reconnaissance and surveillance, for instance, to monitor and keep tabs on insurgents, and yet insist upon more simple and uncomplicated vehicles to carry this equipment. This may at first appear completely inconsistent but if the technical facts of life demand complicated auxiliary equipment, this might be offset to some extent by striving for a simple vehicle and interchangeable equipment. This rationale was apparent in a draft Advanced Development Objective which we considered last year. It has never been validated but it has served the purpose of challenging the imagination and abilities of the Air Force R&D community and industry. The ADO differed from previous approaches to the problem, such as the LARA, in that it envisioned development not only of an aircraft for Special Air Warfare but the concurrent identification or development of a family of civic action equipment and weaponry specifically associated with the end objective of the system. In a way it was a conceptual amplification on the Special Air Warfare family of aircraft, in that it proposed a family of associated support and operational equipment with maximum commonality within that equipment structure. In addition to the basic aerial vehicle, the development would include compatible COIN weapons and compatible civic action equipment. For example, all power units, to include ground equipment, would use the same grade fuel and lubricants. Airborne and ground communications subsystems would use common and interchangeable components. Even though, for economic reasons, all associated agricultural equipment, construction equipment and public health equipment might be of commercial design, commonality of lubricants, powered units and other parts would be a system objective. And if this part of the ADO was not sufficiently thought-provoking, the aircraft itself was to be mastered by the pilot in 40 hours, be capable of 3000 maintenance-free flight hours, and like some of your automobiles be factory lubricated for its design service life. The system would be capable of mapping, charting and surveying; geological survey; aerial distribution of fertilizers and pesticides; engaging in public health; road building and public construction; and civil air-line-of communications activities. Not surprisingly the design of the equipments for civic action activity would be coordinated with the U.S. Army and Navy, the Agency of International Development and the Peace Corps. Like the Chrysler Airflow and the Tucker Torpedo, this vehicle may have been before its time, but I still think it is needed.

By now you can sense the facets of the COIN aircraft problem that pull at the requirement in one direction or another. We have the desire for simplicity, the need for commonality, and recognize the prestige factor of jets and the political implications that complicate the whole issue. These have all been covered many times in studies, in attempts to reach positive conclusions as to what types of aircraft and associated equipment can best accomplish the COIN mission. In one respect, these studies have shown that consideration of the political and social elements of remote area conflict for all possible situations are difficult, if not impossible, of evaluation. Terrain, climate, communications, airfields, and general skills of the people of various areas are covered in existing studies. But the establishment of the political environment and the enemy threat, actual and potential, often becomes unmanageable. Although these inputs of the political and social elements and assumptions of the hostile opposition are frequently the controlling elements, their vagueness or undetermined nature makes them useless in establishing worldwide models. Many studies, including the SIERRA and REDWOOD studies of limited war by the RAND Corporation, bring political variations in underdeveloped areas into scenarios. In doing so they show that these political elements frequently overshadow the military problems and radically change both military operations and the outcome of the conflict. In short, the political element dominates the military, as I suggested from the beginning. However, political factors are highly variable and subject to change. Therefore, it seems reasonable that physical factors affecting equipment design should remain our primary area of concern. These factors have also been rather thoroughly studied so perhaps what we need is someone to synthesize and validate what has already been written. Then we may find that what we really want is a silent airplane with Wankel engines or maybe even a specialized COIN aircraft for indigenous forces that is completely incompatible with our own needs, but is a really inexpensive aircraft.

Any aircraft designed to meet the various requirements that would ultimately be advanced by the Services probably has no chance of being sufficiently inexpensive.

On leaving the subject of studies, it may appear that the next best course of action would be to substitute hard experience as a basis for definition of our COIN equipment requirements. We have this not only from Vietnam but also from our friends in Latin America.

Many Latin American Air Forces have been able to attain an enviable record in counterinsurgency air operations ranging from extensive and highly beneficial civic action projects to direct combat against bandit or guerrilla forces. In an effort to develop a strong and truly inter-American counterinsurgency effort, we sponsored an Inter-American Air Forces Symposium on this subject, with the first gathering held at Eglin AFB in late January of this year. The deliberations of the COIN Aircraft Panel provide the type of thinking based on experience which I believe should augment our various studies.

We seem to have, then, sufficient information at our disposal to determine our requirements for a COIN aircraft and we should consider this a high priority R&D task.

There is no doubt, however, that the political climate and its influence on the extent and timing of the use of air power, holds the key to the future applications of aviation and its attainable capabilities. Political considerations, by their very lack of predictability, emphasize the fact that the day may indeed arrive when our diplomatic policy will specify the timely and decisive application of air power to a budding insurgency situation, and the Military Services - the Air Force in particular - will have the opportunity to put into practice the applications of aviation I have suggested today. I don't expect this to occur in the immediate future, but there appears to be continuing trends in this direction. Prior to the dissolution of the Special Group (CI) and its replacement with the Senior Interdepartmental Group (SIG), General Maxwell Taylor submitted conclusions on deficiencies in the U.S. countersubversion effort. The first deficiency he identified concerned the need for greater emphasis on the prevention of subversive aggression. This was treated more concisely in his Committee III report which called for - a conscious decision to lower the threshold at which U.S. support will be given. It is with this in mind that I say air power has such a tremendous potential, and because of this possibility that I say we must become better prepared to meet the challenge. General Taylor's report again justifies our concern when it states that "while much military equipment is general purpose in nature and can be counted against the requirements of counter-subversion, it is striking how little procurement and how little R&D can be attributed to the specific needs of counter-subversion." It reveals that only about 4% of a $12 billion Defense R&D budget can be so identified.

In light of these findings, which are really only the confirmation or restatement of known facts, it is indeed timely that a Symposium such as CIRADS is specifically oriented to focus the efforts of the R&D community on the world-wide problems of internal defense and counterinsurgency. The Air Force has a contribution to make in continuing its current activities and in improving its capabilities with respect to future situations. Air power will offer an even greater potential when it is matched with a national policy which recognizes its capabilities and chooses to exploit them in the earlier phases of counterinsurgency. It is imperative that we be prepared for that eventuality and I solicit the support of all of you in helping us meet this challenge.

BRIGADIER GENERAL ROBERT R. WILLIAMS

Brigadier General Williams has been serving as Director of Army Aviation, Department of the Army General Staff, since April 1966. He served as an Assistant Division Commander of the 2nd Infantry Division in Korea. His achievements in the field of Army aviation began shortly after his graduation from the United States Military Academy in 1940, when he was named operations officer for an aircraft test group. In 1942, he was appointed Chief of the Flight Division in the Department of Air Training of the Field Artillery School and became the first ground force officer to receive an instrument rating. In 1947, as Aviation Officer of the United States Constabulary in Europe, he organized the first ground force operational aviation unit. General Williams was the first chief of the Army Aviation Branch, G3. He was later assigned Chief, Air Mobility Division, Office of Chief of Research. After a year in the Office of Secretary of Defense, he was appointed Commanding General of the U. S. Army Aviation Center and Commandant of the U. S. Army Aviation School, Fort Rucker, Alabama. Later he served as Deputy Test Director and as Commanding General of an air test group at Fort Benning, Georgia.

General Williams is well known in Army aviation as the first Army aviator to be designated Master Army Aviator. He received the Alexander Klemin Award in 1961 and in 1962 was a panel leader on the Army Tactical Mobility Requirements Board.

ASPECTS OF THE AIR CAVALRY CONCEPT IN A CI ENVIRONMENT

(Unclassified)

Brigadier General Robert R. Williams

Director of Army Aviation

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(b)(6) [redacted] has asked me to speak on "some technical aspects of the Air Cavalry concept in a counterinsurgency environment, including if possible, comparison of the lessons of Ft Benning and Vietnam".

My basic theme will be the impact on requirements and R&D for other than aircraft resulting from employments of the airmobility concept. However, first I would like to make some basic points about this concept. The airmobility concept briefly stated, is the close tactical integration of heliborne troops with airborne or air lifted firepower and highly responsive air surveillance and supported by rapid reaction air logistics. The essence of this is that aircraft are substituted for ground vehicles and complete reliance is now placed on the aircraft for maneuver, firepower, reconnaissance and resupply. With the acceptance of this concept as demonstrated in the 1st Cavalry Division, Army aviation became of age. Until now aircraft have been added to military units as a premium and supplementary means of movement. Each aircraft added adversely affected the ratio of teeth to tail. The real breakthrough came when the concept of eliminating ground vehicles and replacing them with aircraft was accepted. This is illustrated in the 1st Cavalry Division. Sixteen hundred ground vehicles have been replaced by 333 aircraft and these aircraft are the primary means of fighting.

What did we need to prove by test at Ft. Benning to have the concept approved for use in Vietnam?

First that the aircraft were a dependable means of movement. There will always be times when aircraft cannot fly but ground transport will move.

Conversely there are times when ground movement is stopped-by mud, snow or obstacles - when aircraft will fly. We proved that helicopters could conduct tactical operations in weather down to 200 feet ceiling and ½ mile visibility. This proved favorable odds for movement with ground transport. There is no question about how this has worked out in Vietnam. The terrain and "obstacles" there are such that by air is the only way to go.

Second we had to prove that the airmobile force could be logistically supported, particularly in regard to POL. Although the test division (11th Air Assault Division) required 550 tons of supplies per day, as compared to 450 tons for a standard infantry division, the requirement was met to include the retailed distribution of these supplies by air. The distribution of supplies by air is working in Vietnam just as it did on Air Assault II using the same methods and same equipment. During a recent visit there I didn't find a single aviation unit that had run into difficulty by lack of POL - but they had experienced a few tight situations. I will come back to the logistics problem as it relates to R&D - it's a key point.

Next we had to produce evidence that the aircraft could be expected to live in combat. No one will ever develop conclusive proof of this point. The Air Assault II tests and those conducted by the Combat Development Command Experimentation Center at Ft. Ord, produced evidence of survivability. The evidence was quite accurate. In Vietnam, the statistics show that a helicopter for example is being hit by fire once in each 350 combat sorties and shot down once in each 6,000 combat sorties. Over one half of these are being recovered so we lose only one aircraft in 15,000 combat sorties.

Another interesting challenge that was frequently made to the air mobility concept was that we could not operate so many aircraft of different types in the battle area without many mid-air collisions. We were sure we could for the air traffic density in the battle zone of an airmobile division was only about 1/10th the density at Ft. Rucker, the

Army Aviation School. Air traffic control was not a problem in Air Assault II nor is it a serious problem in combat operations in Vietnam. Anyone who has ever flown in and out of Tan Son Nhut airfield in Saigon and survived will consider the highest density traffic in a major airmobile operation child's play.

One criticism frequently made of airmobile units was that they have no "staying power". Of course, it is difficult to define "staying power". The unit that can stay and fight against tanks and heavy artillery may not be the unit that can stay and fight in Vietnam. In Vietnam it's the 1st Cavalry Division that has staying power. When I last visited the 1st Cavalry, it had been in continuous contact with the enemy for over 40 days - because it can commit troops, recover them, recommit them and continue to supply them by air.

Much attention has been given, and many dollars spent, on solving the navigation problem. There are Loran C&D, doppler, DECCA, radar control and the old "bird dog". The 180 lb whiskey-drinking vacuum tube, well-oriented in the area of operations, that flies each aircraft is still the best answer. We need the sophisticated types of equipment for longer distance operations and to get into the area but I doubt that electronics will ever do the job that is being done by the pilot who flies the same area day after day and knows every inch of it.

In brief, the airmobile concept as tested at Ft. Benning works in Vietnam. I asked the Chief of Staff of the 1st Cavalry Division what significant changes had been made in the concept as a result of experiences in Vietnam. His reply was "None". Take the SOP at the end of Air Assault II and that is how we do it now".

There are several elements of the airmobile concept that are not too obvious that now apply to all military units involved in counter-insurgency operations of the type being conducted in Vietnam. Primary of these is weight of equipment.

Commanders have for hundreds of years said in many ways "the road to victory is traveled with little impedimenta". This is very true today. A preview of this was actually seen in Air Assault II when the 11th Air Assault Division was maneuvering against the 82d Airborne Division. Since the troops of the 11th Air Assault Division had to be carried in aircraft and the limitation on weight that the aircraft can carry is finite, every effort had to be made to reduce the weight the individual carried and the weight of the equipment provided to support him in the field. The weight reduction took two forms. First, the weight of individual items was reduced to the minimum. Next the number of items was reduced based on the soldier taking only his very immediate needs and depending upon a responsive air supply system to bring in what he needed when he needed it. The cumulative effort of the first of these is reflected in that the total weight of the airmobile division is 1/3 as much as the ROAD infantry division.

An interesting result from Air Assault II was that it was found that after the troops of the 11th Air Assault Division were placed on the ground by airlift, their ground mobility off roads was superior to that of the 82d Airborne Division. They capitalized on this and outmaneuvered the 82d by choosing terrain where the 82d couldn't profitably use their vehicles.

The parallel situation is now found in Vietnam for all U. S. units - not just the 1st Cavalry Division. All go into combat in helicopters and all must place a high premium on foot mobility when on the ground. The enemy travels <u>very</u> light.

This places a very high premium on light weight equipment. We are now back to the old question of trade-offs. Something must give to get light weight. For those of you who visited us during the tests at Fort Benning, this is an old story. The problem simply is we must give up durability or long life, creature comforts and unneeded capabilities for light weight. Technological advances alone will not solve the problem.

Some of the new equipment requires no research and development - for example, issuing paper plates with A rations so the soldier doesn't have to be burdened with a mess kit. Some new equipment can be acquired by just buying on the open market such as using the ½ lb plastic lug-a-jug for the 10 lb 5 gallon water can. Some require application of modern, accepted, commercial methods for old style military methods - as foamite packages instead of heavy, hermetically sealed cans. This requires forcing logistics people to deviate from traditional specifications on long term storage requirements. Radios and other communication equipment cannot be packaged in air conditioned vans and built to operate from -60 to +150 degrees Farenheit and stand 10 years of beating over rough roads. They must be built for air travel and operations under a tent.

It is interesting to note that during the testing of the air mobility concept at Fort Benning, we selected 205 off-the-shelf items to substitute for standard Army items in our quest for light weight and small size. The testing indicated 141 of these were suitable for continued use by the division. Due to additional experimentation, the 1st Cavalry Division authorized 177 non-standard items at the time of their deployment. Six months experience in Vietnam has indicated only 10 items should be deleted entirely - although replacements and/or modifications are necessary on 24 other items of non-standard equipment.

My point here is that searching of commercial developments and past R&D efforts can be most fruitful in meeting future requirements. This is an inexpensive and quick solution to many of our problems. It will not meet all requirements and I do not intend to degrade the requirement for the continued application of advanced technology.

Technology is constantly developing ways of making things smaller and lighter. In applying this technology we must emphasize the capability to make each item <u>much</u> smaller and <u>much</u> lighter - not in making each item much more capable, more fascinating, more durable or providing longer life at the same weight.

I will leave you with three requirements for equipment for counter-insurgency where airmobile operations are concerned. First we must keep equipment light enough that it is highly air transportable - whether the soldier carries it, it supports him, or it is involved in resupply of the soldier or in support and repair of any Army equipment.

Second, we must make the individual soldier, after he is placed on the ground, as highly mobile as possible by reducing his load. The development of a six ounce poncho can contribute as much to victory as a highly fascinating development of a 360° scanning device integrating radar, IR and laser.

The third is the requirement for equipment to permit full 24 hour a day operation. This is one area in which technology has made and can make greater contributions to our capability in CI operations. Darkness has always been on the side of the insurgent. Night provides him with a safe haven to lick his wounds, rest, regroup, plan his next move and position his forces. Most of his resupply and logistical operations are accomplished under the cover of darkness. New devices and new tactics and techniques would rob the insurgent of the cloak of security. Some of the most significant advances in this are the star light scope, low light level television, xenonlights, and the use of IR and SLAR.

We have had considerable success with helicopters equipped with xenon searchlights. Further evaluation under operational conditions is continuing and additional systems are being sent to Vietnam.

Additionally, we are considering a weapons system employing a lightweight infrared triggering device in conjunction with 2.75 inch rockets. Up until now IR has been used in concert with SLAR only for aerial surveillance and target acquisition purposes.

The star light scope holds promise for aerial usage. To the present date, we have been unable to perfect a suitable system for use in Army aircraft.

The use of these developments in helicopter operations will help realize the full potential of the helicopter, and particularly, of the armed helicopter.

Our ever increasing capability to operate 24 hours a day will make a major difference in CI operations. The insurgent cannot stand the continuing push and harassing.

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COST EFFECTIVENESS ANALYSIS OF COUNTERINSURGENCY AIRCRAFT (U)
(Unclassified)

(b)(6) [redacted]

Institute for Defense Analyses
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ABSTRACT
(Unclassified)

This paper presents a methodology for estimating the cost of providing a flexible force structure in cases where requirements change from time to time or where the planners' estimates may turn out to be in error. The main question addressed is whether a homogeneous fleet of multipurpose aircraft should be procured for counterinsurgency operations or whether a mixed fleet of various specialized aircraft should be provided. The cost differentials between pure and mixed fleets are quantified; however, a final selection among the these alternatives must be related to the particular case of interest.

1. INTRODUCTION

Military systems can be categorized into two main classes: specialized or multi-purpose. Specialized systems are inherently designed to perform one class of missions, whereas multi-purpose systems are designed to perform more than one class of missions. Hence, a U-2, designed as a reconnaissance aircraft is a specialized aircraft, whereas the OV-1C COIN aircraft, designed to transport cargo and personnel and to attack targets, is a multi-purpose aircraft. As a result of designing the system to perform one class of missions (such as aircraft attacking ground targets), the system cost to accomplish that mission should be less than the cost of a multi-purpose system to perform the same mission. If, however, the specialized system is required to perform a mission for which it was not designed, its cost to perform the mission would exceed that of the multi-purpose system. Thus, the multi-purpose system offers a degree of flexibility over the specialized system but usually for an additional cost. If the requirements of the system are known and constant over time, the specialized systems offer the minimum cost solution. However, if the requirements are varying over time, or are related to a set of contingencies, then the minimum cost solution incorporates the multi-purpose systems as well as the specialized systems.

It is the purpose of this paper to set forth a method (utilizing cost-effectiveness analyses) for determining a minimum cost force-mix* of specialized and multi-purpose systems in light of fixed, time-varying or uncertain mission requirements.

The method used to determine the minimum cost force-mix consists of specifying a set of linear relationships between the system types, effectiveness per dollar of expenditure, and requirements. A typical example, utilizing specialized and multi-purpose aircraft, is discussed in the body of the paper. This example considers only two contingencies, i.e., two alternative sets of requirements. Thus, it is small enough to solve by hand and to present graphically. More complicated examples can be expressed in the terminology discussed below and solved with the aid of an existing linear program algorithm.

2. GENERAL METHOD**

2.1. ANALYSIS MODEL

Let R^k be a vector, representing the k^{-th} contingency set of requirements, $k = 1, 2, \ldots, K$. The elements of R^k are r_i^k, representing the number of units of the i^{th} requirement needed in contingency set k, where $i = 1, 2, \ldots, n$. Let a j subscript stand for the system or equipment types being considered with $j = 1, 2, \ldots, m$. Now, if $\bar{C}_{\cdot j}$ represents the total expenditure on the j^{th} system regardless of which contingency occurs and $C_{\cdot j}^k$ represents the cost of j^{-th} system in contingency k, then $\bar{C}_{\cdot j}$ must take the highest value of $C_{\cdot j}^k$ or $\bar{C}_{\cdot j} = \max_k C_{\cdot j}^k$. Here, $C_{\cdot j}^k = \sum_{i=1}^{n} C_{ij}^k$ where the C_{ij}^k represents the cost of the units of system j needed to fulfill the k^{-th} requirement, $r_i^k \, r_{nj}$.

The objective of the analysis is to minimize the total cost summed over all the systems needed to provide a capability sufficient to meet any of the requirements regardless of which contingency actually occurs. A method for obtaining the solution is through the use of a standard linear programming algorithm. Briefly, the linear programming formulation is as follows: select $\bar{C}_{\cdot j}$, $j = 1, 2, \ldots m$, so as to minimize

$$\sum_{j=1}^{m} \bar{C}_{\cdot j}$$

subject to the constraints

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*The force level problem is not considered.

**The authors are indebted to Dr. Martin Bailey for suggesting this approach and to Dr. J. G. Cross for developing the program.

$$\bar{C}_{\cdot j} = \max_k \sum_{i=1}^{n} C_{ij}^k \qquad j = 1, 2, \ldots m$$

$$\left.\begin{array}{l} \sum_{j=1}^{m} a_{ij}\, C_{ij}^k = r_i^k \\ \cdot \\ \cdot \\ \cdot \\ \sum_{j=1}^{m} a_{ij}\, C_{ij}^k = r_i^k \end{array}\right\} \quad i = 1, 2, \ldots n$$

$$a_{ij} \geq 0$$

$$C_{ij}^k \geq 0$$

$$r_i^k \geq 0$$

Here the a_{ij} represents the number of units of requirement i that can be obtained for a dollar of expenditure of equipment j. The selection of $\bar{C}_{\cdot j}$ also provides for the allocation of the j^{th} equipment for the i^{th} requirement in the k^{th} contingencies. Hence, the program also provides the C_{ij}^k for each i, j and k*. It should be noted that the number of systems available is assumed to be unlimited. A minor revision in the format can allow for the case where the number of systems j available is limited.

The methodology outlined above has been used to determine whether specialized aircraft or multiple-purpose aircraft should be used to provide a flexible response capability. This is a typical problem in which military operations impose diverse requirements on the equipment and forces at hand. This is particularly true of the use of aircraft in counterinsurgency, where the mission requirements characteristically change from time to time. (Experience to date has indicated that significant changes in mission requirements can occur, in fact, from day to day within the same country.)

It appears that in order to cope with such a diversity of requirements, a multi-purpose aircraft would be desirable. Such an aircraft should have the capability to perform attack, escort, and transport missions as required. While such a design is within the state of the art, versatility, or the ability to perform a variety of different missions, produces, as

*The linear program format could also be expressed in terms of number of aircraft and aircraft cost with the solution minimizing total fleet cost to perform the requirements of any set of contingences. However, the solution obtained above can be easily converted into total aircraft costs and vice versa.

discussed previously, some performance compromise in each mission. In other words, a good strike airplane is not likely to be a good transport and vice versa. Hence the same total capability tends to cost more with a fleet of one type of versatile aircraft rather than with a mixed fleet tailored for a particular set of missions. This is because the versatile aircraft is less efficient in either the attack or transport role than the specialized aircraft designed with these specific requirements in mind.

In the example presented below, the cost of flexibility is computed in cases where the requirements change from time to time, or where the planner's estimates turn out to be in error. The main question addressed is whether a homogeneous fleet of multi-purpose aircraft should be procured for counterinsurgency operations, or whether a mixed fleet of various specialized aircraft should be provided. The cost differentials between the pure and mixed fleets are quantified in this paper and results are applied to several situations of interest.

Essential inputs to the analysis are mission definitions and aircraft types. For the purpose of the evaluation, several missions are defined. They include strike, reconnaissance observation and cargo transport. While not all inclusive, these missions cover a wide range of possible aircraft employment in the situations to which this study refers.

Several aircraft types are evaluated. They include:

- A single-engine transport with STOL capability;
- A single-engine attack aircraft with high-load-carrying capability;
- A multi-purpose utility-type aircraft capable of performing either attack or transport missions.

2.2. METHODOLOGY

The evaluation proceeds stepwise. First, the effectiveness of each aircraft is determined for each mission. Second, an efficiency measurement, called aircraft productivity, is computed. Finally, fleets of aircraft are compared: first, for sets of known and fixed requirements, and then in the light of varying or uncertain requirements.

In somewhat more detail: One first assumes a budget constraint, i.e., a given level of budgetary expenditure. In this study the budget constraint was assumed to be 500 million dollars. This is a more or less arbitrary number which places the aircraft purchase far enough along the production learning curve to render negligible the effects of reasonable variations in the program size.

The second input is the five-year program costs per aircraft, which consist of initial investment plus five years' operating costs, based on an assumed 600 flying hours per year per aircraft. Using the budget constraint and the five-year program cost, the number of aircraft of each type is calculated that could be procured and operated for five years if all $500 million were spent for that particular type of aircraft.

Turning to the effectiveness computations, the first step is to calculate mission productivity per aircraft for each aircraft type. Productivity is based on the 600-flying-hour per year constraint and takes into account:

Airfield availability*;

Payload;

Range;

Speed, etc.

Finally, fleet productivity is determined for each mission by multiplying the per aircraft mission productivity times the number of aircraft procured. Thus, fleet productivity is defined as the annual number of missions that can be accomplished by a fleet of single type aircraft procured and operated for 5 years within the budget constraint of $500 million.

For example: Figure 1 shows the productivity of four different aircraft types on a strike mission with the following fixed parameters: no loiter and 10-minute combat time. Productivity is plotted against the number of weapons delivered. The uppermost attack aircraft is a single-engine attack aircraft with high load-carrying capability. Attack* is a somewhat smaller attack aircraft, while Attack** is a small jet attack aircraft.

Figure 2 shows another strike mission with the parameters of three-hour loiter, 20-minute combat time. Again the variable parameter is the number of weapons delivered. In Figure 3, a cargo airdrop mission, aircraft productivity is plotted against mission payload.

The preceding figures show the results of the efficiency computations in terms of the annual number of missions per 500 million program dollars. Per mission costs for each particular type of mission are computed by inverting the productivity calculations. These costs are used in calculating the fleet costs discussed in the remainder of the paper. For example, the costs per mission for the three aircraft types considered, first for a 50-weapon attack mission and second, a 2000-lb. transport mission, normalized on the least expensive mission, are shown in Table I.

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*Airfield availability was the subject of the following paper, The Influence of Airfield Availability on Airplane Effectiveness in Counterinsurgency Missions, presented before American Helicopter Society Twenty-first Annual National Forum, May 12-14, 1965.

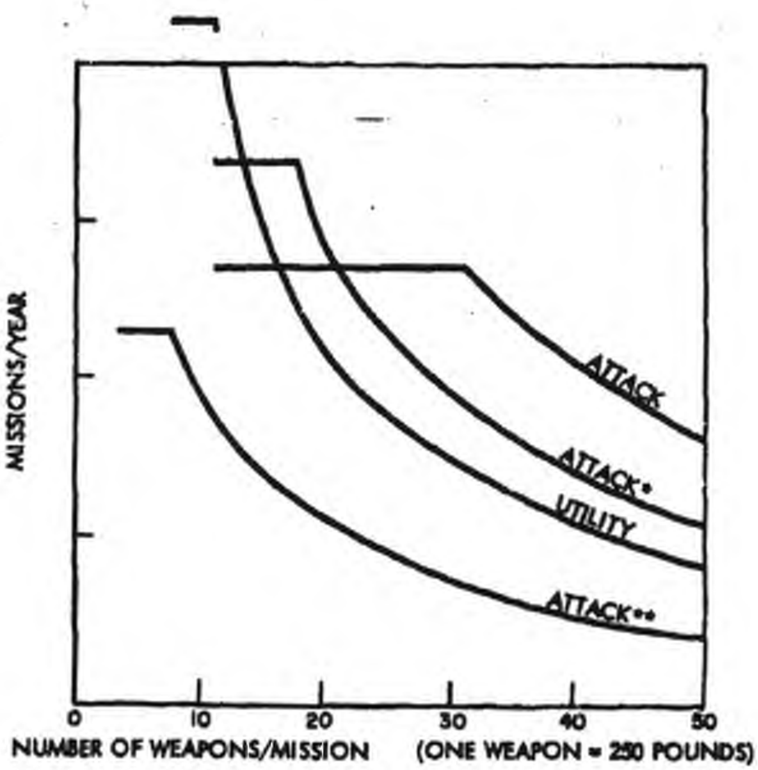


FIGURE 1. STRIKE, NO LOITER, 10-MIN. COMBAT TIME

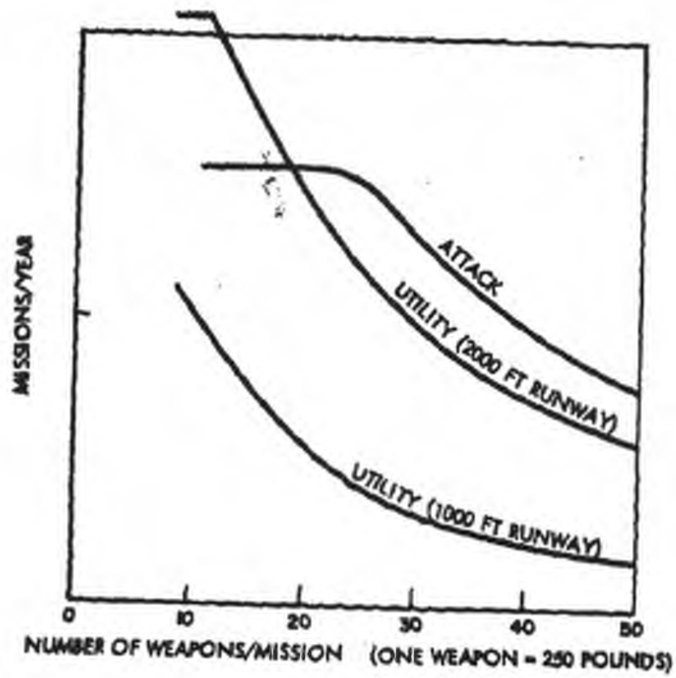


FIGURE 2. STRIKE, 3-HR LOITER, 20 MIN. COMBAT TIME

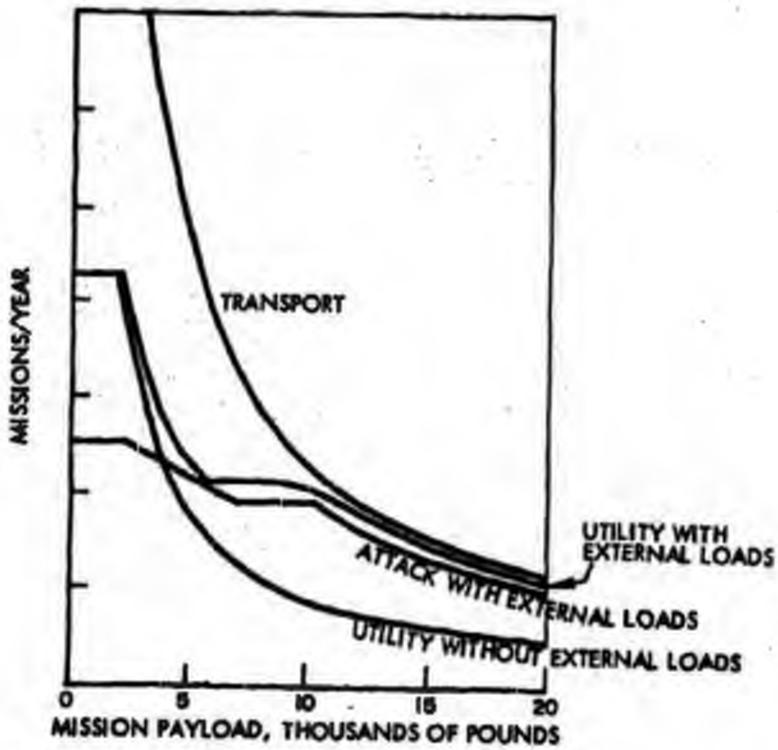


FIGURE 3. CARGO AIRDROP

TABLE I. NORMALIZED COST/PER MISSION

Aircraft	Mission	
	Attack (50 Weapons)	Transport (2000 lb.)
Utility	5.28	1.64
Attack	4.57	--
Transport	--	1.00

2.3. CONSTANT MISSION MIXES

It is convenient to begin by discussing fleet costs in the case of constant mission mixes. This serves to introduce the problem of varying mission mixes. A known and constant mission mix, for example, might be 40 percent attack and 60 percent transport, a proportion which repeats itself period after period. The question addressed is one of comparing the cost of pure (unmixed) fleets to that of an optimally mixed fleet. This is shown graphically in Figure 4 over the range of cases from 100 percent attack-zero transport to zero attack-100 percent transport. Shown vertically are the relative costs of the various fleets with the required capability and horizontally the expected mission mixes.

As could be expected, the pure utility fleet costs more than the optimally designed fleet which utilizes the more efficient specialized aircraft or mixes of the utility and the specialized aircraft. In the 100:0 case, the cost of the all-utility fleet over the all-attack fleet (the optimal fleet from an efficiency standpoint) is approximately 15 percent, and in the 0:100 case, the utility fleet is about 60 percent more expensive than an optimal all-transport fleet.

2.5. CHANGING MISSION MIXES

In cases where requirements may change, the difference between a pure fleet (using the utility aircraft) and a mixed fleet is flexibility. That is, if the mix of missions does not turn out as expected, the utility fleet has the best capability to handle changing requirements.

Responding to variations in requirements can be viewed as a surge capability in which the all-utility fleet has the greater capability to respond to unexpected shifts in requirements. As the Fig. 4 shows, the fleet tailored for any expected mission mix costs less than a utility fleet with the same capability. The utility fleet, however, can respond to changes in the mission mix better than the tailored fleet. The price of this capability is the cost differential between the fleet tailored for any constant mission mix and the

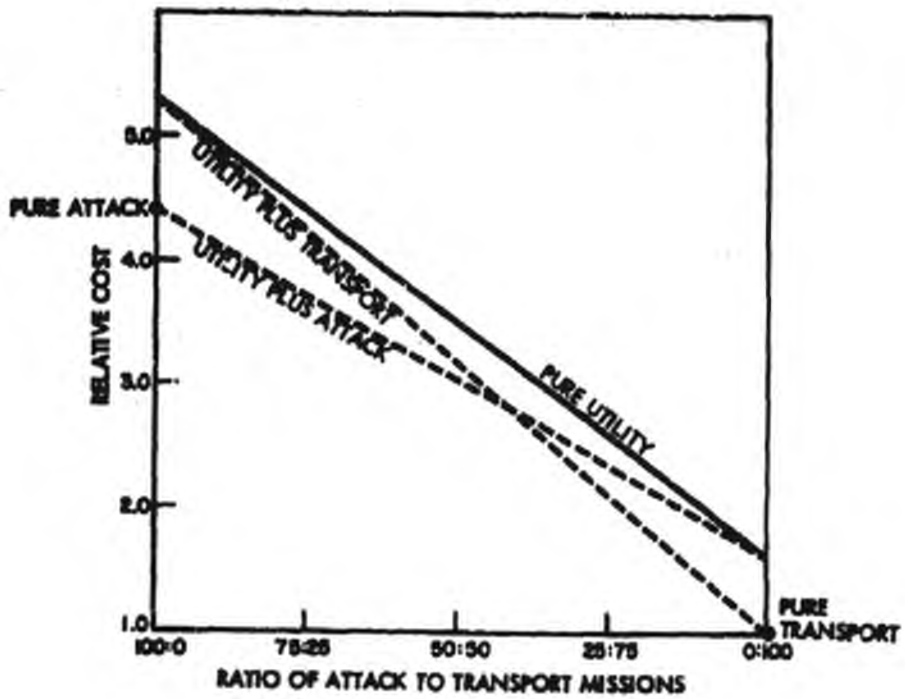


FIGURE 4. RELATIVE COSTS, PURE VS. MIXED FLEETS

cost of the utility fleet.

For any particular example, surge capability can be quantified. Suppose a hypothetical, but likely, expected mission mix was estimated as 20 percent attack, 40 percent reconnaissance-observation, and 40 percent transport missions, for which the procurement of a pure fleet of utility aircraft or a mixed fleet (transports plus utility) was being considered.

In terms of costs, the all-utility aircraft fleet is 53 percent more expensive than the least-cost fleet of the utility plus the transport aircraft for this particular estimated mission mix. But this extra expenditure for the all-utility fleet provides a greater flexibility than the least-cost fleet. In surge capability, defined as a situation when all the available aircraft are assigned to a single type of mission, the all-utility fleet shows considerable advantage in the light-attack mission.

TABLE II. SURGE CAPABILITY

Mission	Surge Capability	
	Tailored Fleet	All-Utility Fleet
	(% above expected mission mix)	
1 Attack (10 weapons)	0	930
2 Reconnaissance-Observation (3-hr. loiter)	40	40
3 Transport (2000 lb.)	420	420

The capability to perform the attack mission can be increased by 930 percent of the initial requirement when the entire all-utility fleet is used for attack. The tailored fleet, however, cannot surge in the attack mission at all.

In the reconnaissance-observation mission, the tailored fleet can surge to 40 percent more missions than in the expected mission mix and in the transport mission to 420 percent more missions. The all-utility fleet can match but not exceed the tailored fleet capability to surge in the reconnaissance-observation and transport missions.

Procuring the all-utility fleet in this instance might be described as procuring escalation insurance since, in essence, the additional cost buys the ability to respond to shifts from primarily logistic-oriented missions to mixes requiring greater proportions of attack missions.

2.5. SELECTING AN OPTIMUM FLEET FOR CHANGING MISSION MIXES

Changes in the expected mission mix result in what can be called multiple contingencies, that is, when the planner expects that several different mission mixes are likely to occur. Multiple contingencies occur either because of uncertainty about future operational requirements or because the mix of missions is known to vary. In either case, if the planner wants to be equally prepared for each expected contingency, it is necessary to provide a flexible response capability.

For problems dealing with many contingencies, i.e., sets of requirements, linear programs can be used. However, for the two-contingency case, it is not necessary to resort to a computer program. When only two contingencies are considered, a simple graphic presentation is possible.

The example that follows considers the two-contingency case which involves providing a fleet of aircraft adequate for one of two possible sets of mission mixes, either of which is likely to occur. For simplicity, each contingency is assumed to contain various proportions of attack and transport missions only. Three aircraft types are evaluated: the attack aircraft, the transport, and the utility aircraft discussed earlier. The example illustrates the manner in which progressively more complex problems can be attacked.

The purpose of the calculations is to obtain the cost of an optimum tailored fleet with the capability to respond to either contingency should it occur, and to compare this cost to the cost of an all-utility fleet with the same capability. The optimal (that is, least-cost) fleet may contain only one type of airplane, a combination of two airplane types, or all three types. Its characteristics are generally such that the minimum contingency requirement for any one mission determines the minimum procurement of the aircraft best suited for that mission. The utility aircraft, because of its versatility, is used to cover the overlap or uncertainty, i.e., the dissimilarity between the two contingencies.

Suppose, for example, that it is estimated that the mix over any 100 missions will be either 60 percent attack and 40 percent transport in Contingency One, or 20 percent attack and 80 percent transport in Contingency Two.

As shown in Figure 5, for this example the minimum for transport occurs in Contingency One; it is 40 percent. For attack, the minimum occurs in Contingency Two; it is 20 percent. Thus the uncertainty requirement is between 20 percent attack and 60 percent attack, and between 40 percent transport and 80 percent transport. Note that in the two-contingency case, the maximum demand for one mission sets the minimum demand for the other mission. The maximum demand for attack is 60 percent and occurs in Contingency One, as does the minimum transport demand of 40 percent. Therefore, as soon as two maxima or two minima or a maximum or a minimum for the same mission are specified, the other requirements follow.

In the particular example, it turns out that the least-cost fleet would utilize all three aircraft types: the attack, the transport, and the utility plane. On the basis of cost, expenditures on the least-cost tailored fleet are 30 percent for attack aircraft,

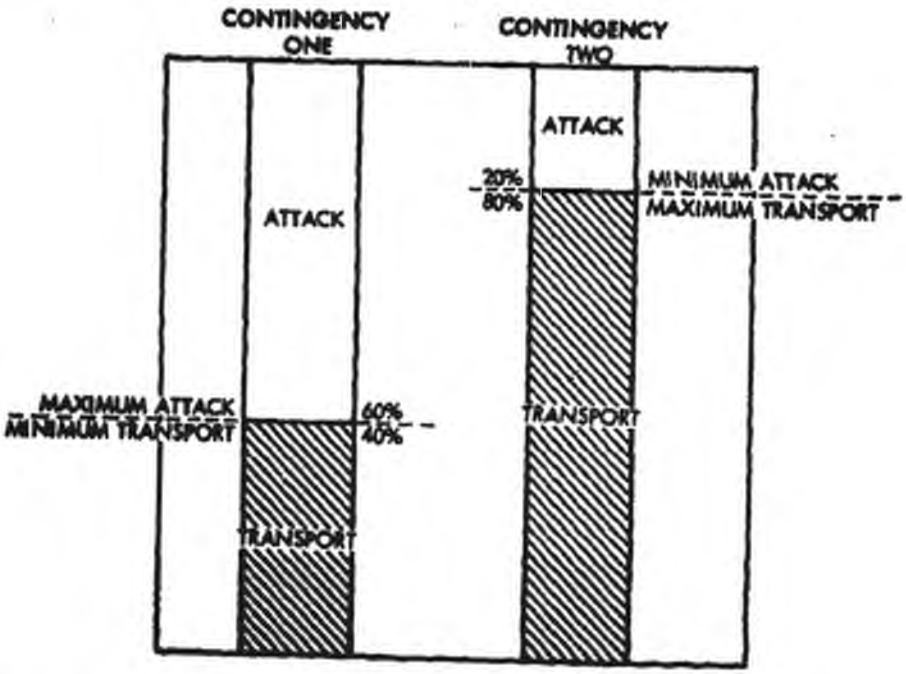


FIGURE 5. MINIMUM AND MAXIMUM REQUIREMENTS - TWO CONTINGENCY CASE

26 percent for transports, and 44 percent for utility aircraft. The cost of an all-utility fleet with the same capability has also been computed. If an all-utility fleet had been procured rather than the least-cost tailored fleet, the total cost to provide the same response capability would have been approximately 30 percent more than the tailored fleet.

The next figure (Figure 6) illustrates over a range of cases the type of approach used in the above analysis. Any point on the boundary or within the triangle shown on the figure represents the cost of a least-cost fleet, tailored for a particular set of contingencies. As uncertainty increases with regard to the upper and lower limits of the mission requirements likely to be expected, moving to the left on the figure, the cost of a fleet capable of responding to both contingencies increases. In addition, as will be shown later, as the relative degree of uncertainty about mission requirements increases, the cost of the least-cost tailored fleet with the necessary flexibility approaches the cost of the all-utility fleet with the same capabilities.

The vertical axis shows the cost of providing a tailored fleet to meet any set of contingencies, from among those considered here, measured relative to the cost of the fleet tailored to meet the least expensive set of contingencies. The latter, the lower left-hand intercept, occurs when it is assumed that both contingencies are the same, i.e., when there is no uncertainty about requirements and when both contingencies consist of 100 percent transport missions. This is because transport missions are less expensive than attack missions. Therefore, the cost of providing the necessary capability is the least when each contingency consists of 100 percent transport missions.

The horizontal axis shows the minimum attack requirement. This requirement can occur in either of the two contingencies for which the fleet is being tailored. As the minimum attack requirement increases, it follows that the maximum transport requirement must decrease. Therefore, attack aircraft replace transport aircraft in the fleet. For any particular mission mix, the least-cost fleet is obtained by procuring in the optimal proportions the aircraft specialized in each mission included in the mix.

The lower bound of the cost envelope reflects the introduction of attack aircraft to the fleet. As attack missions increase relative to transport missions, the cost of providing the response capability increases. The right-hand intercept represents a case of 100 percent attack in both contingencies. Along the lower bound, no utility aircraft are procured since there is no uncertainty about requirements.

The most expensive fleet is one which has the capability to respond when there is maximum uncertainty about requirements, i.e., where one expected contingency is 100 percent attack and zero transport, while the other contingency is just the opposite, zero attack

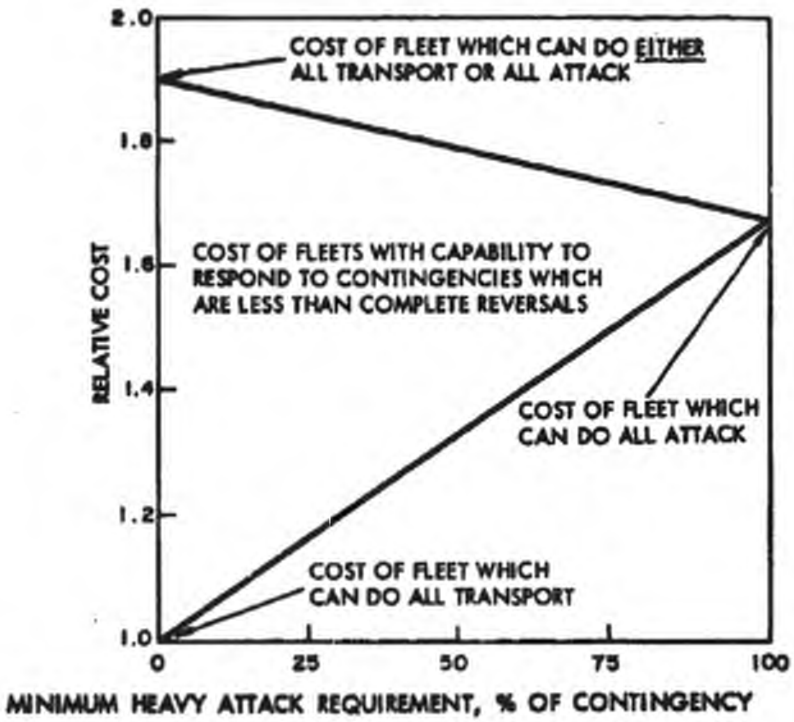


FIGURE 6. MIX OF ATTACK AND TRANSPORT MISSIONS - TWO CONTINGENCIES

and 100 percent transport.

One method by which this capability could be provided would be to procure two fleets, one composed of all attack aircraft for the 100 percent attack contingency and the other with all transport aircraft for the 100 percent transport contingency.

However, if the transport contingency occurred, then the attack aircraft, since they have no productivity in the transport role, would not be used, and if the attack contingency occurred, then the transport aircraft, since they cannot do attack missions, would be idle. The sum of the cost of these two fleets would be off the top of the figure. In cases like this, the utility aircraft, since it has productivity in both missions, can be used, and a single fleet with attack and utility aircraft, but no transport aircraft, turns out to have the same capability but is less expensive than the two specialized fleets of attack and transport aircraft. The cost of this fleet is the upper left hand intercept.

If the uncertainty about requirements can be narrowed, then costs can further be reduced. For example, suppose the maximum attack requirement remained at 100 percent in one contingency, but an attack requirement greater than zero was expected to occur in the other contingency. Then because specialized attack aircraft can be used in both contingencies, more attack aircraft are procured and the number of utility aircraft is reduced. As a result of the greater use of specialized aircraft, costs decrease. This is shown by the downward sloping upper bound of the cost envelope.

Costs are also reduced if the maximum attack requirement is estimated to be less than 100 percent. In the two-contingency case when the maximum attack requirement is reduced below 100 percent, a minimum transport requirement greater than zero is generated. Figure 7 shows the cost reductions due to lowering the maximum attack requirement. Plotted against minimum attack requirements, the upper bound of the cost envelopes for less than 100 percent maximum attack are parallel to the downward sloping lines labeled "Maximum attack requirement 75 percent and 50 percent."

To review, along the lower bound, no utility aircraft are included in the fleet because there is no uncertainty about mission requirements. Along the upper bound, there are no transport aircraft since the requirement for attack is 100 percent in one contingency and, thus, the minimum transport requirement is zero. Areas in between show the relative costs of least-cost fleets for other sets of contingencies and contain all three aircraft.

Figure 8 shows the cost envelope for all-utility fleets capable of providing the same flexible response as the tailored fleets shown in the previous figure. The former are shown by dotted lines. For reference, the costs of the tailored fleets are repeated. In the case of the pure utility fleets, the most expensive of any set of contingencies is always

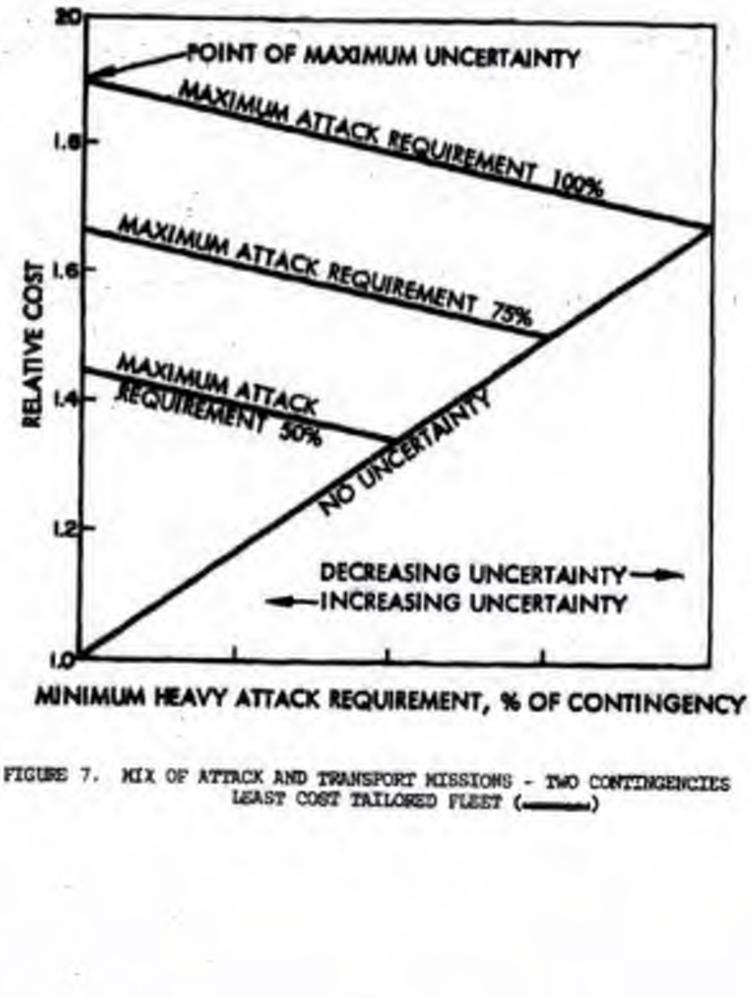


FIGURE 7. MIX OF ATTACK AND TRANSPORT MISSIONS - TWO CONTINGENCIES
LEAST COST TAILORED FLEET (———)

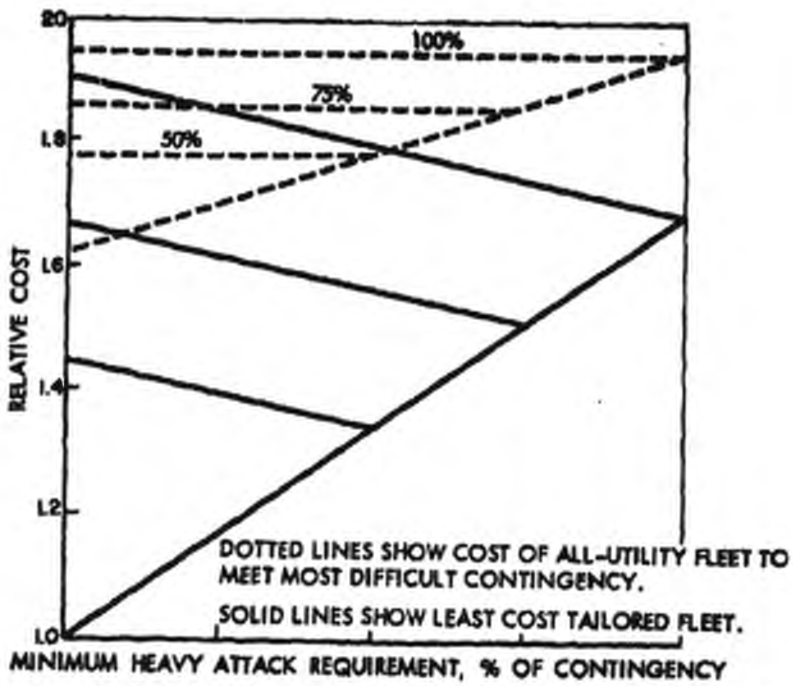


FIGURE 8. MIX OF ATTACK AND TRANSPORT MISSIONS - TWO CONTINGENCIES
ALL UTILTIY FLEET (---)

the one with the larger attack requirement. Thus, for any given maximum attack requirement, the costs are the same regardless of the minimum attack requirement. This is shown by the dashed horizontal lines which represent "Maximum attack requirement 100 percent, 75 percent and 50 percent." Therefore, the all-utility fleet designed for any particular set of contingencies can do any other set of contingencies that have maximum attack requirements below that of the initial set, i.e., any set of contingencies falling below the line plotting the maximum attack requirement.

The cost differential between the all-utility fleet and the tailored fleet with the same capability is the vertical distance between the intercept of the maximum and minimum attack requirement carried over from the previous figure, and the same contingencies plotted for the all-utility fleet.

As uncertainty about requirements increases, i.e., as the similarity between the two contingencies decreases, moving to the left on Figure 8, the cost of the least-cost fleet approaches that of the all-utility fleet with the same capability. Therefore, the cost differential between the two fleets is narrowed. At high levels of uncertainty, the savings provided by the least-cost fleets are only on the order of 10 percent. One might question whether such a saving is substantial enough to justify operating three different types of aircraft in what are often primitive logistics environments.

3. SUMMARY

This paper has attempted to indicate a method of calculating the cost of providing a flexible response capability as dictated by a set of contingencies. The results of the two-contingency case indicate that savings can be realized through appropriate forces structure planning even though uncertainties in requirements exist. The study also shows that utility aircraft offer an efficient means to offset uncertainty. Finally, where there is a wide range of uncertainty about requirements, the choice of an all-utility fleet seems to be warranted.

APPENDIX

The least-cost fleet envelopes shown in Figures 7 and 8 are computed as follows:

Let M_i = the mission

A_j = the aircraft type

α_{ij} = the cost effectives coefficients

R = maximum requirement mission one, and

r = minimum requirement mission one.

Order a matrix of α's such that mission one is the most costly type of mission and aircraft one is the specialized aircraft best suited for that particular mission. In the example above, mission one is the attack mission and aircraft one the attack aircraft. The second aircraft should be the utility aircraft and the third the transport. The second mission is, of course, the transport mission. Therefore, the matrix is:

		Attack	Aircraft Utility	Transport
missions	Attack	α_{11}	α_{12}	--
	Transport	--	α_{22}	α_{23}

and $\alpha_{11} < \alpha_{12}$ and $\alpha_{23} < \alpha_{22}$, since the specialized aircraft are more efficient than the utility aircraft.

To determine the least-cost fleet, one minimizes the sum of the expenditures on aircraft types one, two and three. These are designated as C_1, C_2, and C_3.

If $\frac{\alpha_{23}}{\alpha_{22}} + \frac{\alpha_{11}}{\alpha_{12}} > 1$ then $\sum (C_1 + C_2 + C_3)$ is minimized when

$$C_1 = \alpha_{11}r + \alpha_{11}\left(1 - \frac{\alpha_{22}}{\alpha_{11}}\right)(R - r),$$

$$C_2 = \alpha_{22}(R - r), \text{ and}$$

$$C_3 = \alpha_{23}(100 - R)$$

If on the other hand $\frac{\alpha_{23}}{\alpha_{22}} + \frac{\alpha_{11}}{\alpha_{12}} < 1$ no utility aircraft are used. In this case $C_2 = 0$ and $\sum (C_1 + C_3)$ is a minimum when $C_1 = \alpha_{11} R$ and $C_2 = \alpha_{23}(100 - r)$.

(b)(6)

[redacted]

STOL AND V/STOL TRANSPORT AIRCRAFT
IN SUPPORT OF
COUNTERINSURGENCY OPERATIONS (U)
(Unclassified)

(b)(6) [redacted]

McDonnell Aircraft Corporation
St. Louis, Missouri

ABSTRACT
(Unclassified)

This paper contains a comparison of STOL and V/STOL transport aircraft with CTOL transports performing military and civil missions in a counterinsurgency environment. The major factors which bear on aircraft selection are discussed. These include productivity, loadability, landing site preparation, and site security. Mission costs associated with each of these aspects illustrate how STOL and V/STOL aircraft are often more economical than CTOL regardless of their poorer productivity and the weight penalties that they pay for better take-off and landing capability.

1. INTRODUCTION

The evolution of more efficient aircraft propulsion systems in recent years has caused more and more emphasis to be placed on the development of various types of aircraft other than rotary wing types having short take-off and landing (STOL) or vertical/short take-off and landing (V/STOL) capabilities. These aircraft will provide freedom from reliance upon fixed bases with long costly runways which are both fixed and relatively vulnerable to enemy attack. The advent of counter-insurgency operations has intensified interest in transport aircraft which can permit a higher degree of troop mobility and closer support of ground troops in a battle area as well as support of the civilian population in isolated villages.

I will discuss major military and civil applications of STOL and V/STOL transport aircraft associated with counterinsurgency operations and will address myself to two questions:

(1) What factors predominate in the comparison between CTOL, STOL, and V/STOL?

(2) Which mission types favor STOL aircraft or V/STOL in contrast to CTOL?

For comparison, I will also discuss VTOL (helicopter) aircraft primarily to place STOL and V/STOL in the proper context. The cost-effectiveness of each aircraft type will be determined in terms of cost to perform the various missions. In this context, effectiveness will be measured in terms of the number of vehicles required to perform the given mission. The job to be done will be constant for all aircraft types performing the mission.

2. MISSION TYPES

The military missions of interest are shown in Figure 1 with some indication of the relative tonnages and distances involved. Radii of interest are less than 500 miles with most emphasis on 100 to 300 miles. Redeployment and assault missions are triangular in nature in that the aircraft and fuel supply will be at one location, the troops to be moved at a second location, and their

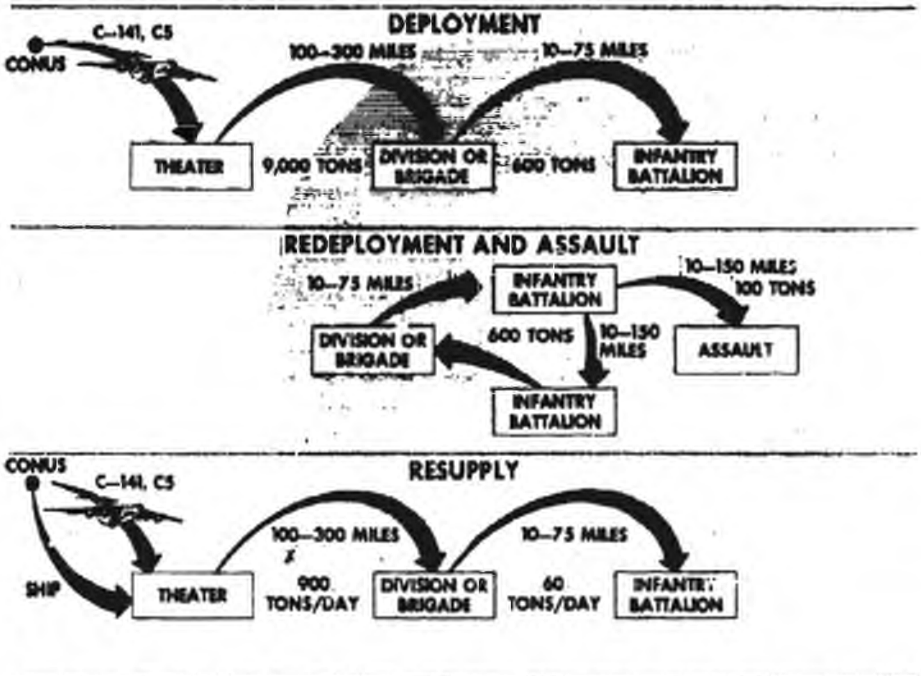


FIGURE 1. MILITARY MISSIONS - (AIRMOBILE)

destination at a third location. Figure 2 lists both military and civil operations and indicates the aircraft characteristics and landing site characteristics which bear upon selection of the best aircraft type.

MISSION TYPES / AIRCRAFT CHARACTERISTICS	MILITARY OPERATIONS			CIVIL OPERATIONS
	DEPLOYMENT OF TROOPS TO TROUBLE SPOTS	REDEPLOYMENT OF TROOPS DEFENSIVELY OR OFFENSIVELY	RESUPPLY OF TROOPS IN BATTLE AREA	RESUPPLY OF FOOD AND SPARE PARTS (HAMLETS)
PERFORMANCE				
PAYLOAD/RADIUS	✓	✓	✓	✓
CRUISE SPEED	✓	✓	✓	✓
TAKEOFF DISTANCE	✓	✓	✓	✓
CARGO LIMITATIONS				
CABIN SIZE	✓	✓		
DOOR LOCATION				
CARGO HANDLING			✓	✓
LANDING SITE CHARACTERISTICS				
SITE PREPARATION AND MAINTENANCE				
AIRSTRIP LENGTH	✓	✓	✓	✓
SURFACE PREPARATION AND MAINTENANCE	✓	✓	✓	✓
BATTLEFIELD MOVEMENT		✓	✓	
SITE SECURITY				
LANDING PATTERN		✓	✓	✓
ENEMY WEAPON CHARACTERISTICS		✓	✓	✓
ENEMY FORCE SIZE		✓	✓	✓

FIGURE 2. AIRCRAFT SELECTION CHARACTERISTICS

3. FACTORS AFFECTING SELECTION OF AN INTRA-THEATER TRANSPORT

There are four important factors involved in the selection of an intra-theater transport:

- productivity
- loadability
- landing site preparation
- site security

Productivity, as defined here, is a function of payload, radius and block time. It is normally higher for CTOL (conventional take-off and landing) aircraft than for STOL or V/STOL since CTOL aircraft are designed for high payload/radius and cruise speed with less attention to take-off and landing requirements.

Contributing to the penalties of STOL or V/STOL is the need for achieving lift augmentation at take-off. There is an interdependent effect of horizontal thrust and lift coefficient on take-off distance. For a given wing loading, as the take-off distance is reduced, either horizontal thrust or maximum lift coefficient must be increased. Whether lift or thrust augmentation is achieved by thrust vectoring, refined wing lift augmentation schemes or by auxiliary power plants, penalties in empty weight and cruise efficiency are incurred. The design compromises to achieve true STOL and V/STOL capabilities will normally result in greater installed power, means for lift augmentation, refined control systems, and interconnection of power plants; all contributing to higher empty weight to gross weight ratio and probably lower aircraft cruise efficiency (Reference 1). Figure 3 shows the trend of take-off distance versus ratio of empty weight to gross weight for turbojet and turboprop transports. Both existing technology and 1975 technology are

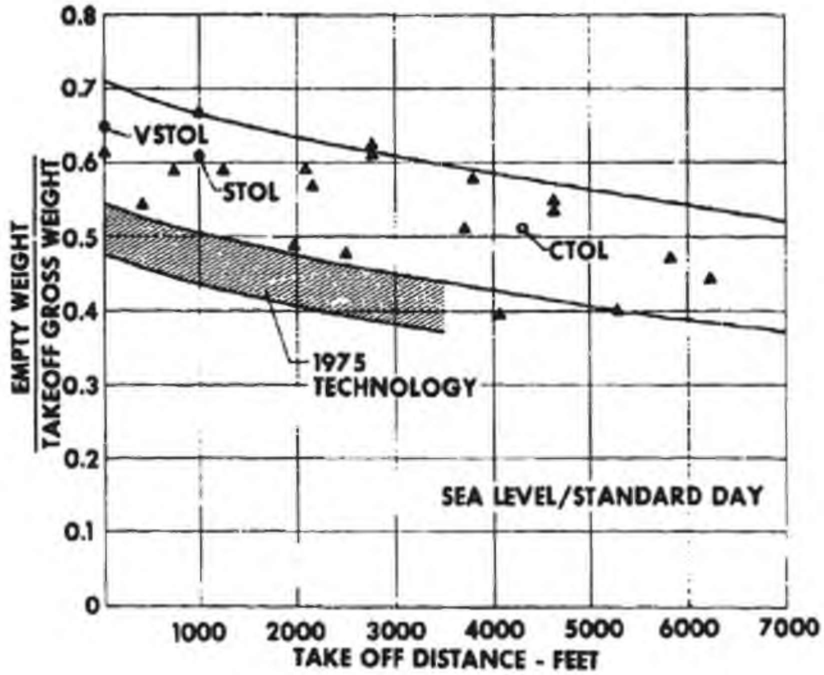
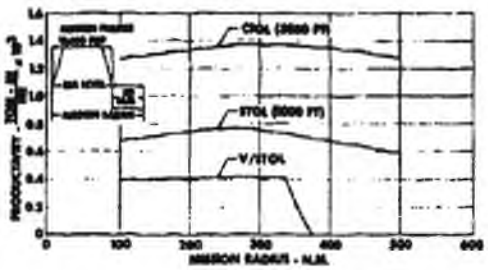


FIGURE 3. MILITARY TRANSPORT EMPTY WEIGHT TREND WITH TAKE-OFF DISTANCE illustrated. Sixty existing fixed wing commercial and military transports were analyzed and the military transports trend is shown here. Typical existing CTOL, STOL, and V/STOL transports whose performance and costs will be used throughout this paper are shown, illustrating the weight penalties paid by STOL and V/STOL.

Loadability, a function of cabin size and payload, also tends to be higher for CTOL aircraft. However, there does not appear to be any basic reason why a CTOL aircraft should have better loadability than a STOL or V/STOL aircraft. Productivity and loadability are shown in Figure 4 for these same examples of current CTOL, STOL, and V/STOL aircraft whose payloads are 24,000 lb., 17,500 lb., and 8,000 lb., respectively at the landing and take-off distances indicated.

PRODUCTIVITY



INFANTRY BATTALION (TOE 7-15E) LOADABILITY
(VEHICULAR ITEMS)

AIRCRAFT	PERCENT OF TOTAL ITEMS LOADABLE	PERCENT OF TOTAL WEIGHT LOADABLE
V/STOL	89.3%	40.4%
STOL	98.7%	88.8%
CTOL	99.0%	93.9%

FIGURE 4. PRODUCTIVITY AND LOADABILITY COMPARISONS

Items which are not loadable by the STOL or V/STOL but are loadable by the CTOL aircraft must be moved by the CTOL aircraft and airdropped or delivered by a cargo extraction technique when comparing aircraft on an equal effectiveness basis. The number of aircraft required to perform the missions is given in Figure 5.

TYPE	MILITARY MISSIONS				CIVIL MISSION
	DEPLOYMENT	REDEPLOYMENT		RESUPPLY	HAMLET RESUPPLY
	DIVISION	BATTALION	COMPANY	DIVISION	
		DEFENSE	ASSAULT		300 HAMLETS
	200 MI.	100 MI.	100 MI.	200 MI.	100 MI.
	1 WEEK	12 HOURS	2 HOURS	DAILY	DAILY
V/STOL	125	32	17	71	71
STOL	59	21	10	43	43
CTOL	49	15	6	29	29

FIGURE 5. NUMBER OF AIRCRAFT REQUIRED TO PERFORM EACH MISSION

In this part of the analysis, productivity and loadability play the only role. This chart shows the relative trucking capability of CTOL, STOL, and V/STOL and also indicates the relative numbers of aircraft required to perform these typical missions. The number of aircraft required for daily resupply of an Air Mobile Division are sufficient to deploy the division in 14 days, redeploy an infantry battalion in six hours, conduct an assault in less than one hour or resupply 300 besieged hamlets of 1000 persons each with food and other necessities.

The number of aircraft required to deploy or redeploy a military unit is a function of the time allowed to complete the operation as well as the size of the unit. Figure 6 shows the number of aircraft required to deploy an Air Mobile Division composed of 15,954 troops, their equipment and three days' supplies, 200 miles, as a function of allowable time. Not only do numbers of aircraft

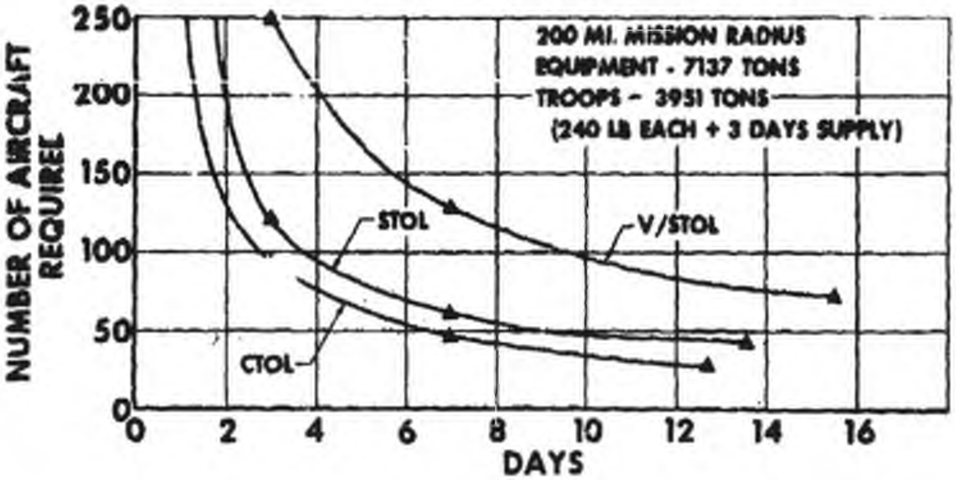


FIGURE 6. AIRCRAFT REQUIRED FOR DEPLOYMENT VS. TIME AVAILABLE

required increase rapidly for deployments of less than three days, but cargo handling and storage facilities are likely to be over-taxed. Since troops are often deployed to a temporary location, it may not be economical to construct large airstrips for CTOL aircraft operations if airstrips are not already available.

Redeployment of troops or assault operations will nearly always require STOL or V/STOL aircraft since suitable CTOL take-off and landing facilities are not likely to be close enough for practical use and since time available for the operation will be of the order of one day or less.

It becomes difficult to redeploy a battalion in less than three hours because of the numbers of aircraft and storage space required and time required for cargo handling.

The mission costs, which include production and operating costs corresponding to the numbers of aircraft and flight hours shown in Figure 5 are shown in Figure 7. Production costs are based

AIRCRAFT TYPE	MILITARY MISSIONS				CIVIL MISSION
	DEPLOYMENT	REDEPLOYMENT		RESUPPLY	HAMLET RESUPPLY
		DEFENSE	ASSAULT		
V/STOL	$1,931,000	$ 66,000	$11,000	$5,792,000	$2,970,000
STOL	$850,000	$31,000	$5,000	$2,549,000	$1,410,000
CTOL	$737,000	$26,000	$4,000	$2,213,000	$1,169,000

FIGURE 7. MISSION FLYING COSTS

on a minimum aircraft buy of 300 aircraft amortized over a 20,000 hour aircraft life. Operating costs include crews, POL, maintenance and accident repair. The costs of these CTOL, STOL, and V/STOL aircraft operations per ton-mile are $0.41, $0.47, and $1.07 respectively. The resupply costs include costs for moving the material to battalion level. The last leg of the trip is done by trucks in flat (valley) terrain or helicopters in mountainous terrain.

4. LANDING SITE PREPARATION

Landing site preparation time, manpower and equipment required, which is determined by the size of the site, condition of the surface and tire pressure of the aircraft, is generally less expensive for STOL and V/STOL aircraft. An indication of manpower and time required for airstrip preparation of STOL and CTOL aircraft in two different kinds of terrain is shown in Figure 8. In a counterinsurgency environment, where landing sites must often be prepared hastily and for infrequent use, preparation time may be excessive or preparation cost may be prohibitive. Since it is difficult to usefully employ more than one engineer battalion at a single airstrip, airstrips requiring more than a few battalion days for construction are not likely to be practical. Typical forward area airstrips are shown in Figure 9 (Reference 2). The CTOL would have to

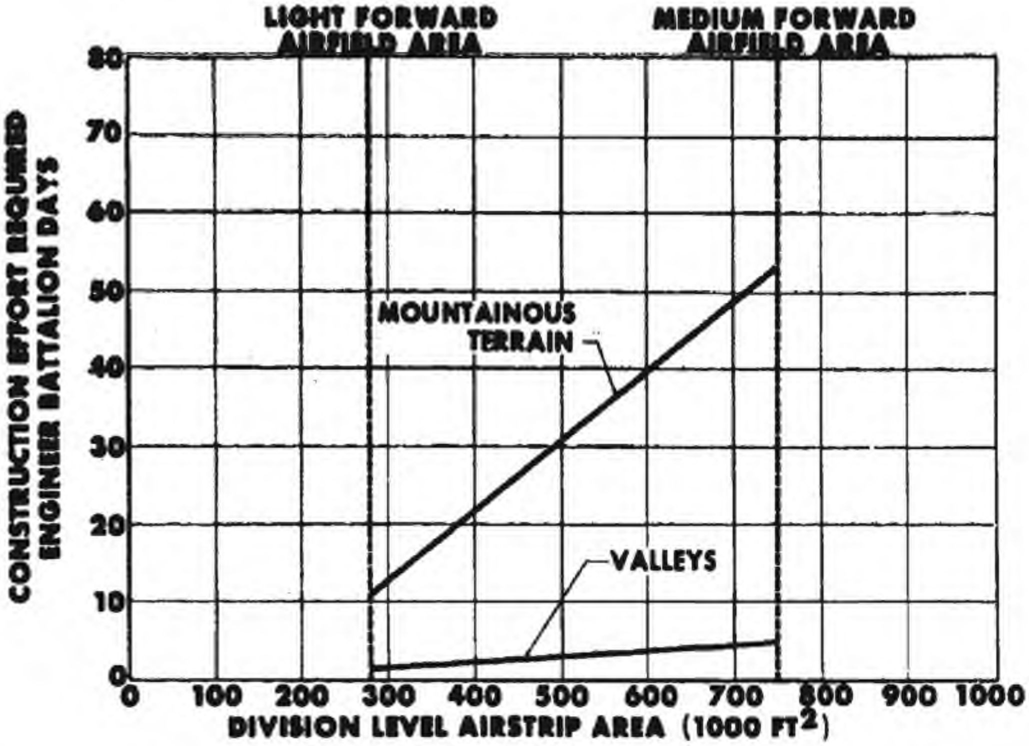


FIGURE 8. AIRSTRIP CONSTRUCTION EFFORT REQUIREMENTS

operate into a medium lift forward area airfield which occupies a minimum of 18 acres of interior area compared with eight acres for the light lift forward area airfield into which the STOL aircraft could operate. To facilitate CTOL operation at large payload, the runway would have to be

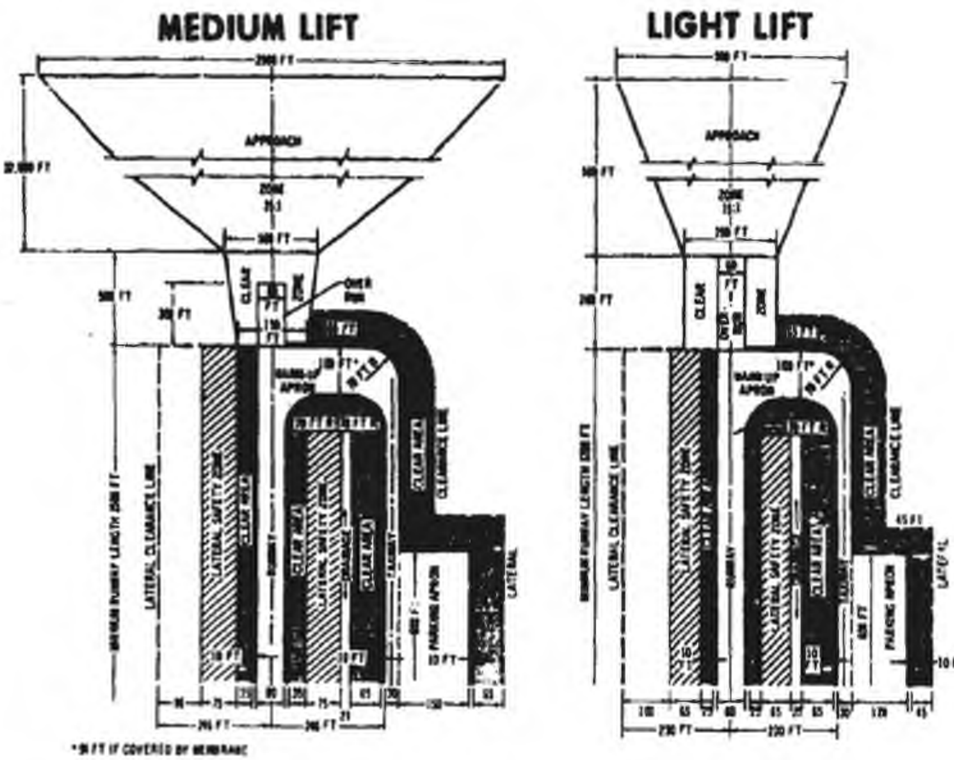


FIGURE 9. FORWARD AREA AIRFIELDS

lengthened to 3500 feet. Otherwise a CTOL aircraft is further penalized because it would operate into a medium lift forward area airfield at a greatly reduced payload.

The light lift airfield approach zone and cleared zones are much longer than that required for a STOL aircraft which will land safely at a 7° glide slope and climb out on take-off at 8° at maximum gross weight. The airstrip need be only 1000 feet long since the aircraft can land in much less than 1000 feet and take-off with full payload in less than 1000 feet over a 50 foot obstacle.

An airstrip tailored for V/STOL aircraft operations would not be appreciably smaller than a STOL strip if it were to handle reasonably high peak loads of traffic (six aircraft on the ground at once) because of the parking area required during loading and unloading. A facility large enough to handle six aircraft simultaneously would require nearly five acres of clear area, taxiway or landing pads, and the pads would require special treatment not required by STOL strips.

The determination of airfield capacity is illustrated by the following example. Transport aircraft will probably fly above 3000 feet to avoid small arms fire, performing a spiral approach over the airstrip to reduce the area which must be protected by friendly troops. Typical operations at a forward area airfield would involve aircraft landings spaced about three minutes apart, which is the approximate time required for an aircraft to descend from 3000 feet plus a minute to enter the pattern. It is assumed that several aircraft would not be performing the spiral descent simultaneously.

Five minutes is allowed for leaving the runway and preparing to unload while another five minutes is allowed for closing cargo doors, starting engines, and moving to the take-off point. Unloading time is calculated at 1500 pounds per minute or 12 minutes for $8^3/4$ tons. Allocating five minutes of the ten minutes on the ground for unloading preparation results in 17 minutes average time that an unloading space is occupied. On the average, six unloading spaces will handle this traffic load. Applying elementary queueing theory where the service rate is 17 minutes for one of six service units available and the arrival rate is Poisson distributed with an average of one per three minutes, the expected waiting time is two minutes. An arrival rate of one aircraft every four minutes results in an expected waiting time of less than one-half minute. The corresponding arrival rate for CTOL is one aircraft every five minutes and one every $2^1/2$ minutes for V/STOL. Increasing the number of unloading spaces to eight permits an arrival rate of one aircraft every three minutes with negligible expected waiting time.

Figure 10 shows the costs of the site preparations and associated engineer battalion-days required to perform the various missions. Clearly, CTOL operations are not competitive for these missions when airstrip cost is a factor. Note also that the airstrip construction costs for V/STOL are not significantly less than those for STOL when compared with total mission costs.

ENGINEER BATTALION-DAYS REQUIRED FOR SITE PREPARATION

AIRCRAFT TYPE	MILITARY MISSIONS								CIVIL MISSION	
	DEPLOYMENT		REDEPLOYMENT				RESUPPLY		HAMLET RESUPPLY	
			DEFENSE		ASSAULT					
	AREA	BN-DAYS	AREA	BN-DAYS	AREA	BN-DAYS	AREA	BN-DAYS	AREA	BN-DAYS
V/STOL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STOL	[illegible]	[illegible]	[illegible]	6.7	[illegible]	6.7	[illegible]	[illegible]	[illegible]	[illegible]
CTOL	[illegible]	24.2	[illegible]	7.4	[illegible]	7.4	[illegible]	[illegible]	[illegible]	[illegible]

SUMMARY OF ENGINEER CONSTRUCTION CRITERIA

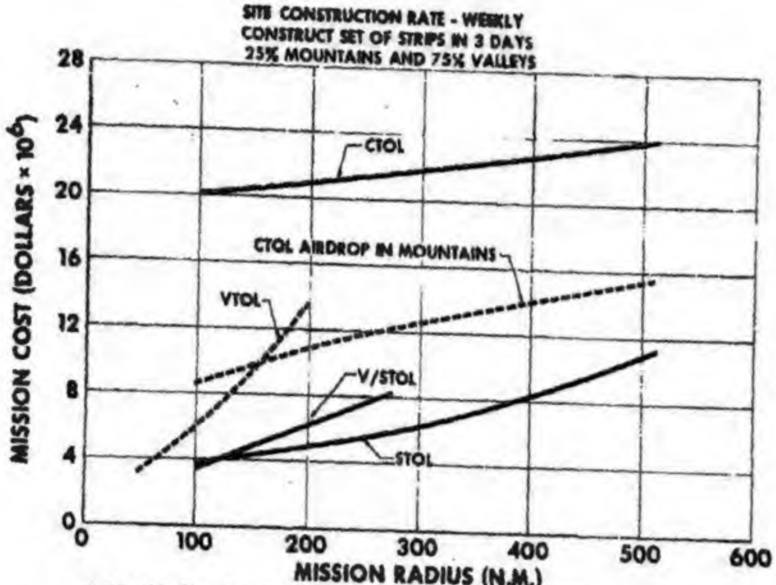
MILITARY MISSIONS		ENGINEER EFFORT REQUIRED TO BUILD	
		CTOL	STOL OR V/STOL
(1)	DEPLOYMENT	ONE SET OF (4) AIRSTRIPS OR (75) V/STOL PADS	
		AIRSTRIP TYPES (TM5-266)	
(2)	REDEPLOYMENT (DEFENSE)	MEDIUM LIFT/BATTLE AREA	LIGHT LIFT/BATTLE AREA
(3)	REDEPLOYMENT (ASSAULT)		LIAISON SUPPORT AREA
(4)	RESUPPLY	FOUR SETS OF DEPLOYMENT AIRSTRIPS OR V/STOL PADS IN ONE MONTH	
(5)	HAMLET RESUPPLY	(150) V/STOL OR STOL STRIPS OR (300) CTOL STRIPS (ASSAULT TYPE, TM5-266)	

MISSION COSTS
(FLYING AND SITE PREPARATION)

AIRCRAFT TYPE	COST CATEGORY	MILITARY MISSIONS				CIVIL MISSION
		DEPLOYMENT	REDEPLOYMENT		RESUPPLY	HAMLET RESUPPLY
			DEFENSE	ASSAULT		
V/STOL	FLYING	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SITE PREPARATION	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STOL	FLYING	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SITE PREPARATION	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CTOL	FLYING	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	SITE PREPARATION	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FIGURE 10. COSTS INCLUDING SITE PREPARATION

Figure 11 shows the effect of mission radius on resupply costs in an environment which is 25 per cent mountainous and where the battle is moving rapidly enough that new airstrips are required each week. Airfield construction costs for CTOL are so high that airdrop is preferable in the mountainous terrain. VTOL and V/STOL are preferable at very short mission radii (under 130 miles) but STOL is superior for radii greater than 130 miles and CTOL is never competitive.



NOTE: 1) CTOL - CONSTRUCTED STRIPS (W/MATS) REQUIRED ALL THE TIME.
2) STOL AND V/STOL - CONSTRUCTED STRIPS (W/O MATS) NEEDED ½ THE TIME.
3) CTOL AIRDROP ASSUMES ½ OUTBOUND PAYLOAD RETURN VIA VTOL.

FIGURE 11. MISSION COST VS. MISSION RADIUS

5. SITE SECURITY

Site security is the fourth and last item that is important in selection of an intra-theater transport system. Next to speed of troop movement, security is probably the most important advantage of intra-theater air transport. Where roads exist, truck transportation is so inexpensive compared with aircraft transportation that it is favored for distances less than 100 miles unless roads are impassable because of weather or enemy action. In counterinsurgency operations weather and enemy action generally combine to make air transport more desirable.

Site security is measured in terms of the size of the area which must be protected by friendly troops and the friendly troop density required. Security for aircraft on the ground and security during landing and take-off are important. Site security for aircraft on the ground depends on the range of the enemy weapon and is relatively independent of the aircraft take-off distance. During landing and take-off, site security is a function of aircraft performance and vulnerable area as well as enemy weapon range. Figure 12 illustrates the differences in landing patterns and protection area between STOL and CTOL aircraft. STOL and V/STOL aircraft will probably have similar landing patterns because of their good controllability at slow speed. Vulnerability to ground fire during landing depends heavily on glide slope, glide pattern, and speed of descent; similarly, vulnerability to ground fire during take-off depends on the climb out pattern and rate of climb. CTOL aircraft with their lower approach angle, higher approach speeds, and higher corresponding turn radii under 500 feet altitude require larger areas of protection than STOL or V/STOL aircraft.

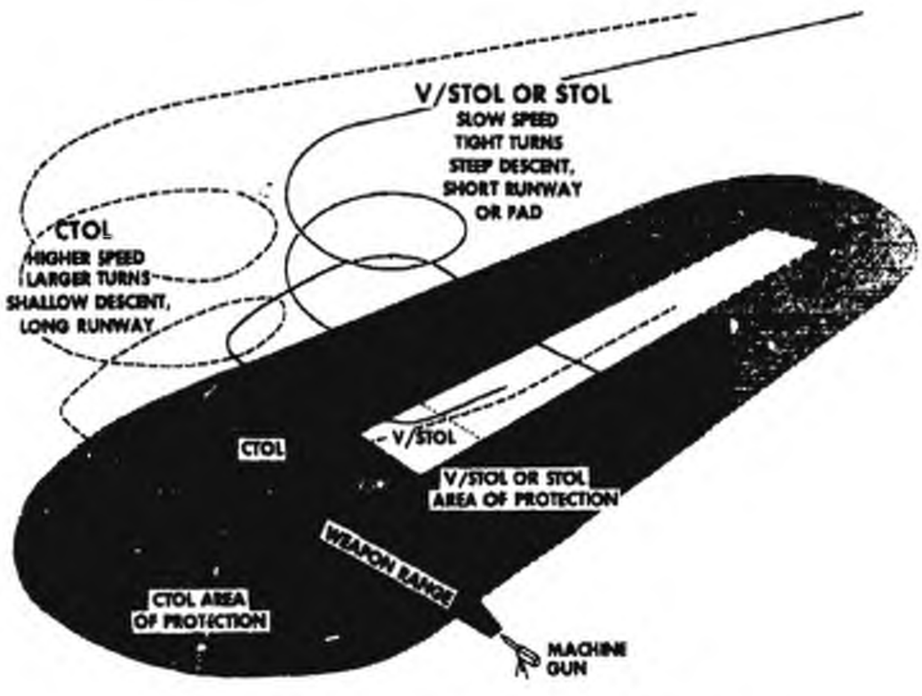


FIGURE 12. SITE SECURITY DURING LANDING

Views of likely CTOL and STOL flight paths which could be used in a hostile environment, and the areas to be secured are illustrated in Figure 13.

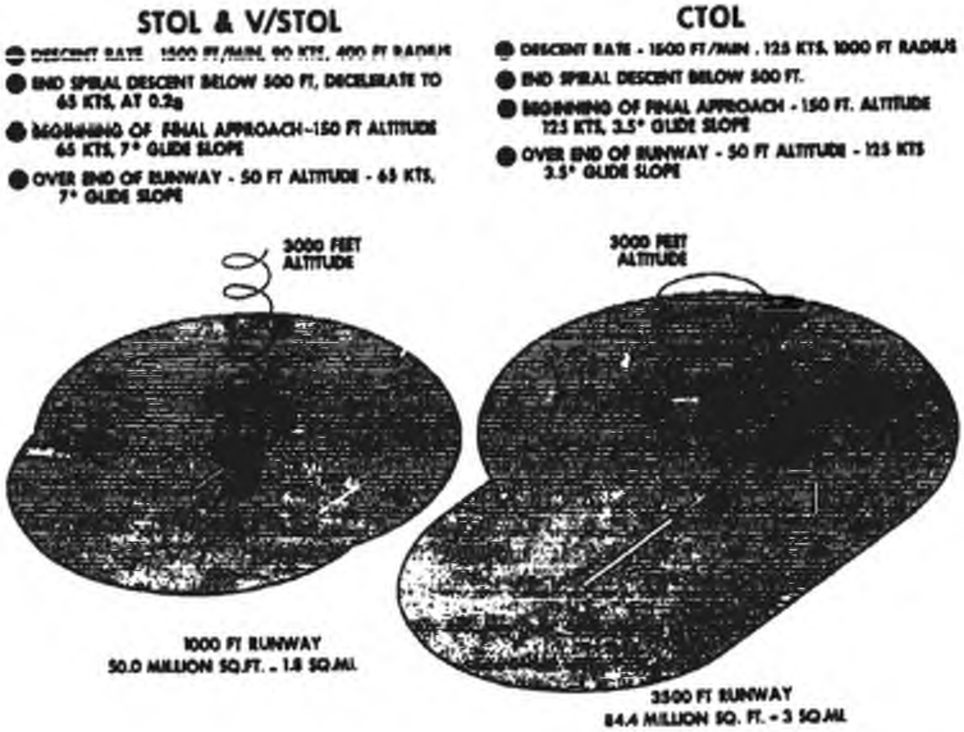


FIGURE 13. SITE SECURITY SITUATION

To achieve high survivability to enemy ground fire (e.g. small arms), it is desirable to descend from 3000 feet as rapidly as practicable in a tight pattern. A typical descent rate for all three aircraft types is 1500 feet per minute from 3000 feet altitude in the landing configuration (full flaps and gear down) to an altitude below 500 feet, at which time the descent rate would be checked and the final approach pattern executed.

During the descent from 3000 feet, CTOL aircraft would achieve a turn radius of 800-1000 feet and STOL and V/STOL aircraft would turn in less than 400 feet radius.

Figure 14 illustrates the relationship between speed, rate of descent, glide slope, and descent time.

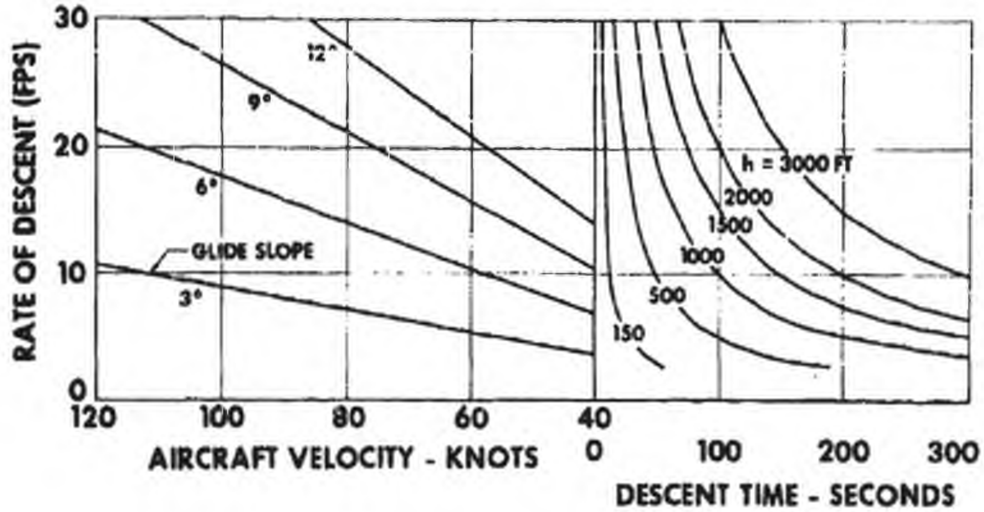


FIGURE 14. LANDING RELATIONSHIPS

Figure 15 summarizes the relationship between protection area, number of men and pertinent landing characteristics. Security must be maintained while the site is being prepared as well as during landing and take-off operations.

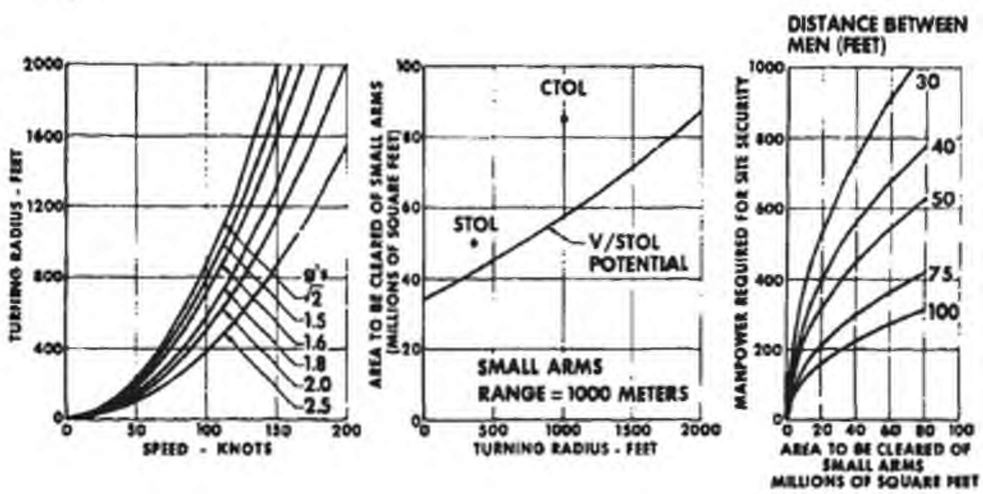


FIGURE 15. EFFECT OF AIRCRAFT PERFORMANCE ON SITE SECURITY MANPOWER

At $9,600 per battalion day, the cost of site security is as shown in Figure 16.

AIRCRAFT TYPE	MILITARY MISSIONS				CIVIL MISSION
	DEPLOYMENT	REDEPLOYMENT		RESUPPLY	HAMLET RESUPPLY
		DEFENSE	ASSAULT		
V/STOL	$425,000	$4,000	$3,000	$1,274,000	$5,490,000
STOL	$187,000	$5,000	$3,000	$562,000	$5,490,000
CTOL	$211,000	$32,000	$30,000	$633,000	$5,490,000

FIGURE 16. SITE SECURITY COST

The resulting total cost of the typical missions are listed in Figure 17.

AIRCRAFT TYPE	COST CATEGORY	MILITARY MISSIONS				CIVIL MISSION
		DEPLOYMENT 1 WEEK	REDEPLOYMENT		RESUPPLY 30 DAYS	HAMLET RESUPPLY 30 DAYS
			12 HOURS DEFENSE	2 HOURS ASSAULT		
V/STOL	FLYING	$1,931,000	$66,000	$11,000	$5,792,000	$2,970,000
	SITE PREPARATION	23,000	2,000	2,000	232,000	170,000
	SITE SECURITY	425,000	4,000	3,000	1,274,000	5,490,000
	TOTAL	3,379,000	72,000	16,000	7,298,000	8,630,000
STOL	FLYING	$850,000	$31,000	$5,000	$2,549,000	$1,410,000
	SITE PREPARATION	56,000	11,000	11,000	557,000	1,624,000
	SITE SECURITY	187,000	5,000	3,000	562,000	5,490,000
	TOTAL	1,093,000	47,000	19,000	3,668,000	8,524,000
CTOL	FLYING	$737,000	$26,000	$4,000	$2,213,000	$1,169,000
	SITE PREPARATION	529,000	114,000	114,000	5,286,000	34,332,000
	SITE SECURITY	211,000	32,000	30,000	633,000	5,490,000
	TOTAL	1,477,000	172,000	148,000	8,132,000	40,991,000

FIGURE 17. TOTAL COST SUMMARY

6. CONCLUSIONS

1. STOL and V/STOL aircraft are likely to be the major air transport vehicles in counter-insurgency environments because of emphasis on shorter take-off and landing distance, cost of airfield construction in time and manpower, and cost of site security.
2. STOL transports are very attractive since much of their operation can take place without extensive site preparation.
3. V/STOL transports will be required in some difficult situations and will normally require about the same site preparation and site security as STOL transports.

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Session 3

GROUND OPERATIONS

(b)(6) [redacted]

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AMBUSH DETECTION — A SURVEY (U)
(SECRET)

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ABSTRACT
(Unclassified)

The problems of ambush detection are reviewed and the various parameters and technical approaches to the detection of people are categorized. The proposals and efforts in the broad classes of chemical, biological, electromagnetic energy, acoustic/seismic, and environment modification are discussed, and the present state of development is described and compared with the desired goals. Where applicable, performance data and equipment specifications are included.

THE PROBLEM (U)

(U) The value of ambush as a regular method of warfare was recognized very early; the ambush of 3500 years ago, described in the Anastasi Papyrus I, is typical of those occurring today.[1] Now, as then, the ambusher combines the element of surprise with advantageous positioning of the ambush site and with continuing intense fire and rapid action to establish initial superiority; he maintains his attack until he either has completed his mission or lost the initiative and advantage.

(U) Ambush can be defined as an enemy-initiated incident which meets the criteria for an attack, and in which the enemy uses surprise in attacking a friendly force for which they have been waiting in concealment. Under this definition of ambush it is possible to ambush stationary as well as moving targets, the latter including convoys or units on roads, patrols or larger units traveling off road, railroads, and vessels on canals or inland waterways. The problem of ambush has three aspects: prevention, detection and counteraction.

(U) In detecting ambush we are trying to find hidden men each of whom can be considered to be a mobile, electrically controlled, chemical factory having raw inputs for producing internal power, its waste products being eliminated as solids, liquids, gases and heat, as having reaction to many elements in its environment, and as absorbing or reflecting intercepted energy. Man's operation as a machine, his reaction with his environment, his environment's reaction with him, together with the characteristics of the weapons, supplies and other equipments he carries with him, provide signatures on the basis of which detection might be accomplished.[4]

(U) Broadly, these signatures may be divided into chemical, biological and physical categories. Although when the Limited War Laboratory began its study of the personnel detection problem there already existed a considerable body of data on various characteristics of man, it was uncorrelated and only a small percentage of this material was directly and specifically applicable to the problem of people detection. To provide the basis for a start, the Limited War Laboratory placed three study contracts to gather and evaluate the state of the art. The biological study was performed by the Biosearch Company,[2] the chemical study by Magna Corporation,[3] and the physical study by Kollsman Instrument Company.[4] These studies were unusually thorough and provided the information for the data base against which LWL assessed the advantages and limitations of the detection principles applicable to each category. Shortly after the LWL program was under way, a Symposium on Ambush Detection was held at Aberdeen Proving Ground to review Army work directly related to the problem. The proceedings of this symposium comprise what was probably the first complete review held on the subject.[8]

(C) Ideally, a personnel detector should be passive, lightweight, require little or no internal power, have the capability to detect, at considerable distances, even a single individual and to count individuals, provide output readings in both range and azimuth and perform its remote sensing in both line of sight and non-line of sight modes. The response should be in real time and no operator skill or training should be necessary. The present state of development of the items in the program of the Department of Defense fall short of this ideal by a considerable margin. As an example, one of the prime Limited War Laboratory objectives is to provide a device for detecting as few as 10 concealed personnel at 100 meters range with substantially real time readout and light enough in weight, with all necessary power sources and other materials for 8 hours of continuous operation, to be manpacked.

(U) The research and development program in ambush detection is sizeable and covers a wide variety of approaches and differing degrees of promise. For convenient reference, Tables I to V list, respectively, the principal efforts in each of the following categories of ambush detection: chemical, biological, electromagnetic, acoustic/seismic, and site preparation/environment modification. The main characteristics of each approach are listed including the principle of operation, range, response time, whether active or passive, whether wind-dependent, and other conditions of operability. Where available, information is also included on power requirements, weight, maintainability, requirement for operator training, cost, lead time, and potential to meet the requirement.

CHEMICAL DETECTION (U)

(S) Of the numerous efforts in the general area of chemical detection, the approach nearest to use in the field is the condensation nuclei detector[5] which is capable of detecting ammonia, condensation nuclei, and an unidentified group of substances which has been collectively termed compound sigma. Based on the principle of the Wilson cloud chamber previously used successfully by the Navy in the ASR-3 for the detection of submarines at sea, its operation is shown schematically in Figure 1. The sampled air is subjected successively to ionization, hydrochloric acid vapor and water vapor before entering the cloud chamber. Its development is proceeding under contracts with the General Electric Company in three forms: as a manpack device, a truck mounted detector, and an aircraft mounted detector. Figure 2 shows the manpack detector being worn and Figure 3 shows its interior with the battery-carrying cover removed. In its present form it can detect 10 individuals or fewer at distances of 90 — 200 meters, and larger groups over considerably greater distances. Sampling air once per second, its response time is approximately one second, and the indication may be read on a meter and simultaneously heard through a bone conduction phone which does not interfere with the user's normal hearing. The power requirements are moderate and its 24-lb weight includes batteries sufficient to operate the unit for 8 hours before recharging. A small number of these items are already in Vietnam and an initial quantity of 200 units will be delivered to Vietnam by August, 1966. The vehicular version has similar characteristics except for a higher sampling rate; an experimental model has successfully completed preliminary tests in Panama. The aircraft mounted version is intended to detect larger groups of individuals and the sites of relatively large scale human activity on the ground. Preliminary tests with a breadboard airborne device have shown successful detection of groups of personnel and ground based human and industrial activity from altitudes over 3,000 feet and at air speeds in excess of 100 knots. It is expected that both the vehicular and aircraft versions will receive operational evaluation in June, 1966.

(C) Because of the general attractiveness of the mass spectroscope as a detector, LWL is supporting an experimental investigation of this technique under contract with Varian Associates. The first phase of this work will check the mass spectra and ionization potential of some 25 compounds of interest and will examine the characteristics of selective permeable membranes. Our preliminary assessment indicates that a miniaturized instrument possessing desirable characteristics may be feasible. If feasibility and practicability are demonstrated, this technique will offer the capability of monitoring simultaneously several characteristic effluents from individuals, thereby possibly permitting determination of the ethnic origin of the individual or provide an indication of the recent activities of an individual because of subtle differences in metabolism and alteration of effluents resulting from unusual or specific diets. If diet or the characteristics of recent environment (as confinement in a tunnel) can be related to the detected effluent, it may be possible to obtain clues for discriminating between friendly and enemy personnel on the basis of these differences.

(U) The Air Force has completed an interesting study on remote detection of personnel[6] in which they assessed the possibilities of UV spectroscopy, gas chromatography, flame ionization, flame emission spectroscopy and ionization particle counting. Of these, the latter approach appears to offer promise in detecting personnel by detecting the organic dust particles stirred up by movement in the target area. Earlier work by Picatinny Arsenal[8] in assessing the usefulness of gas-liquid chromatography has indicated that the time required for an indication is impractically long.

(U) Both the chemical approaches and biological approaches to be discussed next have received a thorough and critical evaluation by the Institute for Defense Analyses.[7]

(S) BIOLOGICAL DETECTION (U)

The use of pigeons to detect people appeared attractive at the outset because the pigeon offered mobility and a highly refined detector combined with a proven correlation mechanism; the very survival of the pigeon is based on its ability to detect and assess, while in flight and across considerable distances, both threat and opportunity. It was discovered early in the studies that the pigeon could be conditioned to detect people in a photograph, in a projected slide, or in actual environment, and that it could be taught to fly a reconnaissance path along a road or trail, making brief excursions alternately over opposite sides of the road or in the open and seek out only those in hiding. The final step of conditioning was to teach the bird to signal once detection had been made. After numerous trials it was determined that the optimum signalling arrangement would be to train the bird to land briefly after sighting a target. This action changes the modulation of a one-ounce transmitter carried by the bird from a warbling tone to a steady tone, and the altered signal is detected by the receiver hundreds of meters away. In the system presently being developed, transmitter-equipped pigeons are being specifically conditioned to fly from a loft on a moving truck, Figure 4, perform a surveillance flight along each side of the road and ahead of the vehicle, signal when an ambush has been sighted and return to the vehicle. The pigeons normally fly from 100 to 300 meters ahead of the vehicle and are able to detect individuals in hiding up to 50 yards off the road. The development of a 12-pigeon vehicle-borne system is now in progress and will be submitted for military potential tests and/or operational evaluation by September, 1966. The principal problem area still to be resolved is to consistently achieve the unique, reliable response which the bird is to make when detection has been made.

The possibility of using trained German shepherd dogs to detect ambush had been reported by Project Michigan in a study for the Electronics Command.[8] The practicability of the off-leash technique which permitted the dog to range freely ahead of a patrol was established during the summer of 1965.[11] In practice, the dog will customarily range 150 to 200 meters ahead of the patrol and be able to detect hidden personnel at distances up to 100 meters away. Upon making detection his conditioned response is such as to change the modulation of the signal from a 2-lb transmitter carried around his neck; this change in modulation, picked up by the handler's receiver, is the cue that detection has been made (see Figure 5). Current plans call for a joint program between the 26th Scout Dog Platoon and LWL to develop a dog system for military potential test and/or operational evaluation. These plans are now awaiting approval by CONARC.

A study of the possibilities of instrumented biosensors indicated considerable promise through use of whole giant bedbugs and a feasibility investigation of the scheme is underway. Using a simple breadboard arrangement, Figure 6, air is drawn into a chamber in which a giant Mexican bedbug is mechanically coupled to a crystal pickup and the amplified output of which is heard in the user's earphone, preliminary tests in Panama have shown that one or two men can be detected at ranges up to 40 meters, even under adverse terrain conditions. A second phase of this program has been initiated to determine whether it is possible to directly monitor the signals from insect antennae in order to obtain a more reliable response. Similar work has been reported by the Air Force in measuring nerve potential in instrumented cockroaches.[10]

ELECTROMAGNETIC DETECTION (U)

(C) The wind-dependent non-line of sight characteristics of the chemical detector and the instrumented biosensors are unsuitable if location of the target in azimuth is desired, and for this reason a number of electromagnetic techniques have been examined. One of the more recent efforts in this category is that of exploiting backscatter from a laser beam. The study presently being undertaken for LWL by Melpar will determine the nature and extent of interaction between a laser beam and some of the specific effluents from man, Figure 7. It is hoped that the laser beam which is reflected in small concentrations of these effluents will be sufficiently altered by characteristics to permit detection and identification at reasonable distances. Evaluation of the data resulting from this approach will be made during the first quarter of FY 67. Other optical effects have been considered and found unpromising. One of these was the possibility of detection by ultraviolet radiation of the mercury vapor released to the air as a result of firing ammunition in which mercury is an ingredient. Although attractive because it might provide specific identification of the enemy since U. S. ammunition does not contain mercury, a preliminary study indicates that the possibility of producing a practical device is poor and no activity is planned.

(U) Passive infrared radiation detection in the 8 to 15 micron range offers possibility for aerial detection of ambush under favorable conditions. The equipment is already in existence and some tests have indicated the practicability of detecting thermal gradients on the ground resulting from a variety of human activities and the use of powered equipment. Various active near-IR devices now in the supply system such as the IR rifle scope and some proposed devices based on scanning with an IR laser beam should offer promise in detecting ambushes at night.

(C) Microwave radiometry in the 600 gigacycle range has been investigated preliminarily by Frankford Arsenal[8] to determine what promise it offers in ambush detection. It should be possible through this technique to detect metal, such as portions of guns and other equipment, which would reflect sky temperature and thus appear as cold bodies. Airborne microwave radiometry devices offer greater promise than those carried on the ground because of the more favorable angle presented from the air for seeing reflections from the sky. LWL is presently studying the potential of this technique in the 10 to 125 gigacycle range. Radar of several types has been investigated at LWL including X-band, sub-nanosecond short-pulse techniques,[12] and CW-FM radar[13,14] in an attempt to see individuals through considerable thicknesses of brush and trees. In spite of the relatively large radar cross-section of man, the low signal-to-noise ratio, ambiguities and equipment size and complexities have shown that these approaches hold little promise, confirming the results reported on similar approaches by the Electronics Command.[8] The PPS-5 doppler radar developed by ECOM, now undergoing test in Vietnam, provides fairly good detection of infiltration over a wide variety of terrain conditions but is not effective through brush and dense undergrowth. Other ECOM work of interest is the combination of airborne infrared and side looking radar installed on the Mohawk aircraft and the Airborne Cowcatcher Radar.[8] An LWL study based on a suggestion made by two students at the University of Rochester will determine the practicability of a scheme using radar at 150 megacycles for detection of rifle barrels at a distance through employment of resonance phenomena.

ACOUSTIC AND SEISMIC (U)

(S) It would seem that passive acoustic and seismic approaches are practical for detecting ambush over short distances and might also be attractive from the viewpoint of detecting intrusion. One device which has been developed to explore the possibilities of this technique is the ultrasonic acoustic detector which responds to sounds in the 27KC frequency range and capable of detecting sounds generated by a quietly moving individual at distances out to 50 and even 100 meters. Several models of this device, Figure 8, which provides an auditory output have been built for evaluation and are being refined and improved for field trial. LWL has also examined the possibility of using highly sensitive, highly directional microphones in the audible frequency range.[15] With experimental devices, Figure 9, in which selected frequency bands are used, it is possible to clearly identify human voices and other human activities in the normal noise level of a forest at 100 meters range.

(U) There appeared to be some evidence that the presence of humans in a forest or wooded area, in an ambush situation, would alter the normal sounds of the forest because the human intruder would inhibit the singing of birds, the calls of small animals and possibly the sounds of insects. The feasibility of this approach was studied and considerable data were obtained in experiments conducted in Panama.[16] Although some change in the normal forest noise background pattern resulting from the intrusion of humans was noted, most of this change relied on the presence or absence of specific species of birds which were not present in sufficient number to provide a reliable basis for detection.

(U) From time to time it has been proposed that the infrasonic spectrum in the 10 to 30 cycle range should be investigated to determine if individuals can be detected at a distance through the sounds generated by heartbeat and breathing. This approach offers no promise because of the extremely low levels of energy emanating from the human and the normal noise background of the forest.

SITE PREPARATION AND/OR ENVIRONMENT MODIFICATION (U)

(U) There appears to be some promise in detection of ambush and/or intrusion through the use of chemicals, radiant energy, emplanted sensors or the like, where conditions permit or the importance of a specific situation allows, and a number of studies have been made on various approaches.

(S) One interesting Air Force approach[9] is to seed an area with urease for chemically marking and detecting individuals. The urease is rubbed off from foliage onto individuals and reacts with the urea in normal perspiration to produce ammonia in relatively high concentration thereby increasing the probability of detection by chemical or other means. Although the logistics difficulties are extensive, this approach would appear to offer increasing promise with the availability in the field of the chemical detector. Another Air Force technique in the same report proposed disseminating an ultraviolet excited fluorescent powder which can be detected through use of a UV source, either airborne or on the ground.

(C) Ambush may be prevented through area denial if critical wooded or brush filled areas adjacent to a road can be seeded with an insect attractant. Experiments at LWL indicate that it is possible to sow a chemical in these areas which will attract insects, excite their biting reaction and thereby make the area untenable to visitors because of physiological distress. The chemical, contained in glass microcapillaries, Figure 10, would be dispersed in a selected area, the chemical releasing slowly over a period of hours from the open ends of the glass tubes. Field experiments are scheduled in Vietnam for the first quarter of FY 67. Various physiologically effective agents for producing distress have also been considered for direct sowing onto an area to be denied to the enemy. In view of the low promise of this approach no further action is planned.

(S) It has been proposed from time to time to employ high intensity sound for flushing out the enemy or reducing their activities through physiological distress. An examination of this approach shows that it is not promising. The use of flickering lights or high intensity light flashes for the same purpose is also considered unpromising because of the uncertainty of effectiveness, the high powers required and the liklihood of effective countermeasures. Although advances in the state of the art may permit effective anti-personnel application of high power laser flashes in ambush situations, much higher powers and efficiencies must first be achieved. Similarly, the proposed use of high energy UHF radiation to induce seizures or other forms of incapacitation has been dropped after some experimentation.

(C) Numerous efforts are underway to determine the effectiveness of emplanted acoustic, seismic or electromagnetic sensors which, when combined with a suitable transmission link, will signal the presence of the enemy. Although the logistics problems of such schemes are high and there are bound to be frequency band limitations, there may be applications for this technique in specialized instances. Work in this area includes the implanted carrot radar MTI done for Electronics Command by University of Michigan,[8] the active seismic system developed at ECOM which detects deformation of the ground resulting from movement of individuals or vehicles[8] and the interesting experiments reported by the University of Michigan in which a free-flight balloon carrying a microphone and transmitter was permitted to float over relatively long distances to relay the sounds of activities on the ground. The work in this field by various agencies and laboratories of the Army, Navy and Air Force is constantly being cross-monitored.

(C) FUTURE PROGRAMS (U)

Based on the existing state of the art it is highly unlikely that the idealized detection system employable on the ground and in the air, which is specific with regard to people, provides range and azimuth information, is reliable in all weather and performs under both day and night conditions, is achievable in the foreseeable future. Our immediate hope lies in improving the systems now under development and in combining two or more systems together to improve detection reliability and reduce false alarm rate.

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(S) TABLE I CHEMICAL (U)

	CN Manpack	CN Vehicular	CN Aircraft	Mass Spectro-meter	UV Spectros-copy	Gas Chroma-tography	Flame Ionization	Ion-ization Particle Count	Flame Emission Spectroscopy
Basis	Detection of effluents of man (ammonia, compound sigma, condensation nuclei)			detection of specific effluents	detection of specific effluents	detection and identifi-cation of specific effluents	measure-ment of total or-ganic content of air stream	detection of organic dust par-ticles stirred up by move-ment in target area	measurement of emitted light from metal ions in skin particles, etc.
Range, meters, <10 indiv.	90-200	90-200	90-200	Unk	Unk	Unk	Unk	Unk	Unk
Range, meters, >10 indiv.	> 200	> 200	> 200	Unk	Unk	Unk	Unk	Unk	Unk
Active or Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive
Response time - Sec.	1	1	1	10 est.	—	~1000	—	—	—
Readout	meter + auditory	meter + auditory	meter + auditory	meter	chart trace	chart trace	meter	meter	chart trace
Line of Sight	No	No	No	No	No	No	No	No	No
Wind Dependent	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Affected by Rain	No	No	No	Partial	Partial	Partial	Partial	Partial	Partial
Day and Night	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Operable while moving	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Power Requirement	Mod	Mod	Mod	Mod	—	—	—	—	—
Weight - pounds	24	100	100	10-15est	—	—	—	—	—
Maintainability	Mod	Mod	Mod	Unk	—	—	—	—	—
Degree of Operator Tng	Mod	Mod	Mod	Mod	—	—	—	—	—
Estimated Cost, $ (quantity)	3500	15000	15000	Unk	—	—	—	—	—
Lead Time (months)	5	5	5	Unk	—	—	—	—	—
Potential	Good	Good	Good	Unk	Poor	Poor	Poor	Fair	Poor
Agency	LWL	LWL	LWL	LWL	AFSC	AFSC	AFSC	AFSC	AFSC
Status	(1)	(2)	(3)	(4)	(5)	(5)	(5)	(5)	(5)

(1) 200 to be in Vietnam by August 1966.
(2) Operational evaluation, RVN, beginning June 1966.
(3) Operational evaluation, RVN, beginning June 1966.
(4) Study in progress.
(5) Completed Study.

(S) TABLE II BIOLOGICAL (U)

	Pigeons	Dogs	Insects (bedbugs)	Other Instrumented Biosensors
Basis	Visual recognition by transmitter-equipped pigeons specifically conditioned to find personnel in hiding.	Olfactory detection by transmitter-equipped dogs trained to find personnel in hiding.	Movement response of bedbugs to specific effluents of man.	Monitoring of electrical signals directly from insect antennae.
Range, meters, <10 indiv.	100-300, 50 from bird	100-200, 100 from dog	30-40	Unk.
Range, meters, >10 indiv.	100-300, 50 from bird	100-200, 100 from dog	Unk.	Unk.
Active or Passive	Passive	Passive	Passive	Passive
Response time - Sec.	2-3	2-3	2-3	2-3 est.
Readout	Modulated radio link	Modulated radio link	auditory	meter + auditory
Line of Sight	Partial	No	No	No
Wind Dependent	No	Yes	Yes	Yes
Affected by Rain	Partial	Partial	No	No
Day and Night	No	No	Yes	Yes
Operable while moving	Yes	Partial	Yes	Yes
Power requirement	low	low	low	low
Weight-pounds	250	2-lb radio	5	Unk
Maintainability	low	low	low	Unk
Degree of operator training	mod	mod	low	mod
Estimated Cost, $ (quantity)	1000	1000	100	Unk
Lead Time - months	3-4	2-3	3-4	Unk
Potential	good	good	fair	Unk
Agency	LWL	LWL	LWL	LWL
Status	(1)	(2)	(3)	(4)

(1) Development of 12 pigeon vehicle-borne system in progress for military potential test and/or operational evaluation.
(2) Feasibility program completed. Development of system for operational evaluation under consideration.
(3) Feasibility investigation in progress.
(4) Study and experimental program initiated.

(S) TABLE III ELECTROMAGNETIC (U)

	Laser Backscatter	UV Detection of Hg	IR 8-15μ	IR 2-5μ	Microwave Radiometry 10-125 gc	Radar High Res.	ORCRIST 150 mc Radar
Basis	Optical interaction with specific effluents.	Absorption of UV by mercury vapor from fired shell.	Radiation from humans in 10μ range.	Reflection of IR from target.	Detection of "cold" bodies such as metals reflecting sky temperature.	Detection of large radar cross section of man.	Detection of rifle barrel resonance.
Range, meters, <10 indiv	Unk	N/A	Unk	Unk	Unk	Dep on foliage	Unk
Range, meters, >10 indiv	Unk	N/A	Unk	Unk	Unk	Dep on foliage	Unk
Active or Passive	Active	Active	Passive	Active	Passive	Active	Active
Response Time - Sec.	<1	10 Est.	<1	<1	<1	<1	<1
Readout	meter	—	Scope or meter	Scope or meter	Meter	Audible, scope, meter	audible, meter
Line of Sight	Yes	No	Yes	Yes	Partial	Yes	Yes
Wind Dependent	No	Partial	No	No	No	No	No
Affected by Rain	Yes	Yes	Yes	Yes	Partial	Partial	No
Day and Night	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Operable while moving	Yes	Yes	Yes	Yes	Yes	No	Partial
Power Requirement	Mod	High	Mod	Mod	Mod	Mod	Mod
Weight - Pounds	Unk	Unk	50-100 est.	<30 est	50 est.	30-100 est.	<100
Maintainability	Unk	Unk	Unk	Unk	Mod	Poor	Mod
Degree of Operator Tng	Mod	Mod	Unk	Unk	Mod	Mod	Mod
Estimated Cost, $(quantity)	Unk	Unk	Unk	Unk	20 K	Unk	Unk
Lead Time - Months	Unk	Unk	Unk	Unk	Unk	Unk	Unk
Potential	Unk	Poor	Fair	Fair	Fair	Fair	Fair
Agency	LWL	—	ECOM	ERDL	ECOM, LWL	LWL	LWL
Status	(1)	(2)	(3)	(4)	(5)	(6)	(7)

(1) Study in progress.
(2) No action planned.
(3) Equipment available.
(4) Equipment Available, additional effort underway.
(5) No action planned.
(6) PPS-5 (doppler) now in Vietnam (ECOM). Short pulse (10 gc) and FM-CW studied (LWL); no further action planned.
(7) Current program.

(C) TABLE IV ACOUSTIC AND SEISMIC (U)

	Acoustic ultrasonic (27 KC)	Acoustic audible (20-22000c)	Forest Sound Spectrum	Infra-sonic (20 cycles)
Basis	Sounds generated by moving target.	Sounds generated by target.	Change in normal forest noise background pattern resulting from intrusion of humans.	Sounds generated by heart-beat and breathing.
Range, meters, <10 indiv	50-100	100	100 est.	<2
Range, meters, >10 indiv	50-100	100	100 est.	<2
Active or Passive	passive	passive	passive	passive
Response time - Sec.	<1	<1	<1	<1
Readout	auditory	auditory	scope	visual
Line of Sight	no	no	no	no
Wind Dependent	partial	partial	partial	no
Affected by Rain	yes	yes	yes	yes
Day and Night	yes	yes	yes	yes
Operable while moving	partial	partial	partial	partial
Power requirement	low	low	mod	low
Weight - pounds	1	5	—	—
Maintainability	good	good	Unknown	—
Degree of operator training	low	low	mod	—
Estimated cost, $(quantity)	300	500	—	—
Lead time - months			—	—
Potential	fair	fair	nil	nil
Agency	LWL	LWL	LWL	—
Status	(1)	(2)	(3)	(4)

(1) Development Program on-going

(2) 4 acoustic telescopes being procured to meet field requirement.

(3) Study program completed. No further work planned.

(4) No work planned.

(S) TABLE V. SITE PREPARATION AND/OR ENVIRONMENT MODIFICATION (U)

	Insect Attractant	Physiologically effective agent	Seeding with reactant (urease)	High Intensity Sound	Light Flicker	High Intensity Flash	Laser Flash	Emplanted Sensors
Action	area denial	area denial	human effluent enhancement	flushing out, reducing enemy effectiveness	reducing enemy effectiveness	reducing enemy effectiveness	reducing enemy effectiveness	transmission of info re enemy presence or activity
Basis	physiological distress	physiological distress	reaction with perspiration produces ammonia which can be detected chemically	physiological distress	physiological distress	physiological distress	partial blindness	acoustic, seismic or electromagnetic sensors with transmitter
Hazard to friendlies	low	moderate	low	moderate	none	low	low to mod	none
Period of Effectiveness	hours	seconds to minutes	minutes to hours	—	—	—	unk	hours to days
Logistics difficulties	moderate	high	high	high	high	high	mod to high	high
Power requirements	low	low	low	high	high	high	mod to high	low
Potential	fair	poor	fair	poor	nil	nil	unk	poor to fair
Agency	LWL	LWL	AF	LWL, others	LWL, others	—	—	—
Status	(1)	(2)	(3)	(4)	(4)	(4)	(5)	(6)

(1) Field experiments in SEA scheduled for 1st Qtr, FY 67
(2) Study only, no further action planned
(3) Air Force study continuing
(4) No further action planned
(5) State of the art being monitored
(6) Numerous efforts wholly or partially directed to this are monitored by LWL and most other agencies and Labs in Army, Navy and Air Force

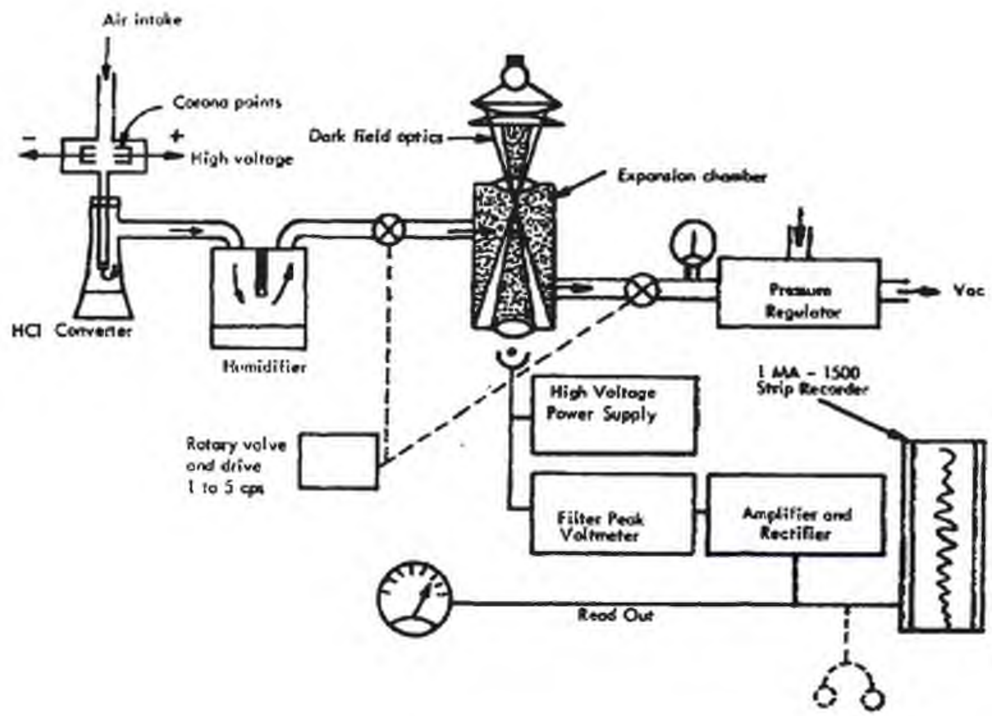

FIGURE 1 CONDENSATION NUCLEI DETECTOR (U)

FIGURE 2 MANPACK DETECTOR IN USE (U)

FIGURE 3 MANPACK DE:ECTOR, COVER REMOVED (U)

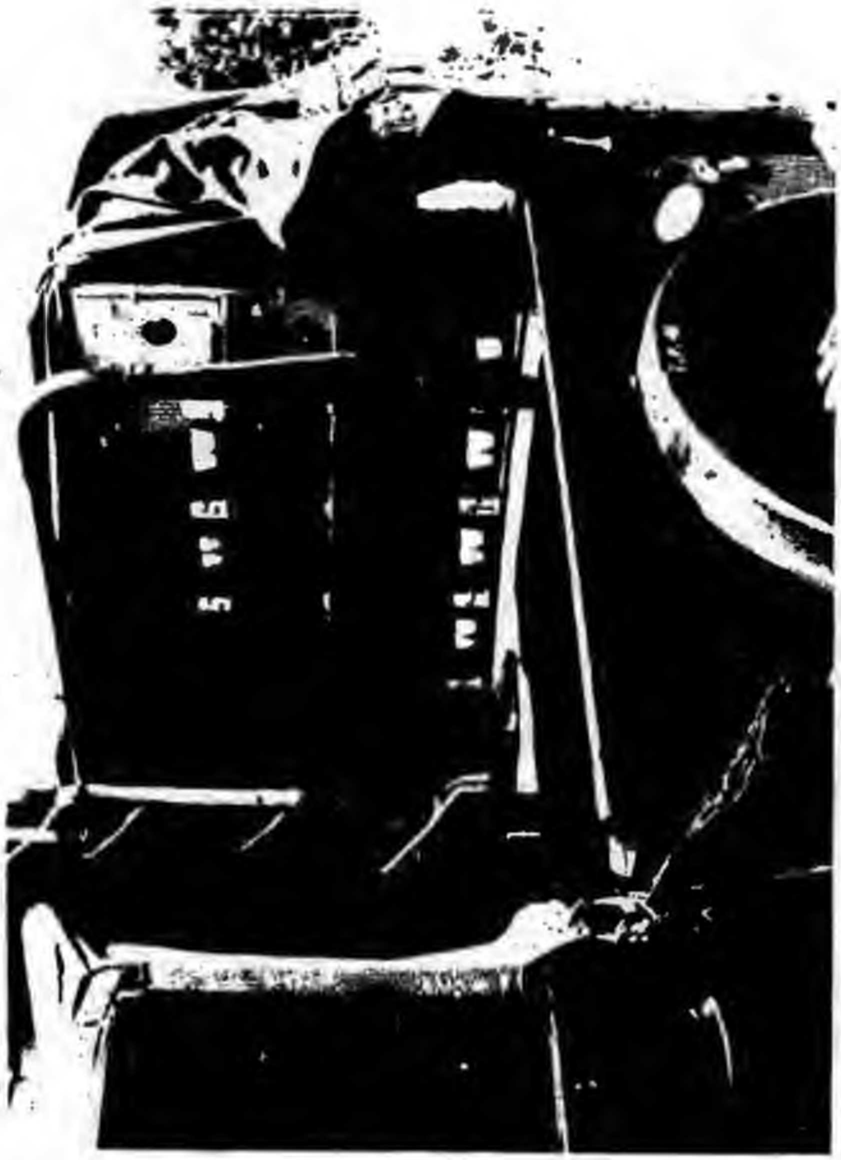

FIGURE 4 TRUCK MOUNTED PIGEON LOFT (U)

FIGURE 5 DOG AND TRANSMITTER (U)

FIGURE 6 BREADBOARD MODEL BEDBUG-BASED DETECTOR (U)

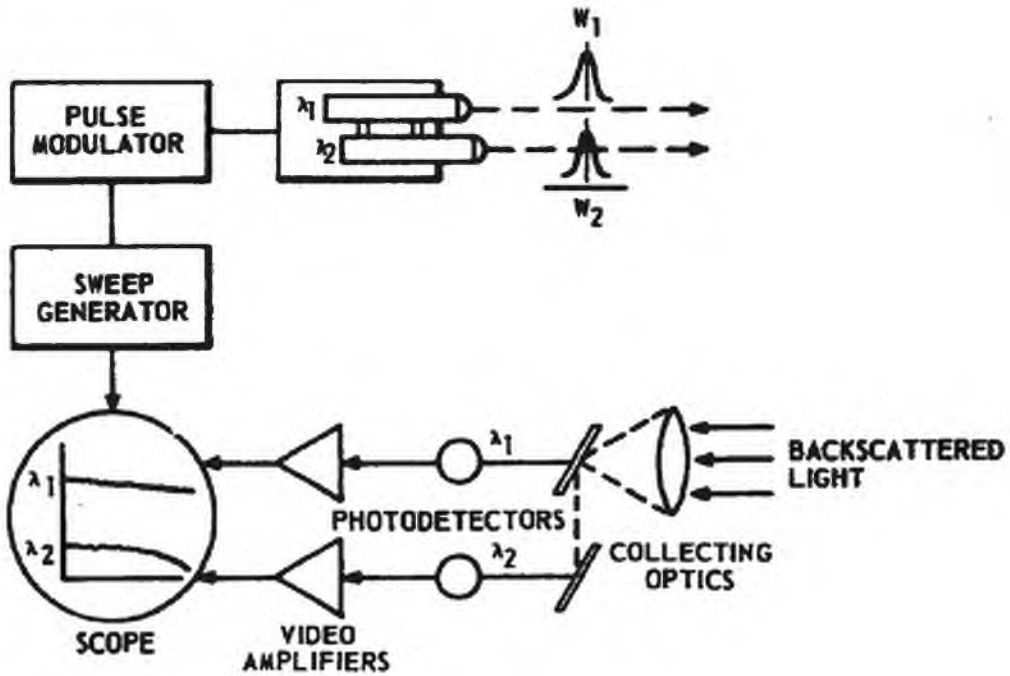

FIGURE 7 BLOCK DIAGRAM - LASER BACKSCATTER DETECTOR (U)

FIGURE 8 ULTRASONIC ACOUSTIC DETECTOR (U)

FIGURE 9 ACOUSTIC TELESCOPE (U)

FIGURE 10 MICROCAPILLARIES (U)

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Mr. Denton is a member of the Society of Engineering Physicists. His fields of interest are surveillance and detection systems and operations research and systems analysis as related to inshore undersea warfare.

DEFENSE AGAINST UNDERWATER SWIMMER ATTACK (U)
~~(Secret)~~

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ABSTRACT
~~(Secret)~~

A description of the environment and conditions at several locations in Vietnam and their relationship to possible swimmer attack are discussed briefly. The results of tests in CONUS and Vietnam with antiswimmer nets indicate the lack of usefulness of nylon nets in areas with high currents and heavy concentrations of debris. Preliminary test results from a short-range development program indicate that swimmers may be detected by means of the AN/SQS-37(XN) or AN/SQS-28(V) small boat sonar at ranges varying from 50 to 200 yards. A long-range development program for providing a system for defense against underwater swimmer attack through use of a 180-degree sector-scanning multipencil beam sonar utilizing an acoustic lens approach for subsurface surveillance and detection and a high-resolution radar and infrared system for surface surveillance is described briefly. The weapons for the system include over-the-side hand-thrown charges or gun-delivered charges along with acoustic simulation and electrical current deterrents. Field expedient procedures that have been provided to ships in order to minimize the probability of successful attack by swimmers are discussed briefly.

1. DEFENSE AGAINST UNDERWATER SWIMMER ATTACK

Millions of dollars worth of material and many lives may be lost through successful Viet Cong swimmer attack against allied shipping, watercraft, or port installations in Vietnam. Intelligence reports indicate that the Viet Cong are in the process of building a swimmer attack capability and may conduct an all-out effort in this type of warfare.

Based on these intelligence reports, the reasons this type of an all-out effort has not yet been attempted could be the following:

a. Lack of supporting technology and hardware.

b. Scarcity of experienced and trained personnel.

c. The Viet Cong command has not yet reached a level of desperation to be forced into an all out effort of swimmer attacks.

d. The Viet Cong possession of insufficient hard intelligence on the potential and actual vulnerabilities in existing allied antiswimmer defense measures.

Intelligence reports indicate that two categories of Viet Cong swimmers may be encountered in Vietnam. The first category is the sophisticated swimmer who has had formal training in the use of at least one type of underwater breathing apparatus, the use and placement of explosives, and the tactics for carrying out an attack against shipping and shore installations. The second category is the unsophisticated swimmer who has not been formally trained, clad in bathing trunks, swimming on or near the surface, with no aids other than a homemade snorkle and transporting a crude mine to be attached to the ship's hull. Both types of swimmers will use camouflage and water currents to advantage while making an attack.

The swimmer may approach his target:

a. From unsecured river banks or beaches in the vicinity of docks, piers, or anchorages.

b. From unsecured areas upstream from the docks, piers, or anchorages.

c. From indigenous small craft passing through or in the vicinity of the target areas.

The following slides depict typical areas in Vietnam where ships are in the process of being off-loaded, and also will show how easily a swimmer attack could be launched against ships:

a. Slide Number 1 - Ships tied up to docks at Saigon being off-loaded.

b. Slide Number 2 - Ships being off-loaded at Saigon. Notice the density of ships and in particular the houseboats tied to the mooring buoys of the freighters in the middle of the river.

c. Slide Number 3 - This is a close-up of the houseboats tied to the mooring buoy for the freighter.

d. Slide Number 4 - Housing and uncontrolled territory across the river from the loading docks. Notice the small river craft which could transport swimmers.

e. Slide Number 5 - Typical small boat on Saigon River. There are large numbers of these boats on the river at all times, and swimmers can easily launch an attack from these craft.

f. Slide Number 6 - Cam Ranh Bay. This slide shows the LST ramps and open storage for cargo.

g. Slide Number 7 - Close-up of previous slide showing the LST ramps more clearly.

h. Slide Number 8 - Close-up of Cam Ranh Bay showing open storage area and native village in foreground.

i. Slide Number 9 - This slide is of Da Nang Harbor and shows the LSTs being off-loaded at Tien Sa U. S. Navy Base. These are the only ships that can be off-loaded without the use of lighterage. All other heavy ships are in the open anchorage areas, as shown in the next slide.

j. Slide Number 10 - Ships at open anchorage in Da Nang Harbor. These ships are off-loaded by lighterage or barges.

At present these ships and storage areas are vulnerable to swimmer attack. What is being done to minimize the threat to shipping by swimmer attack?

Presently, programs are under way at the U. S. Navy Mine Defense Laboratory to develop equipment that will provide a defense against swimmer attack. These consist of both short-range and long-range development programs.

The short-range development program is oriented toward providing an interim capability for swimmer defense until the long-range Antiswimmer System can be developed. Only the subsurface surveillance unit and destructive countermeasures are being considered under the short-range program. The sonars presently being tested for swimmer detection are the AN/SQS-37(XN), AN/SQS-28(V), and the AN/SQS-19. The AN/SQS-37(XN) is a modification of the AN/PQS-1B diver hand-held sonar for application to mine hunting in the river environment. It is a CTFM sonar operating in the 50- to 90-kHz frequency band with a maximum range scale of 240 yards. The AN/SQS-28(V) is a commercial sonar (Sea Scanar) produced by Honeywell, Inc., and is a pulsed CW type operating at 175 kHz with a maximum range scale of 1600 feet. The AN/SQS-19 is a CTFM small boat mine hunting sonar operating in the 64- to 76-kHz frequency band with a maximum range scale of 1200 yards. Under controlled test conditions, the nominal detection ranges for the AN/SQS-28 and AN/SQS-37 have been approximately 50 yards against a surface swimmer and 200 yards against a subsurface swimmer.

k. Slide Number 11 - This slide shows the percent detection versus the detection range in feet for the AN/SQS-28, Sea Scanar Sonar. These were alerted runs. That is, the sonar operator knew the approximate range and bearing of the swimmers. Concentrations of particulate content which may be present in the rivers and bays of Vietnam can reduce these detection ranges appreciably.

The final selection of the sonar will be made when the sonar tests are complete and the test data analyzed. The weapon being tested for the destructive countermeasure is an 81-mm Mark 2 Mod 0 mortar with rounds adapted for use against the swimmer. This mortar can be pier mounted or installed on boats as small as 36 feet in length. Test work is scheduled to be complete for both the sonar and weapon in December 1966.

In late September 1965, the U. S. Navy Mine Defense Laboratory evaluated various types of lightweight nylon nets to determine their effectiveness as a deterrent to swimmer attack. The trammel net, one of the types tested, was found to be effective in the entanglement and entrapment of unalerted underwater swimmers under experimental laboratory conditions. Several prototype nets were taken to Vietnam for operational tests. The environment of Vietnam, including high currents, sea states, and debris concentrations, proved too harsh for any practical application of the nets.

As a part of the long-range development program, limited tests have been conducted at the U. S. Navy Mine Defense Laboratory utilizing an experimental acoustic lens sonar. This sonar operated at a frequency of 25 kHz, source level of 108 db, beam width of 6 degrees in the horizontal and vertical planes, and a variable pulse width from 0.25 to 1 millisecond. Swimmers using scuba equipment were tracked on the bottom (40 feet) and at mid-depth to ranges of 350 yards. Scuba-equipped swimmers exhibit target strengths on the order of -20 db. Target spheres with a target strength of -10 to -13 db were tracked at a 20-foot depth to a range of 500 yards. Test work will continue with an advanced model of the acoustic lens sonar in July 1966.

Under the long-range program, an Antiswimmer System will start in fiscal year 1967. This system provides for subsurface and surface surveillance and deterrent and destructive countermeasures. The subsurface surveillance unit will consist of an active 180-degree sector-scanning sonar using multipencil beam techniques. This sonar will include adapters for mounting on a ship, pier, small boat, harbor, or bottom. Means of electromechanical rotation will be provided for the bottom-mounted configuration. The surface surveillance unit will consist of a radar and an infrared detection device for detection of swimmers on the surface. Deterrent countermeasures will be designed to prevent the swimmer from accomplishing his mission. The introduction of various sounds into the water by means of underwater loudspeakers for the purpose of simulating ships' screws or other noises which may mislead the swimmer as to the amount and type of activity in the harbor area may provide some deterrent. The generation and introduction into the water of relatively fast rise time electrical impulses may be useful in relatively fresh or brackish water in either deterring or killing the swimmers. The destructive countermeasures will be hand-thrown over-the-side charges and ahead-thrown gun-delivered charges. The work on this system will be carried out under advanced development.

Until detection units can be provided to the operational forces, the U. S. Navy Mine Defense Laboratory has provided the Chief of Naval Operations with a set of "Procedures to Minimize Risk of Successful Swimmer Attack." These are generalized instructions that in essence tell the ship captain to make an assessment of the threat of swimmer attack and use field expediency such as anchoring in currents, setting sentries and watertight integrity conditions consistent with the threat, darkening ship, and staying under way if at all possible. The effects of current on swimmer attack were included in these generalized instructions. Slide 12 was provided as a guide to illustrate the approach sectors of a swimmer as a function of current velocity and maximum swimmer endurance. It can be seen that as current velocity increases the approach angle available to the swimmer decreases. Each curve shown represents the boundary inside of which a swimmer attack must be initiated for the given condition of current velocity and swimmer speed and endurance.

The U. S. Navy Mine Defense Laboratory as lead laboratory for Inshore Undersea Warfare and Swimmer Defense is receptive to proposed concepts or equipments that may prove useful in solving the swimmer problem.

FIGURE 1. SHIPS TIED UP TO DOCKS AT SAIGON BEING OFF-LOADED

FIGURE 2. GENERAL VIEW OF SAIGON HARBOR

FIGURE 3. HOUSEBOATS TIED TO FREIGHTER MOORING BUOY, SAIGON

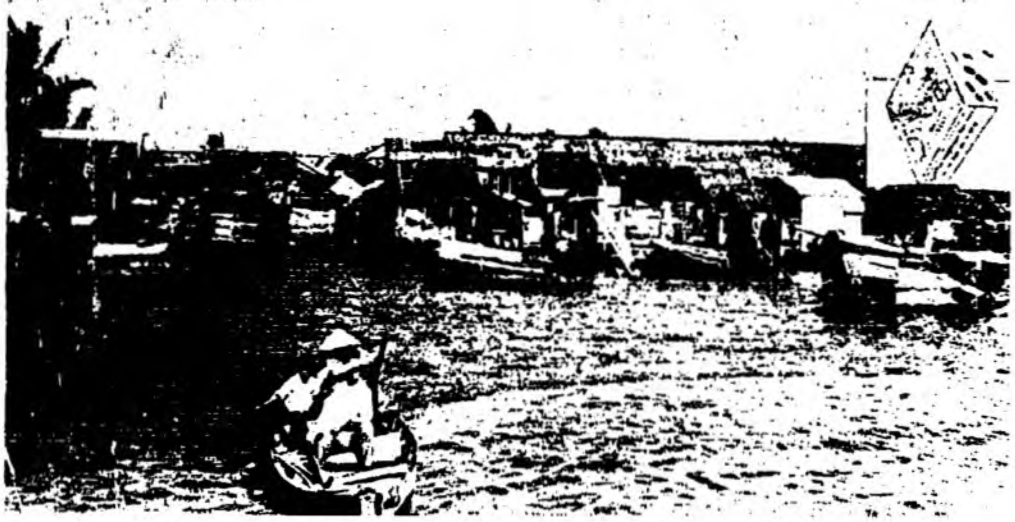

FIGURE 4. HOUSING AND UNCONTROLLED TERRITORY ACROSS THE RIVER FROM THE LOADING DOCKS, SAIGON

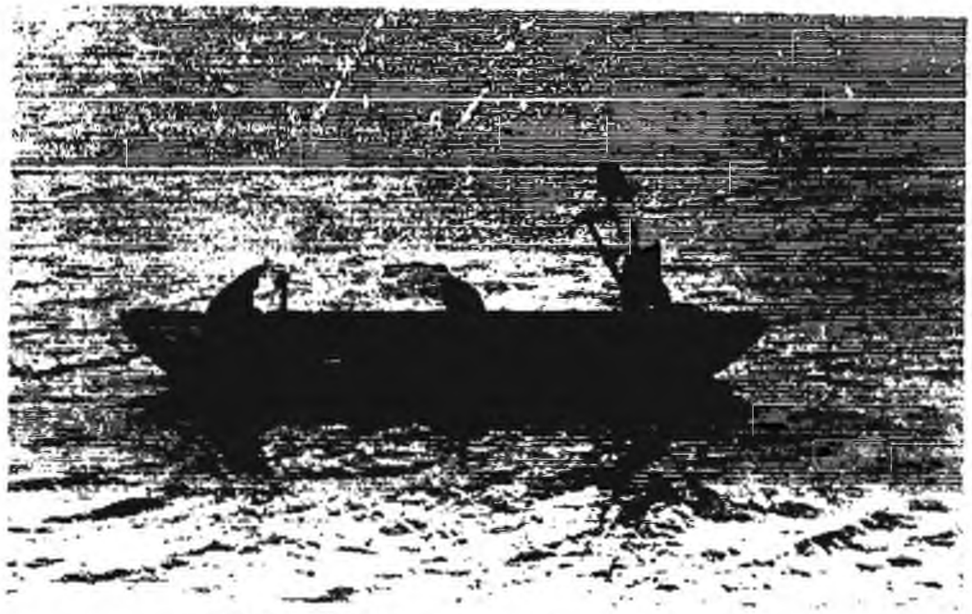

FIGURE 5. TYPICAL SMALL BOAT ON SAIGON RIVER

FIGURE 6. CAM RANH BAY

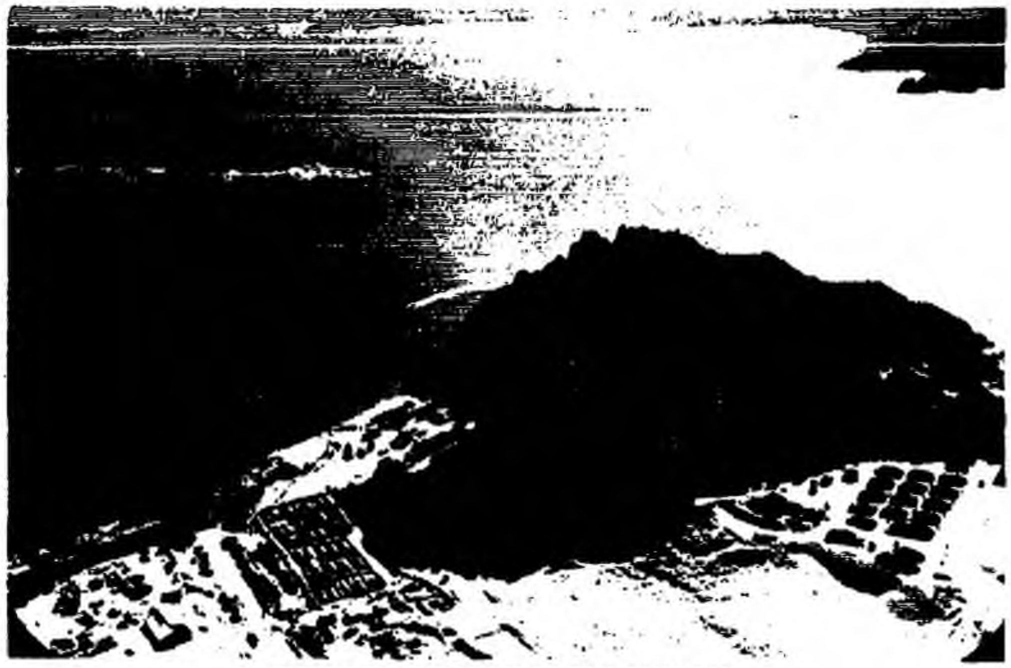

FIGURE 7. LST RAMPS ON CAM RANH BAY

FIGURE 8. OPEN STORAGE AREA AND NATIVE VILLAGE, CAM RANH BAY

FIGURE 9. DA NANG HARBOR, LST RAMPS U. S. NAVY BASE

FIGURE 10. SHIPS AT OPEN ANCHORAGE IN DA NANG HARBOR

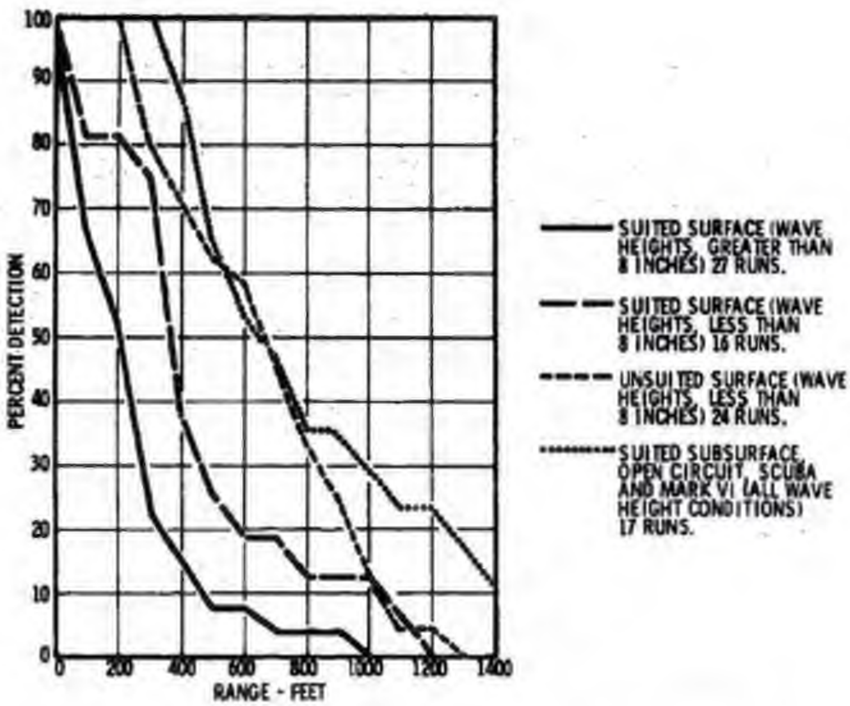

FIGURE 11. PERCENT DETECTION VERSUS DETECTION RANGE

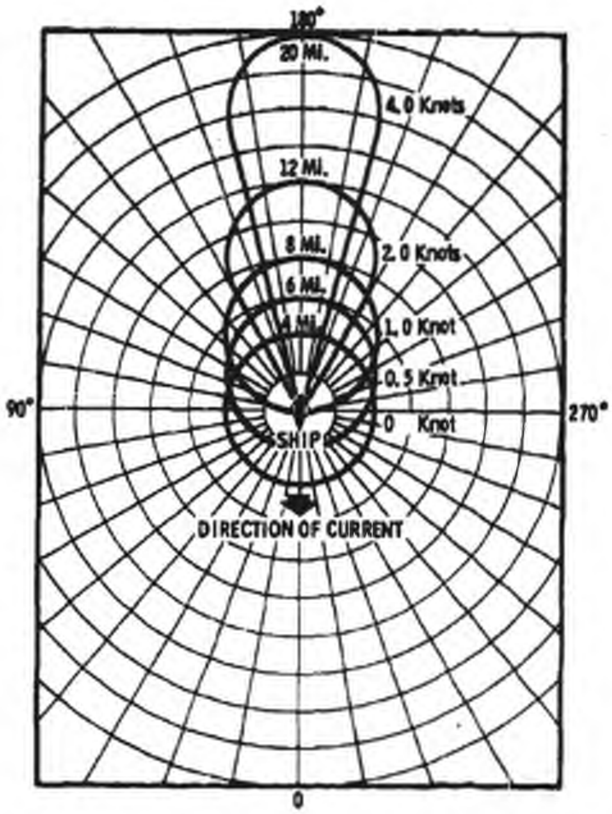

FIGURE 12. APPROACH SECTORS OF SWIMMER AS A FUNCTION OF CURRENT VELOCITY AND MAXIMUM SWIMMER ENDURANCE

(b)(6) [redacted]

TESTS AND MEASURES FOR GROUND MOBILITY (U)
(Unclassified)

[redacted]

Institute for Defense Analyses,
Research and Engineering Support Division,
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1. INTRODUCTION

In August 1965, [redacted] of ARPA AGILE invited me to go with him to the OSD/ARPA R&D Field Unit under the Joint Thai-US Military Research and Development Center, Bangkok, Thailand. The purpose of the visit was to observe the progress of testing of vehicles for remote area operation conducted by the ARPA Field Unit and to suggest improvements where possible.

All methods practiced in the United States were being used; in fact, experts from the U.S. Army had already been there and instructed the research team in the use of such standard soil measuring instruments as the cone penetrometer and the bevameter. Standard tests were run, such as the drawbar pull test and the trafficability-fifty-pass-test. A group of instrumentation experts equipped the vehicles with tachometers, strain gauges, and accelerometers.

I had read about similar tests in reports on the extensive Swamp Fox II tropical environment operation conducted by the U.S. Army Transportation Corps in the Republic of Panama in the summer and fall of 1962, and in other less extensive reports, but it was quite an experience observing such tests actually being run.

The tests had revealed a tremendous amount of variability; they had shown that predictions of a vehicle's hill climbing ability were invariably optimistic, but I was not prepared for the arbitrariness inherent in some of the measures. For instance, just by changing the position of our feet we were able to get more than 50 percent variations in readings of the cone penetrometer. A bicycle wheel which was being pulled by a vehicle to record that vehicle's actual speed was so stuck up with mud that it skidded. One would now wrongly underestimate the actual speed of the vehicle and thus infer that its tracks were slipping more than they actually were. The measurements on the soil were necessarily not completed until some hours after the vehicle test performance. This is because each measurement takes a lot of time and because the soil, not being uniform, is sampled at many different points. In a hot, tropical sun the tidal mud flats on which the vehicles were being run began to dry out. It is very doubtful whether the greater part of the soil readings had much to do with conditions as they were during the test.

Before deciding if it were possible to improve the accuracy of the measurements being taken, I thought that we should reexamine the whole philosophy of the testing and see if the right things were being measured in terms of the decisions that were to be made as a consequence of the test reports. The results of that investigation follow.

1.1 Those Who Need to Know.

They may be divided into three main categories:

(a) Vehicle designers. This group in the remote area situation will include those who modify existing vehicles to make them more suitable for the peculiar conditions which exist in particular remote areas.

(b) Vehicle selectors. These are the people who have to decide what vehicles to send into a particular remote area and who also have to decide what vehicles shall perform what functions as part of a general transportation team.

(c) Vehicle users. This group includes the drivers. Is there anything in the testing program which will enable the drivers to direct and control their vehicles more efficiently?

1.2 A Systems Engineering Approach.

To examine the testing properly, it is necessary to view it as part of a larger continuing development scheme in which new and improved vehicles are continually being created.

There are six controlling principles in systems engineering. I find it easy to remember them in terms of the letters of the word "facets." F stands for a proper Formulation of the system to be created and of its performance characteristics. A stands for Alternative solutions for the goals to be attained. C stands for Compatibility considerations, E for the Economics of the solutions, T for Testing in the laboratory and the field, while S stands for the important Software documents needed to insure proper use and maintenance.

In broad terms these principles can be particularized for vehicle mobility as follows:

1.2.1 Formulation. To move objects and people safely and in good condition from one point to another over varying types of terrain, weather, and combat conditions in time to be useful and without paying too much. Thus appropriate figures of merit appear to be:

(1) Vehicle-driver velocity distributions under representative conditions which include soft grounds, varying climates, steep hills, rough surfaces and obstacles.

(2) Condition of human passengers and driver due to travel.

(3) Condition of cargo and vehicle.

(4) Expenditure of effort and other resources.

1.2.2 Alternatives. The alternative solutions in the broadest sense will include other forms of transport, such as helicopters, but for purposes of ground mobility study, the alternatives will be simply the various types of current vehicles available together with modest modifications (e.g., terra tires, modified tracks). New experimental vehicles should be included when possible.

1.2.3 Compatibility. Compatibility considerations should include the future as well as the present insofar as this is possible. How easily is the test vehicle transported by ship, plane, or other available means, present and future? How does it fit with modern tactical concepts? How easily can potentially interested foreign nationals be trained to use it properly? How long does it take to repair and maintain it under the conditions in which it will be used?

1.2.4 Economics. What are initial, maintenance, and repair costs? What are operating and driver training costs? What is the cost of transport? What are modification costs, when modification is needed to adapt the vehicle to different conditions (e.g., tropics vs. arctic; snow vs. sand; highway vs. soft soil)?

1.2.5 Tests.

(1) What models have been developed by theory which can be used to design tests to estimate the values of meaningful parameters?

(2) What are the relevant variables involved and how can they be controlled and measured during testing?

(3) What are the parameters and variables best tested in the laboratory?

(4) What can best be tested in the field?

(5) How can the tests be designed so as to properly identify causes of performance?

(6) How can the tests be designed so as to identify the general characteristics of superior vehicles?

(7) What tests can be made to identify the characteristics of superior drivers?

1.2.6 Software. How can the results of testing be best presented to give appropriate information to vehicle designers, assigners, and drivers, as well as to maintenance and repair men?

2. TESTS AND MEASURES

Current field tests, when looked at in the light of the above testing requirements in a systems study, suffer from the following inadequacies:

(1) The models which have been developed to explain vehicle behavior are quasi-static, in that they suppose the vehicle to be moving at a constant rate with all forces in equilibrium. Thus, phenomena due to rate change are ignored.

The importance of these ignored acceleration phenomena is shown in Fig 1. A set of points are connected in serial order according to the time of their occurrence. The plus, minus and zero signs close to the curve indicate whether the track of the M116 tracklayer, the vehicle under study, is accelerating, decelerating, or moving at constant velocity. The abcissa of each graph point is the vehicle slip coefficient, i.e., 1 less the velocity of the vehicle divided by the velocity of its track ($1 - v_a/v_t$). The ordinate of each point is the tension acting contrary to the motion of the vehicle and applied to its drawbar with the appropriate force subtracted or added to compensate for deceleration or acceleration inertial effects, respectively. Tension is measured in units equal to the mass of the vehicle.

The curve of Fig 1 was obtained by reading a tape recording of an M116 dragging another vehicle over the tidal mud flats of Bang Pu, Thailand, 29 August 1965. Each point represents the values indicated, averaged for a period of one second. It was possible to process the tape (but tedious) because readings of speed were indicated by spaced blips and the strain gauge reading, which was a displacement, was comparatively free of noise. Such a tape is usually processed by looking only at assumed steady state portions of it and throwing the rest away. Surely the inadequacies of theory should not command that testing be inadequate also. Here are phenomena that need to be understood and recorded.

(2) The vehicle models which have been developed allow for no differences in drivers. In the soft soil case, for example, the driver is very important. All that is necessary is to look at some poor fellow spinning his wheels in snow while you go merrily on your way. Or is it the other way around? In any case, the adroit application of power is unquestionably significant. We must consider driver differences.

(3) The soil models so far developed contain no stickiness or slipperiness coefficients. In other words, they leave out soil properties which are sometimes the controlling ones. Stickiness certainly was controlling in Bang Pu. Bare feet proved better than sneakers, and the Siamese walking fish had it the best of all. The XM571 undergoing a trafficability test by going back and forth in its own tracks finally got

so much mud on the inside of its tracks that internal friction, rather than modest rutting of the soil, caused power train failure. There is no model formula to explain that. In sum, there is as yet no set of descriptors which characterizes the state of a given terrain from a vehicle mobility point of view.

(4) There is no agreed set of descriptors enabling the consumers of test results really to know the circumstances under which a test was made in its relationship to other tests on other vehicles at other times.

(5) The tests have not been designed to identify causes of performance.

(6) Tests designed for use in the laboratory--where they have been meaningful--have been performed in the field where the variations in readings due to uncontrolled and unidentified variables have made any attempt at curve-fitting a farce.

(7) The appropriateness of the tests and their relevance to the decision problems for which they should supply facts is not clear.

(8) Numbers resulting from the tests are given as absolutes when, in fact, they are random variables. In general, many more repetitions are needed than are now performed, so that confidence limits may be obtained.

(9) Wear and tear on the driver, crew, and cargo are scarcely ever mentioned.

(10) Limits in accuracy due to instrumentation, reading, and data processing are not available from test reports.

It is certainly easy to criticize, and surely a lot harder to suggest specific remedies. Some of the model (by this I always mean theoretical or analytical models, formulas and sets of equations) inadequacies with which we are now living will stay with us for a long time, although perhaps some of the work that ARPA AGILE and others are sponsoring may produce results with surprising speed.

Nevertheless, it should be possible to extend in a modest way some of those very fine beginnings in theory made by [redacted] and others. The most complete account of theory to date is in [redacted] two books, and in articles appearing in the Journal "Terramechanics." With a slight extension, and with more care in the statistical design of the testing, results should prove far more meaningful, even without a quite adequate theory. A discussion of these theories appears in my July 1965 IDA Research Paper P-189.

In order to spell out more clearly what I have in mind, let me just examine what can be done in improving our understanding and recording of the behavior of vehicle-driver systems over soft soil. The same principles will apply to the other performance milieux such as steep hills, rough surfaces, and obstacles.

2.1 Some Suggestions for Improving Vehicle Tests in Soft Soils.

First, let us look at the vehicle-driver velocity distribution which is one of the four main figures of merit which I have identified.

Assume with [redacted] that motion can be described by considering components separately, using the principle of additivity. However, admit accelerations by using Newton's law with a resistance term due to velocity. Thus, considering action in the forward direction, we write

$$Ma = F - k\cdot v^2 \qquad \begin{aligned} M &= \text{mass of vehicle} \\ a &= \text{acceleration} \\ v &= \text{velocity} \\ F &= \text{force in direction of motion} \end{aligned} \qquad (1)$$

Using the identity $adx = vdv$ and putting $T = F/M$, we may rewrite (1) as

$$1/2\,\frac{dv^2}{dx} + kv^2/M = T(x) \qquad (2)$$

For a vehicle starting from rest, the solution of (2) may be rewritten as

$$v^2(x) = 2\int_0^x e^{2k(s-x)/M}\,T(s)ds \qquad (3)$$

x is the distance along the path at which the vehicle happens to be, so that $v^2(x)$ is the squared velocity which the vehicle has at the indicated point of the path. (s is just the dummy variable of integration.) Equation (3) need not be interpreted as deterministic. In fact, because of soil irregularities and differences of power application on the part of the driver, $T(x)$ is a random variable and consequently $v(x)$ is also. The mass of the vehicle is not random, nor is it unreasonable to assume that k, the coefficient of motion resistance due to vehicle velocity, is deterministic also.

Thus, if $\overline{T}(x)$ is the average value of $T(x)$, $\overline{v}(x)$ the average value of $v(x)$, then equation (3) holds if the random variables are replaced by their averages. This leads, after some straightforward mathematical calculation, to the equation

$$\overline{a}(x) = T\cdot e^{-2kx/M} \qquad \text{for } \overline{T}(x) = T,\ \text{a constant} \qquad (4)$$

$T(x)$ may be broken up into components according to the Bekker scheme. Since most vehicles are designed so that an increase in sinkage produces a larger tractive area (a desirable design feature), it is convenient to take this into account. In many cases the relation

$$dA/A = f\cdot dz/z \qquad A = \text{tractive area},\ z = \text{sinkage} \qquad (5)$$

is an adequate description of the increase. For the wheel (5) is a good approximation for small sinkages with $f = 1/2$. For actual shapes of tracks and wheels used, f is never greater than 1/2. This leads to the following possible formula for $T(x)$

$$T(x) = \tan\varphi + c \cdot v_1 \cdot M^{-n/(n+f)} - c_3 v_2 M^{(1-f)/(n+f)} - c_4 v_3 (1-e^{-mx}) \qquad (6)$$

where φ = Coulomb internal friction angle for soil

c = Coulomb coefficient of cohesion

c_3, n = sinkage parameters

c_4, m = adhesion parameters

are soil parameters, and v_1, v_2, v_3, and f are vehicle geometry parameters, M being the vehicle mass (as before).

The above formulation of $T(x)$ assumes that the power of the tractive elements of the vehicle is applied in the most efficient way possible. This will involve some optimum amount of slippage. When the power is applied unevenly, this will further increase the random effect of soil irregularities. An attempt should be made to include power application in the above formula.

The constant k may be resolved into

$$k = k_i + k_e - k_{vis} \qquad (7)$$

k_i = internal resistance and air resistance

k_e = exterior resistance

k_{vis} = shearing force developed because of viscoid properties of the soil.

Even with possible inaccuracies in the above model, we still find ourselves in a better position to plan a test.

Before getting down to the test details, however, let us examine (3) probabilistically. The right hand side, as an integral, is the limit of a sum. After motion has settled down from the initial acceleration, the elements in the sum will appear as identically distributed random variables. If the variations about their mean value are independent of each other, that is, if the properties of the soil which produce $T(x)$ are stochastic processes with independent increments, then one may invoke the central limit theorem and conclude that the average speeds maintained by a given vehicle following exactly similar routes of the same mileage are such that the squares of these average speeds are normally distributed.

One implication of the above is that it will not be sufficient to take only averages of soil properties to estimate average velocities, for if v^2 is normally distributed, then the average of v is less than the square root of the average of v^2 and the discrepancy depends upon the coefficient of variation of v^2. Thus greater variation in soil characteristics will penalize average velocities.

Another implication of the above is that the standard deviation of the average speed attained on a trip is proportional to the square root of the distance traveled.

By actually substituting in the expression (6) into equation (3) and treating the latter stochastically, certain other conclusions are possible. For one thing, it appears that vehicles having high ground pressure, although perhaps achieving lower average velocities, will tend to have smaller variations in their performance.

Such implications should be checked by experiment. If it turns out that the distribution of v^2 departs markedly from the normal, then an improved theoretical explanation will be needed. What should be avoided is the temptation to simply dig into the collection of well-known distributions, such as the beta, gamma, etc., and reduce the problem to one of academic curve-fitting.

One may attempt further stochastic analysis by the use of power spectral density functions. Equation (3) will yield

$$\varphi_{v}2(s) = \varphi_{T}(s)/\left[s^2 + 4k^2 \cdot M^{-2}\right] \qquad (8)$$

as the relationship between the velocity square spectrum and the force spectrum.

We are now ready to discuss testing implications.

2.2 An Acceleration Test.

According to equations (1) and (4), a vehicle starting from scratch will accelerate on the average according to (4) and will have a limiting velocity = $\sqrt{P/k}$. If it takes too long to reach the latter, due to the smallness of k, for example, then by observing the acceleration at certain points it will still be possible to determine T, hence P, and also k unless k/M is extremely small, in which case it is not of interest.

The measurements can be taken by equipping the bicycle wheel currently used for drawbar pull tests. The wheel should be weighted more than it is at present to prevent its bouncing off the ground. A strain gauge can be included in its attachment to the vehicle, thus measuring any extra drag caused by it, and, at the same time, measuring the soil properties which resist the motion of a towed wheel. In addition to a tachometer to measure true speed, an accelerometer can be placed on the bicycle wheel in the direction of forward motion. This should prove better than attempting to measure acceleration directly on the test vehicle because of all the noise introduced by the vibrations of the latter.

After the test vehicle has achieved maximum speed or gone some preassigned distance, then all power should be cut off and the vehicle allowed to coast to a halt. Thus the resisting forces of the soil can be measured apart from the tractive coefficients tanφ and c already described.

Since there are many parameters in equations (1) through (6), and probably should be more, it is desirable to test more than one vehicle at a time. With a sufficient number of diversified vehicles it should be possible to infer the values of all soil properties and their variations.

Of course, the usual soil measuring instruments can be used and their predictive value verified.

In order to properly compare the different vehicles, the driver problem must be considered. This is not at all insurmountable. There are many statistical designs ready and waiting for testing several things at once. One of the simplest models is the latin square. By having each driver drive several different vehicles, and having every vehicle driven by several different drivers, it is possible under very general assumptions to separate out driver effects from vehicle effects and even to study their interactions, as well as the interactions of different types of soil with both drivers and vehicles. When the random variables are normal and effects are linear, the analysis is particularly simple, and computer programs for the principal types of design are already in existence. Even when variances do not satisfy certain uniformity assumptions, functional transformations can often be found which will convert the problem into a standard one. More details about this are given in (b)(6) [redacted]

In conducting any test of this kind, it is wise to break driver performance and vehicle performance into as elemental sub-tasks as possible, so as to reduce the confounding of effects. An acceleration test over one type of soil and in a straight line is one such elemental task. By plowing the test field beforehand, variation can be even further reduced. However, this is an unrealistic reduction and, although suitable from a point of view of laboratory technique, is probably not to be recommended as a field trial procedure.

Turning in soft soil, with a prescribed angle, would be another element task. Here angular acceleration is involved, and the proper accompanying analytical model is much more complicated.

With acceleration tests of this kind, the performance of a vehicle in soft soil is more easily characterized than by the drawbar pull test. The same soil reaction is measured, but only one individual is involved, there being no second towed vehicle under the control of another human being. Thus there are less unknown quantities irrelevant to the problem. Also, rate sensitive phenomena are now frankly included and can be recorded and interpreted.

Human reaction is included. This is something about which we seem to know very little. For example, what displays should the driver have? Is a speedometer necessary for off-the-road travel? Would it help to have a display of the torque on each wheel or track, with driver differential control of power? Should torque control be automatic? if so, how? The last question will best be answered when we know better what makes superior drivers superior.

In the acceleration test we have thus far only discussed accelerations and speeds, which we shall now assume all properly recorded and analyzed.

We turn next to the second mobility figure of merit, namely, the condition of the driver and his crew. Although in soft soils this is not apt to be much of a problem, as soft soils are not apt to produce uncomfortable vibrations and we are not looking at the obstacle problem, we will assume that the test vehicles are equipped with jerk meters and accelerometers located to test the actual motions to which driver, crew, and cargo are all subjected. Oral reports can also be helpful.

It is probably not necessary during field trials to get an accurate recording of accelerations at all frequencies. Rather, the total power of certain key frequencies could be recorded by suitable filtering or by the use of reed tachometers.

The condition of the vehicle after the test should be noted and entered into the record of the test.

Fuel consumption should, of course, be noted. This, too, will vary under apparently identical circumstances. The appropriate mobility model should be able to account for these variations as well as for the other variations previously discussed.

2.3 Summary. The testing must be designed to obtain information which in content and form is useful to designers, planners, and drivers. It should be clear what are vehicle effects and what driver effects. An attempt should be made to understand the mechanisms involved. Parameters estimated, such as speeds, should include variation estimates as well as estimates of averages. Every test should have a sufficient number of replications, with tasks broken up into simple units. Because it is so hard to characterize the conditions of a test, comparative testing is the most valuable.

BANG PU }
THAILAND }

DRAW BAR PULL TEST OF M116, 29 AUGUST 1965
AT EACH POINT ACCELERATION OF THE VEHICLE TRACK IS INDICATED AS NEGATIVE, ZERO, OR POSITIVE. THE POINTS ARE CONNECTED IN PROPER TIME SEQUENCE.

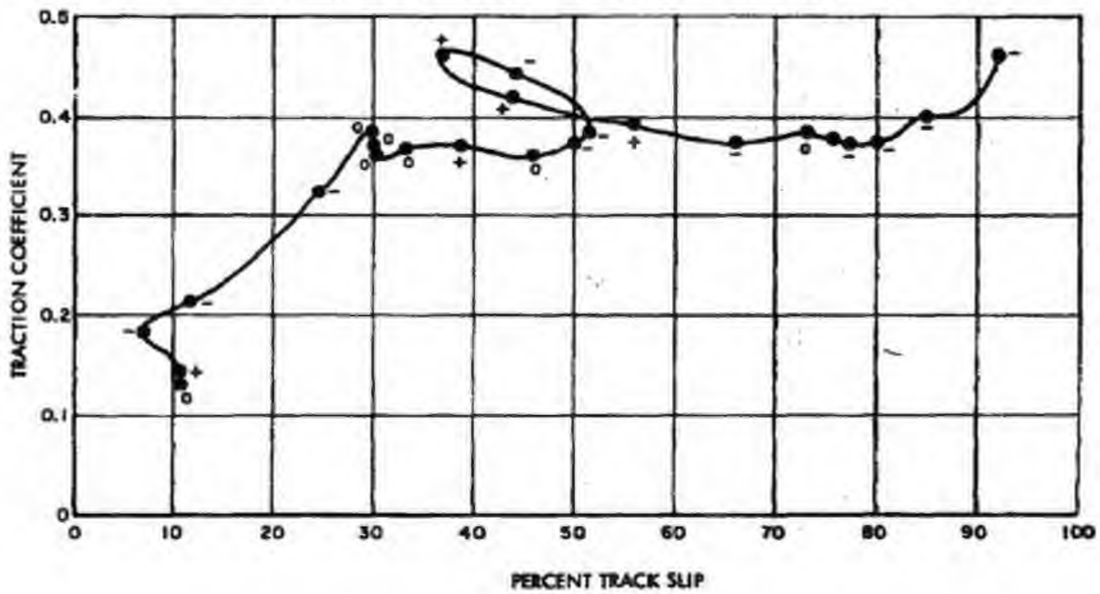

Figure 1

(b)(6)

[redacted]

TROPICAL RADIO PROPAGATION RESEARCH PROGRAM (U)

(Unclassified)

(b)(6) [redacted]

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of
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ABSTRACT
(Unclassified)

This paper reviews radio-frequency propagation studies in tropically vegetated environments typical of those found in Southeast Asia. Specifically, the paper describes the propagation studies being conducted in Thailand by the Jansky & Bailey Research and Engineering Department of the Atlantic Research Corporation. The program is sponsored by the Advanced Research Projects Agency as part of Project SEACORE, and is directed by the United States Army Electronics Command.

The propagation studies range from frequencies of 100 kc to 10 gc, and distances from 100 feet to 30 miles. Both horizontal and vertical polarizations are used, and antenna heights vary from 7 to 80 feet. The large base of measured data demonstrates the effects of irregular terrain as well as of relatively dense vegetation.

In addition to providing an over-all review of the work, the paper focuses attention on the magnitude and nature of the "vegetation factor" as indicated by available measured data. "Vegetation factor" is defined here as the difference in propagation loss between that observed in a tropically vegetated environment and that which would be expected in the absence of significant vegetation.

Although it is too early to draw final conclusions, the data is beginning to show definite well-defined trends which will contribute significantly to the eventual development of a computational model for communications and detection systems within vegetated environments. In particular, present data suggests the existence of an "antenna-to-foliage coupling factor" and a separate, although not necessarily independent, "vegetation attenuation factor."

The propagation research program discussed in this paper is one of several communications research programs sponsored by the Advanced Research Projects Agency of the Department of Defense as part of its Project SEACORE SEACORE being a loose acronym for Southeast Asia Communications Research. This research program is under the contractual and technical direction of the United States Army Electronics Command, Fort Monmouth, New Jersey.

Friendly local forces in remote area conflict, or counterinsurgency, situations are very likely to become engaged in small unit operations against an elusive foe who, by his nature and training, takes advantage of the terrain features and other characteristics of the natural environment. This situation obviously places a premium on effective ground-to-ground and air-to-ground communications through the use of ultra-lightweight, rugged and operationally simple radio equipments. But, the natural environment of typical remote area conflict situations often introduces severe communications problems in the form of high levels of radio-frequency noise; dense vegetation, which seriously reduces the range performance of radio sets; and rugged terrain, which often interferes with ground-wave radio propagation. Also, although not within the scope of this paper, the physical and educational qualities, social characteristics, and command and control structures of the local population may also introduce specialized communications requirements. However, radio communications equipment for regular United States forces generally is not designed to meet these specific types of needs, although a few mobile equipments more suitable for this type of deployment have recently become available. Furthermore, until some of the experimental results of this program had been obtained and widely distributed, through the semiannual reports, to interested Government and industrial laboratories, there was not enough data on the attenuation effects of dense foliage to permit a realistic prediction of the range performance that could be expected from these equipments in such environments.

The attenuation effects of tropical vegetation upon ground-based radio transmissions is not a new subject, having been recognized more than 20 years ago in World War II operations in the South Pacific theater. In 1943, [redacted] and [redacted] conducted experimental studies in Panama,[1] and, in 1945, [redacted] conducted similar studies in a tropical forested region in New Guinea.[2] These studies were conducted at test frequencies of 2, 2.2, 3, 6, 9.5, 12.75, 29, 49, 50, and 99 mc, and demonstrated some of the attenuation effects to be expected out to about a mile from the transmitter. Following these investigations, no directly applicable work has been done until the last three or four years, when events in Southeast Asia brought the subject to the forefront again.

This propagation research program is one of several that ARPA has initiated in response to these problems. A detailed statement of all the specific objectives of the program is beyond the scope of this paper. In general, however, the principal objective is to collect and analyze fundamental radio propagation data, from actual tropical forested environments, needed to improve the design and performance of communications and related equipment for use in such environments. With respect to this objective, an important aspect of the program is that the data is collected in as near to fundamental units of measure as possible so that the results can be applied to a wide variety of problems in the general areas of communications, surveillance, navigation, and intrusion detection systems.

Before proceeding further into the details of the radio propagation research program, it may be helpful to review some of the basic considerations involved in the concept of radio path loss. The power radiated from the antenna of any transmitting device is ordinarily spread over a relatively large area. As a result, the power available at the antenna of the receiving device is only a small fraction of the radiated power. This ratio of radiated power to received power generally is called the radio transmission loss; and, clearly, this parameter is the most important influence on the range performance of a radio communications system.

The basic concept in predicting radio transmission loss is the loss expected in free space between a non-directive transmitting antenna and a non-directive receiving antenna. This concept is essentially the inverse square law in optics applied to radio transmission, and, for two isotropic antennas, is given by the following expression.

$$\frac{P_t}{P_r} = \left(\frac{4\pi d}{\lambda}\right)^2 \qquad (1)$$

where

P_t = power into the isotropic transmitting antenna

P_r = power available from the isotropic receiving antenna in the same units as P_t

λ = the wavelength

d = the distance of separation between the antennas in the same units as λ

Consequently, the basic transmission loss, as defined by Norton[3] for loss-free space, may be expressed in decibels as

$$L_{bf} = 10 \log P_t - 10 \log P_r = 10 \log \left(\frac{4\pi d}{\lambda}\right)^2$$
$$= 36.57 + 20 \log d + 20 \log f \qquad (2)$$

in which d is in miles and f is in megacycles.

In predicting the performance of radio equipments in practical situations, it is necessary to take into account the additional losses in the propagation path due to the terrain and environment as well as the transmitting and receiving antenna gains. For this purpose, it is helpful to define the transmission loss, L, and the path antenna directive gain, G_p, such that

$$L = L_b - G_p \quad (db) \tag{3}$$

or, by equating this loss to the ratio of the powers at the transmitting and receiving antenna terminals,

$$L = L_b - G_p = 10 \log P_t - 10 \log P_r \tag{4}$$

In equation 3, L_b is the "basic transmission loss" to be expected in the actual situation if isotropic antennas were substituted for the real transmitting and receiving antennas. However, since isotropic antennas cannot be created in actuality, it is never possible to entirely separate the quantity L_b from the antenna directive gain, G_p. Consequently, an experimental measurement of L_b cannot be obtained directly. However, in communications system engineering, it is often adequate to deal in terms of the transmission loss, L, especially when antennas of low directive gains are used.

Equations 3 and 4 illustrate in simple fashion the important influence of transmission loss upon the performance of radio links, particularly when lightweight, mobile, or man-pack equipments are involved. The maximum transmitter power, P_t, is ultimately limited by the influence of several factors. Chief among these are the size of the equipment and the size and capacity of the battery pack. On the other hand, the minimum value of receiver power, P_r, required for useful signal detection is limited by the noise in the receiver input, or by the external ambient noise induced through the receiving antenna. Thus, the transmission loss, L, or the basic transmission loss, L_b, between the locations of the receiving and transmitting antennas is the dominant factor in determining the useful range of radio equipments, particularly in tropical forested environments.

It is also important to keep in mind that the transmission loss is influenced in a statistical manner by such physical features of the environment as the terrain variations and elements of the vegetation. In general, its behavior is statistical in both the space and time domains; but, in short-range tactical systems, the time variations are relatively small and can generally be ignored. Each radio system has a maximum allowable transmission loss which depends upon the transmitter power output and the receiver sensitivity. Thus, the effective range performance of mobile and man-pack systems is inherently a statistical parameter that results from the statistical influence of physical environment upon the system. It follows that the ability to effectively conduct small unit, mobile operations within regions of diverse physical and geographical characteristics, in which radio communications is an essential prerequisite to successful operations in such regions, ultimately depends upon the ability to predict the statistical behavior of radio transmission loss in such regions.

The tropical propagation research program is intended to assist and support a variety of scientific and engineering activities which are concerned with improving the design and operation of communications, surveillance, navigation, and intrusion detection systems in remote area conflict, or counterinsurgency, situations.

To illustrate now the program objectives have been designed to support these activities, a much-simplified concept of how these activities function together as a system to provide tactical ground operations with the communications equipments and techniques required for field operations is shown in Figure 1. Two elements of the system have been emphasized in this figure. The communications planning function, the central element, is conceived as any activity directly concerned with the acquisition or improvement of the radio communications support of tactical operations in a tropical region. Functionally, these improvements are ultimately obtained by causing information and equipment to flow, in one way or another, from the activities on the left of the "communications planning" to the tactical operations function, which represents the objective element of the system.

As discussed previously, the physical environment assumes a pre-eminent importance in tactical radio communications, particularly in Southeast Asia. Perhaps the most important aspect of the "system" shown in Figure 1 is in providing an additional degree of system "closure" through the influence of the environment. In other words, for any communications system to support the tactical operation, it must have detailed data on the influence of the environment upon equipment operation. This is true whether the planning function is concerned with operations or with the design and procurement of improved equipments.

All the objectives of the tropical propagation research program are designed to aid and support the communications system planning function in one way or another, and through this function to improve the actual operations. Thus, the ultimate aim of the program is to provide the fundamental data and mathematical tools necessary for this purpose.

In Figure 2, this system is further reduced to five elements. Here, the physical environment represents the independent variables in the system in that they have a direct effect upon, but are unaffected by, the other system elements. Now, within this conceptual framework, mathematical models are visualized as providing planning activities with the essential tools to effectively relate the characteristics of radio equipments to a specific mission and environment, or vice versa. To achieve this, these models must be designed to properly take into account the influence of the environmental factors, in a quantitative way, and here, perhaps, is the unique aspect of this propagation study.

To obtain the experimental data needed to develop these models, experimental propagation studies are being conducted in tropical forested areas in Thailand. The experimental program in Thailand collects propagation data for a great variety of paths, as well as detailed data on the physical environment. The environmental data is parameterized, or converted into quantitative measures, and is used in the study and development of these models. The rest of this paper will discuss some of the results thus far obtained from the analysis and study of this data.

A very considerable amount of data has been obtained, and much of it has been published in the semiannual reports. Only a broad sampling of the results from the studies will be presented here, without going into the details of specific areas of work.

Currently, the program is completing a series of measurements at a site in Thailand about 85 miles north of Bangkok, known as the Khao Yai National Forest. This region is classified as a wet-dry tropical region. It is planned to make another series of similar measurements in an area in southern Thailand, in the vicinity of Songkhla, which is characterized as a rainy tropical region. As Table I shows, these two areas have significantly different environmental characteristics.

The concept and methods for estimating a "biomass factor" as a measure of the total vegetative mass above the earth's surface in a given area have been developed by [redacted] of ARPA,[4] and it appears that this factor is one of the most suitable for the purpose of relating one type of jungle to another from the radio propagation point of view. The biomass factor associated with the Khao Yai area is approximately 1300 tons of vegetation per acre, while the biomass factor associated with the Songkhla area is greater than 3000 tons per acre.

In addition to the total amount of vegetation, the way it is distributed vertically is important to propagation studies. In the height class from 6 to 16 meters, there are roughly 40 per cent more trees per acre in the Songkhla area than in the Khao Yai area. In the height class from 17 to 29 meters, there are only a few more trees in the Songkhla area. However, in the height class of 30 to 50 meters, there are eight times as many trees at the Songkhla area than at the Khao Yai area. Thus, it is seen that the rainy tropical area presents a forest, or jungle, that is much taller and denser than a wet-dry tropical area.

The median tree height at Khao Yai is about 10 meters, and there is relatively dense undergrowth extending up to a height of about 6 meters above the ground. The undergrowth at the Songkhla area is less dense, undoubtedly due to the higher percentage of crown cover in this area.

The experimental studies cover a frequency range from 100 kc to 10,000 mc, and cover distance ranges from 100 feet up to 30 miles. The experimental results have been compared with a number of existing propagation models, that is, models without vegetation, in an attempt to ascertain both the nature and the magnitude of the effects of the jungle. In the frequency range between

30 and 400 mc, the best fitting over-all comparisons to date has been obtained with a propagation model suggested by [redacted] in 1957.[5] modified for jungle terrain.

As shown in Figure 3 [redacted] suggests a median field, E_{50}, which is directly proportional to the antenna heights and inversely proportional to the square of the distance of separation between the antennas. [redacted] also suggests a normal distribution about this median value, whose standard deviation is σ_1, which varies from about 6 db at 50 mc to about 10 db at 400 mc.

Using [redacted] expression and adding a foliage factor, which may itself be a function of many parameters, a new expression is obtained for the median basic transmission loss under the conditions of a vegetated path loss. The term F.F. represents the unknown foliage factor, or vegetation factor, that is, the additional loss apparently introduced by the presence of the vegetation. By substituting the measured path loss data, an empirical foliage factor which varies from about 6 db at 50 mc to 22 db at 400 mc for horizontal polarization, and from 16 db to 24 db for vertical polarization, is obtained. Based on the data thus far obtained, the foliage factor appears to depend upon the heights of the antennas to some extent, but not upon distance of separation beyond 250 feet. Experimental studies are presently being conducted to study the behavior of path loss at distances less than 200 feet from the transmitting antenna, but the details of this data have not yet been fully analyzed.

The apparent independence between the foliage factor and the distance, for distances beyond 250 feet, plus the familiar 40 log d fall-off, strongly supports the theory of a treetop mode of propagation at these frequencies. An extensive analysis of the data at the lower HF frequencies, and MF frequencies, is currently in progress. In this frequency range, the experimental data suggests that the apparent path loss, as measured at the terminals of the antennas, seems to depend strongly on the type of antennas and their proximity to elements of the vegetation.

Another type of data that is important to communications problems in vegetated regions is the height gain to be expected by raising the antenna up in the foliage. In this respect, the results of the experimental program are summarized in Figure 4. The data on Figure 4 applies to vertical polarization; the dotted curve corresponds to a theoretical height gain in db which is proportional to the logarithm of height. The solid curve corresponds to a height gain in db which is linearly proportional to height. By following the stars, which represent measured averages at 25 mc, and the black circles, which represent averages at 50 mc, it is seen that the measured height-gain profile tends to follow the logarithmic curve at 25 and 50 mc. However, at the higher frequencies from 100 to 400 mc, the data tends to follow these linear curves. It is of interest to note in passing that, contrary to initial expectations, no significant differences in path loss between wet and dry seasons have been found for frequencies of 400 mc and below in the Khao Yai area.

In addition to measurements between 100 kc and 400 mc, extensive measurements are being made in the range from 500 mc to 10 gc. Within this frequency range, primary interest is in propagation over paths totally immersed in jungle foliage for several reasons that are related to certain types of surveillance and intrusion detection techniques. As on example of some of this work, Figure 5 illustrates the measured attenuation characteristics which the vegetation appeared to exhibit at a frequency of 2.5 gc. The points on this figure represent average measured values, and the bars represent the range of measured values. The solid bars represent vertically transmitted polarization and the dotted bars represent horizontally transmitted polarization. In this figure, little difference between the two polarizations is evident.

The ordinate represents foliage attenuation in db per meter, and the abscissa represents the height above ground at which the attenuation measurements were made. The dotted level at the top of the graph represents free-space attenuation, that is, zero vegetation attenuation. The dotted level toward the middle of the graph, marked "LaGrone level" represents the empirical foliage attenuation calculated by a formula suggested by [redacted] in his 1960 [redacted]

As this graph shows, at low antenna heights, the attenuation starts out at about 0.5 db per meter. As the height is increased up through the undergrowth, the attenuation decreases until the heavily foliated tree crowns are reached. At this point, the attenuation increases sharply. Then, as the height is increased through the crowns of the trees, the attenuation again decreases until the free-space condition is met.

Similar data is presented in Figure 6. In addition to providing information on electrical parameters, this type of data is also beginning to yield information on the vertical distribution of the vegetation and foliage, at least from the radio propagation point of view.

In addition to short-range propagation measurements in this higher frequency range within the vegetation, a number of line-of-sight measurements are being made over a 3-mile path which includes a well-defined, vegetated obstacle. The antenna heights are changed so that varying degrees of obstruction can be achieved in the course of the measurements. The results from one series of these measurements are shown in Figure 7. By taking the height of the vegetation as the height of the obstruction, the measured data agrees quite well with predicted values, using conventional diffraction theory. In this case, the data was taken at 5 gc. The data in Figure 7 suggests that conventional theory can be used to predict the path loss for line-of-sight installations, even in vegetated regions, with confidence.

The eventual aim of this program, of course, is to develop a predictive system model, similar to that shown in Figure 2, which will allow a realistic evaluation of the effectiveness of improving the technical characteristics of equipment, or changing the way in which the equipment is deployed. The following example will illustrate the essential results of such a prediction. Shown in Figure 8 are the results of a calculation of the range that might be possible from the PRC-10 as a function of the confidence with which that range can be expected. The calculations are made for three different situations. In an idealized smooth terrain situation, a median range of about 7.8 miles could be expected. Over irregular terrain, a median range of 6.5 miles could be expected, and a range of about 4 miles with a confidence of 90 per cent could be expected. However, when the set is operated in a vegetated environment, typical of that around Khao Yai, the median range drops drastically to something on the order of 2.5 miles and, at a confidence of 90 per cent, a range of only 1.5 miles could be expected. This example illustrates that, once adequate propagation models have been developed which can be used with these methods of calculation, the merit of various improved equipments, or tactics that depend upon the range of these equipments, can be assessed much more realistically than at present. When this can be accomplished for any radio communications system, for any type of tropical environment, the objectives of the tropical propagation research program will have been achieved.

In conclusion, the author would like to gratefully acknowledge the assistance of several individuals who have contributed directly and indirectly to the contents of this paper. Many of the basic ideas and aims of this program have been obtained through many discussions with [redacted] of ARPA; and [redacted] an[redacted] Fort Monmouth, New Jersey. Also, credit is due to [redacted] of Jansky & Bailey, for the analysis and presentation of the data in this paper.

TABLE I. SUMMARY OF VEGETATIVE CHARACTERISTICS OF TWO SITES IN THAILAND

Characteristics	Unit	Location: Songkhla	Location: Khao Yai
Biomass	Relative Index, Tons Per Acre	3086	1276
Total Trees	Per Acre	589	362
Height Class			
6-16 m	Trees/Acre	434	290
17-29 m	Trees/Acre	74	62
30-50 m	Trees/Acre	81	10
Upper Canopy Density	Per Cent Crown Cover	60-80%	20%
Rainfall	Inches Annually	95	63

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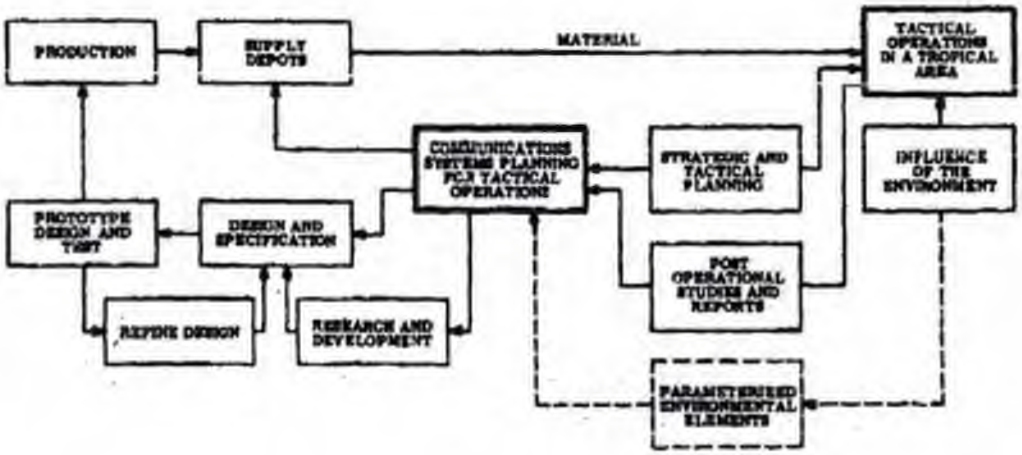
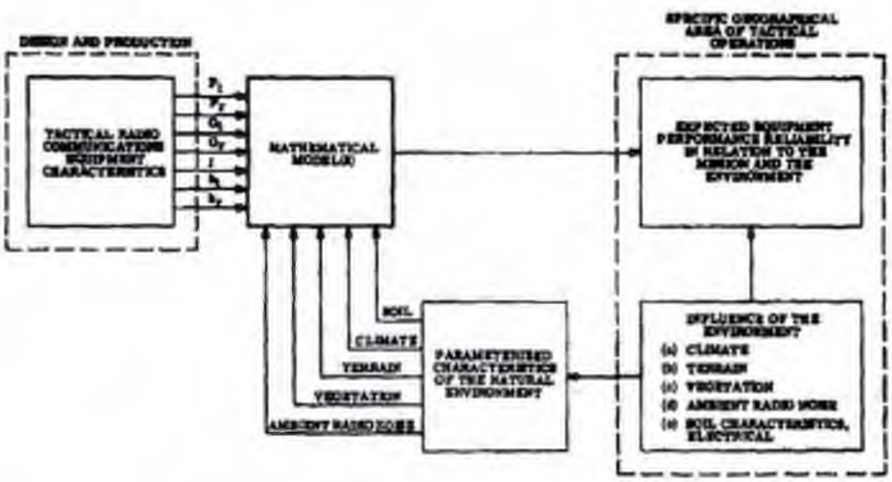


A SYSTEM CONCEPT OF THE PRODUCTION AND DEPLOYMENT OF TACTICAL RADIO EQUIPMENTS

FIGURE 1



A SYSTEM MODEL RELATING EQUIPMENT PERFORMANCE TO THE OPERATIONAL ENVIRONMENT

FIGURE 2

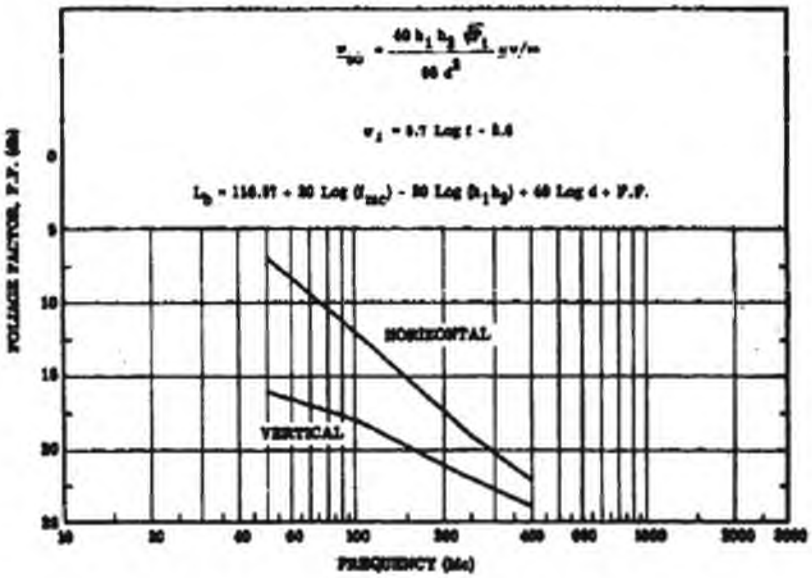


FIGURE 3

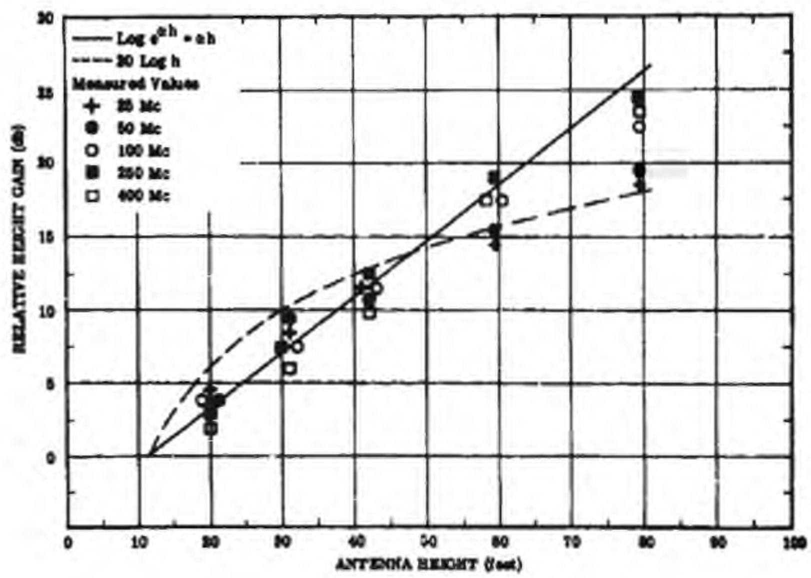


FIGURE 4

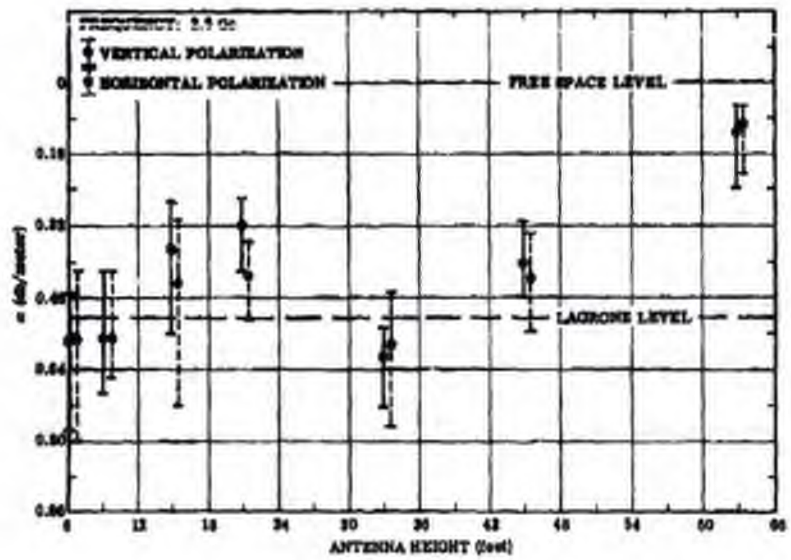


FIGURE 5

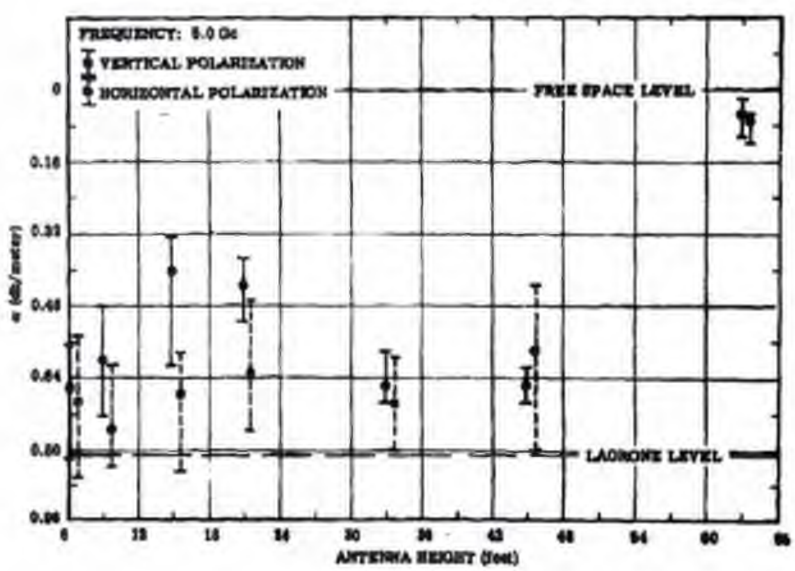


FIGURE 6

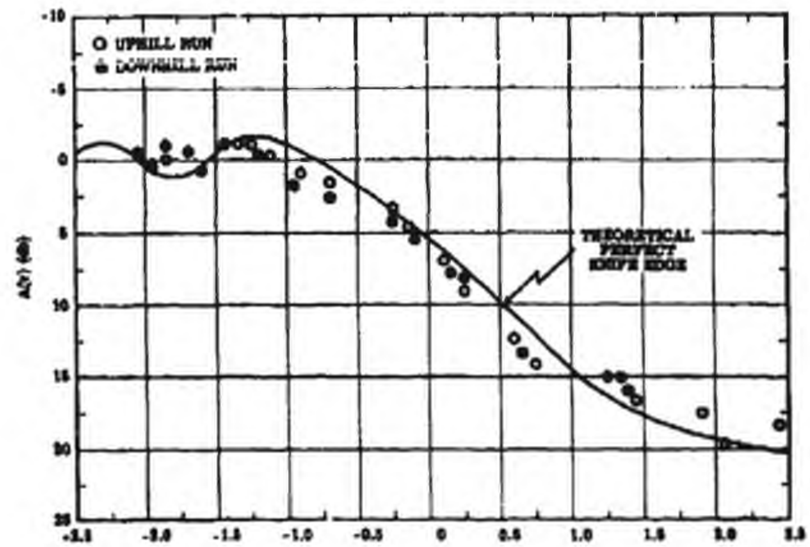


FIGURE 7

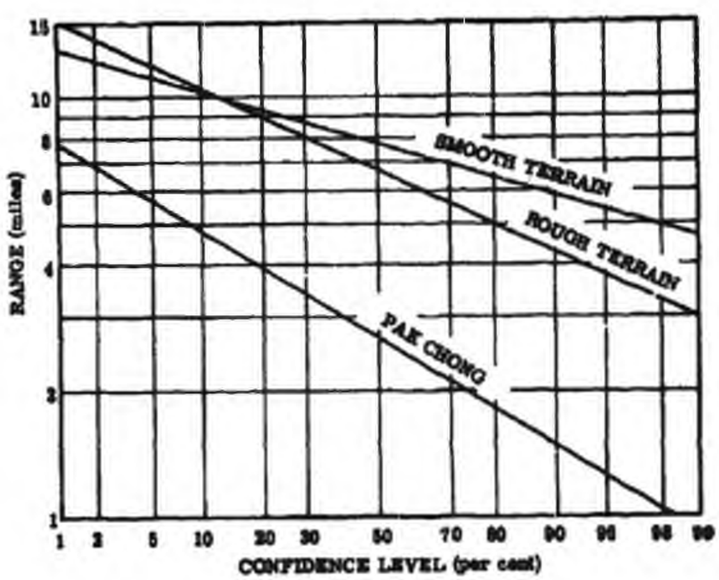


FIGURE 8

Session 4

RESEARCH AND ANALYSIS - I

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APPLIED SOCIAL SCIENCE RESEARCH: PROBLEMS & PROSPECTS

[redacted]
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It can be dangerous to live in a complex society you don't understand. It can be even more dangerous if in addition to lacking understanding you are powerful, because you will probably make more and bigger errors and not learn enough from the consequences. And being powerful you may easily become subject to the delusion that by the use of power you can correct your errors and control their undesirable outcomes.

This delusion is an ancient one, and it is notable for both its persistence and its lack of success. Its bare bones are these. If you are powerful enough among your neighbors you need not understand them, they must understand you; you need not listen, you speak and they listen; you need not adapt, you act and they adapt.

Policies of action based on propositions like these typically yield short run, expensive satisfactions and long run disaster, because the arbitrary use of power, even if the intent is benign, always leads to an accumulation of ill will in the dominated that never fails to find expression; and a thorough experience under domination is excellent schooling for expressing that ill will with effectiveness.

In short, policies that rely primarily upon the uses of power bring about social situations guaranteed to produce highly motivated and appropriately trained enemies.

It has become increasingly evident in recent years that a better understanding of other societies is absolutely necessary, and a great deal of money and effort has been invested in social science studies and research.

I will dismiss without further comment a branch of work that I believe is entirely misguided. I refer to the approach that goes on the assumption that if you have a sufficient social science technique, and if you are willing to control and manipulate information, you can create motives, change attitudes, and alter social realities to suit the occasion. This is merely an undisguised extension of the power philosophy, and it fails just as surely, but this time with an added feature: The machinery of manipulation can seldom be constrained to operate only on "the others"; it soon begins to modify its own "home" environment. And so the spectacle: the manipulators becoming their own prime target, they, themselves, the most accessible and most vulnerable victims.

It is fair to say that relatively few of the attempts to apply social science research to international problems have been rewarding—at least they have not been rewarding to the decision maker who was hoping for some help.

Some of these disappointments are simply the result of bad work. Bad work is bad work, incompetence is incompetence—there is no mystery here. Other disappointments are the consequence of supporting projects with dubious relevance to the problems at hand. I know, of course, that everything is eventually related to everything else, but the connection between some research projects and the client's needs are so remote that one can only suppose ignorance on the one hand and cynicism on the other.

But it is vital to understand the failures that have come out of research that was clearly focused on an important question, research that was well conceived and competently executed.

If you are the client it will sometimes appear to you that, despite long and thorough discussions at the onset, the problem "solved" by the researcher is frequently not the problem you posed originally. You will receive a project report for which you have been waiting only to find that the study was so narrowly defined as to be useless to you, or that the study was primarily concerned with the development of a methodology or a technical language for describing a state of affairs with which you have long felt adequately familiar.

Or you may be a client with a physical science background, who is convinced that you can't expect too much from social scientists, and so you ask only that the researcher collect some simple facts in a reasonable manner. And you may actually believe that if you are supplied with more and more facts—almost of any kind so long as they are face relevant—you will be able to make wiser decisions. It is very likely that you will be strongly disappointed later as you hunt through a shelf full of handbooks.

Or you may be a client at the other extreme who expects far too much from social science, and asks for research that will lead to predictions of complex social behavior, again because of a mistaken analogy between the social and physical sciences.

Whereas in the first instance you asked for too little, you now expect too much. In both cases, disappointment is practically certain.

If on the other hand, you are the researcher you will have a matching set of disappointments and frustrations. You will find that questions for research are put to you in terms that are neither meaningful nor amenable to investigation by the methods of social science. If you are to apply sensibly the research tools available to you, you will have to restate the question. And, very frequently, the more rigorously you state your hypotheses and the more scientifically conservative your work, the more likely it seems that the results will be unusable by your client.

If you are ingenious enough to reduce your client's concerns to a set of testable hypotheses, you may then find that there is no practical way to obtain the data you need. You may find yourself being persuaded to go ahead anyway, using inadequate and contaminated data because it is available.* There is a curious bias that since social science theory is rather untidy, it should be able to do its work just as well with poor data.

Clearly most of these difficulties—on both sides of the fence—stem from misconceptions of what the social sciences are about and what they can do. Well, what are they about, and what can they do? To catalog the areas of interest or the characteristic methods of the different disciplines involved is unnecessary here. They range very widely in area emphasis, the size of the unit studied, and the means employed—from the field study of the anthropologist to the laboratory experiment of the psychologist. But cutting across all of these is a commitment to the discovery of stable patterns of behavior which are a function of general social processes rather than unique situations or individual differences. This orientation is especially clear in the study of large scale social structures—an area of particular interest to us. Let us look briefly at some characteristic approaches in this direction.

There have been attempts to go directly to the discovery of social laws governing regularities of behavior—laws analogous to those that physicists have made so famous with respect to mass, pressure, velocity. The Marxian attempt to create a model of large scale social process with predictions based on the interactions of a few crucial variables is an example. The model does not appear to work, but it was an interesting try.

There have been attempts at what has been called "social physics" based essentially on the study of logistics curves. A large number of social phenomena have been studied from this point of view—long distance phone calls, speed of travel, the size of libraries. The exponential curves describing such diverse phenomena show remarkable regularities—remarkable, at least, at first glance.

Another approach has been the attempt to extrapolate from time series. This differs from what has been called social physics in that it does not try to discover first principles or to create large scale model, but to make a limited prediction about the position or frequency or strength of some phenomenon at some later time. Major examples of this kind of work are found in demography and economic forecasting.

Another attempt does not deal with process or time series, but is based instead on certain structural considerations, often the structure of government, law, custom. The assumption underlying this work is that by taking into consideration the structural certainties within which a society operates a great deal of the human behavior that will occur can be predicted.

*It is hard to resist the appeal to work on current urgent problems. When you do, you must keep in mind that events are likely to change more rapidly than you can work, so that your report, when it is completed, may no longer be of interest to the sponsor. Or there may be relatively little interest right from the very start. You may find yourself at work on a project which is being supported for apparently no other reason than that there is pressure from "above" to have "something" in that area. In such a case don't expect any interest in discussing your progress. But don't let up on the quality of your work because a shoddy final product will only "justify" the neglect.

Still another approach investigates—instead of the open, prescribed rules and structural certainties of the society—the patterned regularities in the behavior that are implicit and often unrealized even by the actors. The scientist tries in this case to infer patterns which are typical in orientations to critical situations such as conflict, and to make conclusions about a national or cultural style.

In all of these lines of work, the specific behavior of a particular individual is of minimal interest and the models developed are not expected to be useful in predicting behaviors and outcomes of unique situations.

In fact, there is, on the part of many social scientists, a conviction that unique events, even when they apparently lead to dramatic, revolutionary changes, are merely transient perturbations of long term developmental sequences.

This does not mean that they minimize or dismiss the significance of the role of leading actors—politicians, generals, or whatever. On the contrary, their view emphasizes the fact that the decisions such men make—quite apart from their momentary effect—will be ultimately beneficial or detrimental depending on their correlation with the impersonal sociological forces that substantially determine long run trends.

For example, studies of the growth of cities show that many aspects of their growth can be understood as a product of impersonal forces of environment and technology. Poorer predictability results if one considers instead the planned, willed changes of groups and individuals whose business it was to make these decisions.

This is essentially the position of many analysts in the forecasting of trends in technological change. They believe that the attempt to predict inventions, fascinating though it may be as an exercise, is usually a waste of time; and that the effect of a particular invention, with rare exceptions, is relatively minor against the swell of the technological trend which goes on independently of unusual and unpredictable individual actions.

This example provokes an objection that must be in your minds, and which bears directly on one of the major concerns of this meeting—the question of relatively short range, tactical, social science research. It may be true that a particular invention--to continue the analogy—will generally have a minor importance in the historical view of technology, but the same invention may also have drastic, short term, local effects.

An industrial firm which faces ruin because of the invention of a new, revolutionary device may take little comfort in the global, philosophical calm of the long view. A firm which fully recognizes the importance of large scale, long time trends in its advance planning, still needs—often desperately—short range information about the likelihood of inventions that would render its product obsolete. It asks for precisely the kind of information that the technology analyst says is unobtainable and in the long run not important.

It is clear that both kinds of information are crucial if you mean to stay in business. But what has not been clear is that the two kinds of information imply different research strategies, methods, and techniques. A lack of appreciation for the difference—by the researcher as well as the client—is a big reason why so many attempts have not been more successful.

To estimate the likelihood that there will be an outbreak of insurgency in a particular nation is a very different problem than estimating the trend of social development in an ecological unit of which the nation in question may be an arbitrary fragment. The two problems are related, but in terms of their intrinsic nature and the current structure of social science, the connection is quite remote.

To take a different example, the process of social communication in bargaining-like situations has been studied intensively by psychologists, but their findings are not likely to be practically helpful to a negotiator on his way to the bargaining table.

A tennis pro with a match to win in the afternoon will not get much help from consulting a ballistics expert—especially one who does not play tennis.

In other words, the body of theory and data in social science, which has accumulated largely as a result of academic research, is seldom capable of practical application in a way that appears helpful to the decision maker.

Am I proposing, then, that the capabilities of social science are irrelevant to the problems at hand? No. I believe that the social scientist has an important contribution to make—if he will and if he is permitted.

I say "if he will," because among competent social scientists it would be more true to say that there was a reluctance to work for the government than to say that there was awareness, interest, and enthusiasm in doing the applied research that's so much needed. It seems to be sometime that where eagerness is found, it _is_ in inverse relation to professional ability and experience.

Some reasons for this reluctance have already been mentioned, but there are others.

There are, of course, questions of political ideology, the ethical question of making available social science knowledge for essentially manipulative use. These, I am sure, are real questions, but as actual reasons for non-participation they are probably less prevalent than one would suppose. They are more likely to be explanations than reasons. In simple frequency, more mundane causes, I am sure, lead the list of inhibitions to participation: such as personal inconvenience, loss of income, career factors, professional status, loss of personal freedom, etc.

The social scientist is the product of an academic society that places a heavy emphasis on a value system of basic research. And there is still enough insecurity in some to make the demand for purity extreme. The still promotable university researcher may incur career penalties by taking extended leaves from his university to do applied work that seldom yields significant scientific outcomes, and which may not yield publications because of security considerations.

(Note that doing work that is not intended from the outset to be scientifically rigorous and which is not open to inspection by peers in the profession is frustrating and annoying to the able but a haven of shelter for the mediocre.)

The same reluctance is as much in evidence among those who have no further promotion and tenure problems.

It is safe to say that considering the very best talent available in the social sciences today, it is seldom that one can employ it for more than relatively short periods—a summer, a semester, perhaps a year. But problems of the kind that we are interested in are much longer range than that. It is, unfortunately, no solution to secure the help of these men on a once or twice a month consulting basis. Such intermittent help can be effective only if it is used by already thoroughly competent full-time personnel. It is a silly idea to think that one can improve the quality of research done by incompetent research teams by buying them occasional advice from experts.

The productive use of "limited service" social scientists would be vastly improved—and their reluctance to become involved reduced—if there existed an effective machinery for executing research once it is specified in detail. (A famous laboratory known for its productivity has as one of its operating principles: hire the best research talent you can find and then give them all the muscle they can use.)

In many instances, the social scientist who is working for a summer or a year on some applied problem, may find that, having succeeded in stating a question not only capable of being answered, but also having a clear practical importance, there is no machinery available to gather field data without hopeless contamination, or without unrealistic demands on his time.

I am convinced that a corps of social science field technicians would go far—perhaps further than any other single change—to make applied social science productive. I would like to explain in a bit more detail my conception of a social science field technician, how he would be trained, what he would do.

I have in mind a person who would normally have an undergraduate degree in one of the social sciences, and an additional graduate degree in applied social science. The advanced work would consist of:

1. Contents and methodology in the social sciences—this would be intended to supplement his knowledge of general problems of method in other social sciences than the one in which he had majored.

2. He would be required to have a working knowledge of data banks, with particular emphasis on those in which data is being gathered in the relevant social sciences such as anthropology, sociology, political science, and social psychology.

3. He would be expected to have technical competence in gathering and analyzing field data, including statistics, survey design, programming for machine analysis, and the construction of interview and questionnaire instruments.

4. He would be expected to have a practical knowledge of field management; that is, the recruiting and training and supervision of data gathering teams; in particular, when these teams are made up of inadequately trained people—for example, volunteer students or housewives.

5. And, he would be expected to have a broad acquaintance with some particular social, cultural, or geographical area.

Except for field management, all the courses implied by this listing are currently being taught at most universities. But they are not taught in the same department or under some unifying title or academic committee.

The fact is that colleges and universities do not normally produce social science technicians. The reasons are:

1. The course listings are found in different schools and departments, and do not come together in an integrated, task-oriented whole.

2. Students who may be employed by social scientists on the faculty to gather data in the field, even when the work is considered as part of the student's training, seldom obtain guidance and training in the art of field application beyond the requirements of the specific study under way.

3. The graduate student himself is strongly oriented toward a career as teacher and researcher and not toward "second-class" career of field technician.

The lack of such technicians not only stands in the way of completing work which is clearly important, it also inhibits the consideration of research efforts which in the absence of the capability do not even occur as possibilities.

How can this need be filled in practical terms? Existing social science departments are very reluctant to undertake the training of field technicians. One will probably have to consider the establishing of a facility to do the job.

There are many practical problems to be faced—such as the underwriting of such an effort financially and academically, where staff would come from, where students would come from, etc. I will not taken the time to explore them here, but in discussion with various academic and governmental persons with experience and judgment no prohibitive problems have been raised.

A facilitating machinery of this kind would allow you to capitalize on what may be the social sciences' biggest potential contribution: methods and techniques for gathering data in such a way that questions can be answered with known degrees of confidence.

I would like to close by suggesting one or two other ways in which the social scientist might be used.

I have often been impressed by the fact that as things stand now the decision maker's most probably helpful source of information is the opinion and judgment of a man of wide practical experience in the situation in question.

Let me stress that I used the phrase helpful source not "accurate or valid source." The difference is important. Being "helpful" to a decision maker does not necessarily imply accurate, valid information. Information which reduces administrative uncertainty may be helpful (for example, by strengthening organizational integrity and allowing the organization to function without excessive internal conflict) without affecting the likelihood that the choices made will be eventually judged to have been correct.

The advice of a man of wide practical experience is so frequently judged helpful because it is shaped not only by the nature of the problem to be met but, also, by an appreciation of the peculiar characteristics of his client, to whom the advice must be useful. In contrast, the research results of a social scientist who has dealt exclusively with the external problem may be irrelevant to any feasible set of actions or, worse, serve only to increase the momentary uncertainty over the available alternatives. The obvious moral for social research is that if practical application is intended, then insight into the internal system of the client is as necessary as the study of the external environment with which the client is trying to cope. It is typical, however, that such internal scrutiny is often considered irrelevant and is almost always unwelcome.

One more point. The administrator frequently states the research question in terms of a solution he would like to have to his problem as he conceives it. It is sometimes possible at the very start to substitute one problem for another which permits more feasible attempts at solution. This is not simply a restatement of the original question but a change of view concerning the nature of the problem to be solved. In problems involving changes in behavior, the social scientist can sometimes be most helpful in suggesting such reformulations. For example, in considering a closed circuit television system for conferences among persons in remote locations, one might ask the question "what network of facilities—among all those which are technically feasible—will tend result in effective and efficient conferences?" Stated in this way one goes on easily to a research program for the evaluation of networks over some set of expected conference activities, with terrible headaches about the generality of lab results to conferees of unique personalities and specific stress situations. But one may take a different tack by proposing "that what is required is any feasible, inoffensive system which is capable of easy modification, and has built into it the kind of process feedback that will allow the men to shape it to their needs." Now we have less of a laboratory research program and more of a social engineering program—and far better chances for practical success.

My time is up. My summary is simple:

1. It is dangerous to be stupid.
2. It is especially dangerous to be powerful as well as stupid.
3. Social science can help.
4. Social science is not being usefully employed.
5. Many social scientists are being conditioned to avoid doing applied research on the subject.
6. It is necessary to produce a corps of applied social science technicians.

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NEW PERSPECTIVES IN TRAINING AND ASSESSMENT OF OVERSEAS PERSONNEL* (U)

(Unclassified)

[redacted] and [redacted]

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ABSTRACT
(Unclassified)

Lack of knowledge of what constitutes successful performance in paramilitary roles abroad is a major barrier to developing valid selection procedures or appropriate training techniques. One approach to the problem is to focus on and attempt to cultivate individual qualities of personnel as elicited in a live simulated advisory situation. Using trained foreign participants in prepared role-playing scripts, a simulated cross-cultural encounter was constructed which provided a realistic face-to-face encounter with a counterpart. In addition, the simulation permitted the conceptualization of a number of interrelated intervening criteria susceptible to measurement and useful to assessing the performance of the trainee. It is concluded that the specific discovery potential and heuristic value of the technique are distinct assets in this new area of research.

Part I. Introduction: Ambiguities of the Overseas Situation

Military operations in counterinsurgency and in psychological warfare tend to blur the traditional role of the soldier. In his paramilitary role, the American soldier comes in frequent contact with peoples whose speech, habits, customs, behavior, and values are vastly different from his own. Success of military operations depends in part, some say overwhelmingly, on the ability of the soldier to win the support and active cooperation of the people. As [redacted] has said, "An individual or a unit may be extremely well-trained for counterinsurgency in terms of tactical and technical proficiency, yet be of little value for want of ability to communicate with the friendly forces we seek to assist, and for want of understanding of the problems and attitudes

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*The research reported in this paper was performed by HumRRO Division No. 7 (Language and Area Training), Alexandria, Va., under Department of the Army contract with The George Washington University. The contents of this paper do not necessarily reflect the official opinion of the Department of the Army.

of the country concerned."*

The problem of laying down valid principles of counterinsurgency is, however, a formidable one. The difficulty may be partly due to the fact that each operation is relatively distinct and has to be understood in its own historical, cultural, and social setting. The nature of an insurgency depends on the specific characteristics of the vested authority and its supporters, and on the environment in which insurgency occurs.

The relative uniqueness of each insurgent movement may be underscored by pointing out that it is a conflict initiated from a position of comparative military weakness, and directed at vulnerable points of the vested authority. Military power is usually counteracted by irregular force and terror and by the exploitation of social, political, and economic discontent. The dimensions of the insurgency depend on the specific nature of the discontent as well as on the vulnerabilities of the vested authority and its supporters.

As an insurgency progresses, and as counterinsurgent measures are taken, the nature of the conflict changes. It is the changing nature of the conflict, the salience of discontent, the specific vulnerabilities of the authority, and the characteristics of the insurgents themselves that render an analysis of principles of counterinsurgency so difficult. Thus far, there is no doctrine which successfully integrates the military factors with the social, cultural, political, and psychological aspects of an insurgency. If this analysis is sound, then the role of the American soldier in counterinsurgency and psychological warfare operations must in turn vary widely depending on the dimensions of the insurgency. It becomes extremely difficult to conduct a careful analysis of the paramilitary role if its requirements cannot be specified.

A similar problem is encountered with AID** personnel, Peace Corps Volunteers, or any other Americans abroad attempting to communicate or understand the problems and attitudes of another people. Whenever members of different cultures work face-to-face, cross-cultural differences are very likely to emerge.

The cross-cultural communicative function of the American engaged in counterinsurgency will therefore be acknowledged by referring to him as an advisor - implying that the key to his success

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*General Rosson's (5) assertion is supported by the conclusions of various military research symposia. The necessity for research on culture-contact problems has been emphasized in a symposium on counterinsurgency sponsored by the Rand Corporation (3), in a symposium on social science research and the Army's limited war mission sponsored by SORO (4), and in several recent conferences (Worldwide Psychological Operations Conference, Ft. McNair, Washington, D.C., 1963, 9; Eleventh Annual Conference on Human Factors Research and Development, Ft. Bragg, North Carolina, 1965, 2).

**U.S. Agency for International Development is perhaps not in the application of military force but in the ability to understand a people and to communicate effectively with them by both word and deed.

Without an analysis of the paramilitary role, the establishment of field evaluations of performance -- in technical language, field criteria of effectiveness -- becomes improbable, and of course, few firm guidelines for the trainer can be proposed. This condition poses one of the most serious problems in conducting research on cross-cultural assignments. Lack of knowledge of what constitutes successful performance abroad has been a major barrier to developing appropriate training techniques, or, indeed, valid selection procedures.

Generally, criteria have been used which, though possessing a kind of face validity, have on further analysis proved to be insufficient and sometimes misleading. Take, for example, superior's or supervisor's ratings. In both military and nonmilitary settings, when ratings are made through the usual administrative channels there is a degree of risk that missions or organizational goals are really being rated, rather than specific individual performances.

This is not surprising in view of the fact that any physical description of the day-to-day behaviors of personnel engaged in paramilitary missions is relatively unrevealing: how many times they meet with their counterpart, what terms they use to address him, how many times they go out into the field, the number of civic action projects initiated. Each of these activities may be indicative of something significant between an American and the indigenous persons with whom he works, but unless they are meaningfully integrated into a pattern of behavior which can logically or empirically be shown to contribute to a successful mission, they remain isolated fragments -- mere tantalizing tidbits of behavior.

Without a set of categories describing critical aspects of the advisor's role -- in short, without an overseas job analysis -- no superior or supervisor can be expected to make an accurate rating of his personnel abroad on the specific criteria or effectiveness. Unfortunately, no such integrative taxonomy of roles or role behavior for overseas work is currently in existence and none apparently is on the horizon.

Another approach to developing criteria of overseas effectiveness is to differentiate the effective from the ineffective behaviors as reported by the individual retrospectively. Here, longitudinal evaluation of an individual's performance is not an issue. Rather, concrete "critical incidents" judged by the individual himself to have made a difference in the success or failure on his mission are catalogued. Incidents that are repeatedly reported are then fed back into the training process and made available to selection boards as examples of overseas behaviors relevant to performance.

The trouble with such a critical incident technique lies in the nature of many cultural confrontations and nonmilitary ambiguities of an overseas assignment. Both the cross-cultural factor and the paramilitary component of the counterinsurgent mission may strip of its significance the critical incident as reported by an advisor. It may not be at all certain what incidents are critical to success of a mission. The outward manifestation of a misunderstanding, as reported by an advisor or technical assistant, may in reality hide dissonant cultural strains of which neither advisor nor counterpart may be fully aware. Cross-cultural conflicts often involve basic cultural premises and habits of thought that are difficult to perceive. It is probably significant that in one area orientation program comprised of experienced AID overseas technical assistants, a vast majority of failures (critical incidents of ineffective behavior) reported by the participants contained <u>no elements peculiar to the overseas situation</u>! (1) In view of the known role of subculturally derived values in miscommunications between employers-employees, management-labor, and so forth, in our culture, such omission of culture conflicts faced overseas is remarkable indeed.

An excessive reliance on unimaginative and unproductive field criteria seems shortsighted when simulated criteria might allow for a more systematic body of knowledge to develop with regard to job effectiveness. [redacted] (8), in a recent article in the <u>American Psychologist</u>, observes that a criterion might be relevant not only to the specific task but also to <u>ideas and concepts</u> which would allow reliable prediction of effectiveness to a <u>variety</u> of job situations. In other words, criteria should be chosen with theoretical constructs in mind, which may lead to the discovery of regularities of performance among successful practitioners cutting across a number of jobs and assignments.

Wallace's statement seems especially appropriate in the area of cross-cultural training and selection. Without knowledge of the situational variables governing various job positions abroad, it is impossible to develop a set of <u>specific</u> prescriptions which can be ubiquitously applied. Before attempting to predict what an advisor must do in any particular instance overseas, some of the impediments to crossing a cultural barrier must be understood. By using theoretically relevant higher-order variables as the input into some participant training exercises (hereafter referred to as role-playing or simulation exercises), we have begun to analyze and study some of the hazards (and perhaps rewards) of such communication.

In the course of our work, we have developed a number of instruments designed to assess the training impact of the simulated exercises. These instruments are all in the spirit of Wallace's recommendations. Rather than relying on a description of the ultimate job requirements abroad, these assessment tools refer to and test for characteristics of individuals (so-called intervening variables) which are hypothesized to be related in complex ways to eventual overseas success. In effect, we have tried to get inside the "black box" of overseas effectiveness, the American on a paramilitary mission, to analyze some of the components, and test for training response according to criteria generated by the analysis.

Part II. New Perspectives in Training and Assessment

If we stop looking at a counterinsurgency as a mission and instead focus upon the individual counterinsurgents, the task of analysis becomes somewhat easier. The training of Americans for paramilitary missions overseas and the evaluation of their performance may then be approached at four levels: technical competence, area knowledge, language skills, and interpersonal communicative skills. Of these four levels, the one which has received the least attention (but was noted by General Rosson) is the last: Interpersonal communicative skills. Perhaps this is due to the fact that it is inextricably combined with other skills and competencies, so that its effects are difficult to isolate. Certainly the way cultural factors affect interpersonal orientations are not at all obvious. Differences in basic cultural premises, how one evaluates himself or the world, how one makes decisions, and so forth, intrude upon everyday behavior, yet do so in such subtle ways that they tend to escape awareness. The study of the influence of culture at the interpersonal level has consequently been relatively neglected by both social scientists and overseas practitioners.

Assuming, as is widely acknowledged and recognized, a need for the development of communication and interaction skills among overseas personnel, what strategies or principles of training can be brought to bear on the problem? Most trainers agree that knowledge which is not seen as immediately relevant to one's job tends to remain unintegrated and cannot be properly "used" by the trainee. Thus, a conference with a body of trainees about the American predisposition toward achievement orientation may have little impact on the way tasks are accomplished overseas because the personal relevance of such knowledge for the individual trainee has not been demonstrated.

A new but encouraging alternative to lecturing in cross-cultural training is a simulated approach which we have developed. Simulation is a promising instructional technique since it directly engages the trainee in the communicative process, and provides for either active participation or direct observation by students in a class. It is a realistic procedure allowing the student to learn about cultural differences in a live cross-cultural experience. These qualities of simulation are important in training since cultural characteristics are deeply rooted determinants of behavior, requiring the application of much training effort and ingenuity to be affected.

In the remainder of this paper, we will review how the simulation was conceived and implemented, the kinds of training input involved, and the level of presentation of such content. Following a brief introduction to our use of the technique, the manner in which our strategy has led to the development of intermediate criteria of training or assessment will be documented in some detail. In the case of those criteria which have been "operationalized" and for which instrumentation has been developed, specific illustrations will be provided.

Introduction to Simulation

The simulation of cross-cultural differences crystallized into three requirements: (1) the development of plausible situations that were critical for presenting cross-cultural differences; (2) representation of American behavior; and (3) representation of counterpart behavior.

Situations were developed from interviews with advisors overseas. They were chosen because they were plausible -- in terms of frequency of occurrence abroad -- and because they raised significant cross-cultural problems. The situations are used as role-playing scenes. They have been carefully constructed to evoke culturally derived behavior from a trainee playing the part of an American advisor. Often, considerable rewriting of scenes has been necessary to elicit predictable, significant behavior from the American. Throughout the simulation, stress has been laid on factors which can illuminate American culture as well as foreign cultures.

The trainee playing the part of an American advisor, a Captain Smith, confronts a counterpart in the role-playing situation. The behavior of the counterpart represents the heart of the simulation. In this part a double objective is attained: representing the cultural behavior of the counterpart and also drawing attention to the cultural behavior of the American. This strategy reflects the assumption that effective functioning in a foreign culture is based in part on an understanding of one's own culture. (The understanding need not be articulate. If an individual can adapt to a foreign culture, or to variations within his own culture, and if his behavior is intelligible, then he has a "latent" understanding of the culture.) The desired objectives were attained by means of the concept of the contrast-American, which was arrived at in three steps:

(1) Those aspects of American culture that seemed to be important for overseas performance of advisors were described as assumptions and values. Although these factors were conceived very abstractly in many instances, they were always defined to refer to the individual and hence presumably governed the behavior of the American. They were also conceived to represent an average value or assumption, in recognition of the fact that Americans vary considerably in what they believe and how they behave.

(2) The second step in developing the concept of the contrast-American was to derive a set of assumptions and values that afforded the greatest contrast with American culture.

(3) Finally, specific behaviors were derived from the contrast-American assumptions and values.

The concept of the contrast-American is a composite representing the greatest contrast possible in a counterpart who still seems plausible to American advisors. He does not represent any one nationality or culture. In the simulation exercises, the purpose of the contrast-American is to clarify for the student his American predispositions, thereby demonstrating their strengths and weaknesses, while giving him realistic experience in advising a foreign counterpart.

Our training exercise, then, consists of (1) role-playing auxiliaries who, by selection and training, emit behavior which is a mirror image of American behavior, and (2) a number of situations or scenes which, through testing, we have found to elicit from American trainees behavior which is typically American, and which quite often causes misunderstandings with counterparts overseas.

The counterpart in the role-playing exercise is aware of the implications of what he is doing, that is, he is purposefully playing out his part. The American trainee, however, is spontaneously playing a role, and, of course, he believes the contrast-American to be doing the same. It should be emphasized that the confrontation involving the two men is between their cultural assumptions and values, and not between their objectives or missions.

Development of Training Criteria

As previously suggested, two major assumptions of the current approach to simulation training are that (1) a significant barrier to successful overseas performance is the unrecognized cultural biases which Americans (or any other people) typically display and (2) induced cultural self-awareness contributes to the ability to understand and cope more effectively with foreign cultures. Thus our training criteria involve the dimension of awareness of American culture as well as awareness of "foreign" (i.e., contrast) culture -- in other words, cultural "self"-awareness vs. cultural "other"-awareness.

The complex nature of the phenomenon of cultural awareness has necessitated the use of three analytic categories which psychologists have found helpful in understanding mental processes: cognitive, conative, and affective (or, if you will, perceptual, motivational, and emotional). Cognitive refers to the perceptual process of organizing or structuring the input received by one's senses; affective, to the emotional component tied to such percepts; and conative, to the accompanying set or predisposition for behavior. No matter how behavior is sliced, these three ingredients will be found present. Correspondingly, we can assume that each category will in turn bear the mark of a cultural imprint. The three categories, when applied to one's responses to both American culture and contrast-American culture, yield the basic framework from which our criteria have been derived.

Both cognitive awareness of oneself as a product of American culture and awareness of one's (role-playing) counterpart as a product of contrast-American culture can be expected to affect one's ultimate advisory behavior in the simulation situation. This is the level of how one organizes the input received by one's senses. Paper-and-pencil tasks of predicting the most appropriate concrete responses of an American in the advisory situation and of the most typical contrast-American responses -- more behaviorally-relevant measurements -- should be even more closely related to the actual simulated performance of the advisor. Thes measures would correspond to the conative or, loosely speaking, "set for behavior" category. The third contributor to the trainee's behavior would be his affective responses to American culture and to contrast-American culture, that is, his emotional reaction to culturally laden stimulus statements, either American or contrast-American.

Note that the awareness of American and the awareness of contrast-American -- as well as prediction of behavioral responses of each -- are seen as related and mutually reinforcing. The logic of the simulation is such that a knowledge, not necessarily explicit, of both American and contrast-American culture is required for successful behavioral execution. More specifically, the trainee is required to forge bridges between his cultural position and that of his counterpart, gradually evolving a mutually compatible position.*

What instrumentation can be generated to accommodate such a conception of interim training criteria? A general multiple-choice test of idealized non-western (i.e., contrast-American) values and assumptions has been designed to tap cultural awareness among Americans at the cognitive-attitudinal level. An example of one of the questions is:

A (foreign) counterpart probably reacts best to advice

(a) which stresses facts and figures about concrete issues.

(b) which is well embedded in a discussion.

(c) which is carefully offered in terms of "opinion" rather than "fact."

(d) which clearly indicates the direction in which he is to move.

The trainee is instructed to assume that the counterpart is a hypothetical non-western person and to select an answer which is most clearly non-American. The correct answer, which is (b), is the

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*Useem, Useem and Donoghue (7) have referred to a mutually compatible position between two cultures as a "third culture." Quoting these authors, "The binational third culture is defined as the complex of patterns learned and shared by communities of men stemming from both a Western and a non-Western society who regularly interact as they relate their societies, or sections thereof, in the physical setting of a non-Western society...the third culture cannot be fully understood without reference to the societies it relates and in which the participants learned how to act as human beings..." [underlining has been added].

one considered to contrast maximally with the assumptions and values derived from an analysis of American culture. The opposite to an American's direct explicit impersonal approach to work issues is an indirect, discursive personalizing approach in which work commitments are indistinguishable from social commitments.

The other alternatives represent varying degrees of American cultural commitments. Response (a), for example, taps emphasis on concrete operational definitions of phenomena ("statistics") which not infrequently become confused with the phenomena themselves. The notion even permeates social science research where indices such as I.Q., for example, come to be accepted as the underlying abstractions themselves -- intelligence is what intelligence tests measure. Response (c), on the other hand, highlights the notion of implementation, which, normatively speaking, is so crucial to Americans whose self-images are tied to progress and accomplishment.

A second instrument* is a more behaviorally directed test of cultural awareness consisting of predicting a contrast-American's reactions in the context of an ongoing interaction. This test is actually a running narrative of a live cross-cultural encounter, appropriately broken at intervals where the "foreigner" gives a critical contrast-American response. The trainee is instructed to select the actual response the foreigner has made from a choice of four provided. The instrument may be described as a multiple-choice test embedded in a real-life case-study format. An example is:

> Foreign counterpart: Well, you see our training comes from the instructors. The instructors know everything.
>
> American: If the people have any questions while they're being trained, (do) they ask the instructor?
>
> Foreign counterpart:
>
> Alternative a: No, the foremen ask the questions. When the people are giving them good answers, they know it's time to give more instruction.
>
> Alternative b: We take care to select our people properly. We see to it that what they have done before makes them already familiar with the kind of work we are training them to do.
>
> Alternative c: You see, we have only a limited time to give them instruction...with these conditions it is more important to dispense information than to answer questions.
>
> Alternative d: I don't think they would have any questions because the Instructors tell them all they need to know. The instructors give them all the training they need. Why should there be any questions?

Alternative d is the correct response here, contrasting more fully with the American idea of student-centered education as embodied, for example, in Dewey's theories of education. Encouraging active student participation and possible student criticism, at the expense of blurring the status

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*Developed b [redacted]

differences between student and teacher, is not countenanced in the traditional non-western world. Alternative a suggests a measured instruction proportionate to rate of absorption of the students, and alternative b, a selection process reflecting training accomplishment. Both are within the American band of the spectrum of cultural assumptions and values. Alternative c acknowledges the precedence of information-imparting to question-asking but cites an American criterion of time-limitation ("time is money") as a justification.

A third instrument measures affective response to both American and contrast-American assumptions and values which are covertly presented as stimuli in a behavioral differential (analogous to semantic differential) format. The test measures connotative meaning of hidden cultural assumptions by requiring the trainee to declare the extent to which he is willing to personally involve himself in a variety of behavioral situations with a person who holds such a stated p- .tion. Examples of such behavioral situations are "would or would not invite this person to my club," "would or would not be partners with this person in an athletic game," "would or would not be on a first-name basis with this person."

An example of a stimulus with an underlying American assumption would be "A person who holds that the lessons of life are best learned from contacts with people of one's own age group." The statement betrays, of course, the American value of peer relations as a socializing influence and egalitarianism as a way of life. A stimulus involving a contrast-American assumption would be "A person who holds that to judge an issue by popular vote is to sacrifice the opportunity to determine right from wrong." This statement taps the non-western assumption that truth, like wisdom, resides in specified roles and isn't likely to emerge from any consensus, and further that it is an absolute truth as distinct from the relative working-type truth from which the American typically operates.

Other instruments measuring cognitive awareness of American values and predicting the specific most appropriate behavioral responses of Americans in the simulation are currently under development and will serve to round out the paper-and-pencil instrumentation.

All such paper-and-pencil measures are now treated as antecedent conditions or as partial criteria which are related in complex ways to the trainee's actual performance in the simulation. Obviously a simulated behavioral test situation is needed. The requirements of such a situation are two-fold:

(1) The task situation must be a valid indicator of what is being trained, that is, the criteria for assessment should be qualitatively similar to the criteria for training input.

(2) The task situation must lend itself to operational definition and reliable measurement.

These two requirements may be well satisfied by a concrete task which presents a problem apparently easily resolvable by "splitting the difference." As previously noted, splitting the difference or operating from a relative working-type truth is a typical American predisposition. Our theoretical position dictates a counter position for the contrast-American where truth is felt to be enduring, absolute, and not to be demeaned by negotiation or compromise.

This theoretical statement of an hypothetical non-western position has recently received striking empirical confirmation in the work of [redacted] involving Greek nationals in negotiation situations. (6) These investigators found that the Greek conception of a final product in a negotiation situation would leave *half* the Greek and *half* the American points intact. Each "truth" was accepted as non-negotiable but if each side *reduced* the number of its "truthful demands," a compromise would become possible. Such an exchange was highly preferred over a final product that would be "in between" two positions.

The above task is but one example of how cultural values and assumptions can be built into an assessment situation in a way that admits of measurement and replication. To the extent that the American trainee can distinguish the different cultural approaches to "truth and compromise" between himself and his counterpart and behaviorally accommodate the difference in evolving a compatible operating position, he is judged successful.

Under such well-defined conditions, the development of a compatible position is relatively easy to assess; the trainee must redefine the compromising act to *exclude* the use of a working-type truth and to *avoid* an approach praising the merits of consensus. Note carefully that neither of these two conditions and nothing generally in the redefinition of the compromising act need represent an abdication of either the trainee's personal values or of his stated advisory mission. On the contrary, by making the trainee aware of possible alternative cultural positions, he should become *more* aware of his own cultural commitments and *increase* his flexibility in the kinds of approaches he can make or avenues of discussion he can confidently explore (and exploit) in his direct personal interactions with his counterpart.

To recapitulate: One of the most serious problems in evaluating cross-cultural operations is the lack of a convincing criterion of effectiveness for such work. This paper has defined a complex of interrelated intervening criteria, both paper-and-pencil and behavioral, all of which have been generated from a simulated approach to cross-cultural communication and training. The cognitive conceptualization of the training input has borne out Wallace's contention that knowledge is advanced in complex areas of prediction when field criteria are temporarily abandoned and simulated criteria, relevant to some conceptualization of the task, are entertained. The specific discovery potential and heuristic value of the technique of simulation are clearly an asset in such a rich but largely untouched area of research.

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RESEARCH IN TRAINING FOR ADVISORY ROLES IN OTHER CULTURES (U)
(Unclassified)

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ABSTRACT
(Unclassified)

Participation by the military in counterinsurgency (COIN) and pre-COIN missions requires a new emphasis in preparing the soldier and airman. Success in COIN depends upon the ability of the American to interact effectively with people in other societies. The cross-cultural training required differs markedly from the traditional stress on hardware. Many training missions abroad are short in duration and depend upon close, intensive interaction between the American advisor and his counterpart. These requirements make it necessary for the American to establish rapport quickly and to communicate effectively with his counterpart. Job and language skill is not enough; the American must also be skilled in the other person's customs, habits, taboos, mannerisms, and gestures. Traditional preparation, via lectures or "area studies" are inadequate - knowing what to do is not the same as doing what you know.

Described in this report is a program of research involving (a) field participation by social scientists on Mobile Training Team missions; (b) development and testing of a survey methodology to collect cultural data; (c) experimentation with a new training technique; and (d) planned experimental field training programs.

The training technique under investigation involves self-confrontation in which a person views a complete visual and aural record of his performance in a role-playing situation, via video-tape recordings. The technique has been shown to provide rapid acquisition and high retention of specified cross-cultural interaction skills.

1. INTRODUCTION

There are two facts which need emphasizing about today's military operations in brushfire war and counterinsurgency. First, there are marked changes in the traditional role of the soldier and the airman. No longer is he sweeping enmasse over clearly delinizted battlelines. Instead he is in close, daily contact with native peoples. These persons are often his counterparts and do the actual fighting, leaving the military man in an advisory or guiding role. What these native people do and think is vitally important; thus the modification of attitudes and motivations of the native personnel is as crucial as the proper employment of weapons or the execution of battlefield tactics. Second, this new, quasi-political role of the military man indicates a wholly new approach to his training. In addition to his technical specialty he should have a firm ideological base, an expert knowledge of insurgency, and an equal understanding of the culture, goals, and aspirations of the people with whom he is working. This paper deals with the last of the issues above; training for cross-cultural contact and interaction skills. In particular, culture-contact research will be placed in the context of USAF participation in counterinsurgency (COIN) and pre-COIN operations. The research problems and approaches described herein, however, are sufficiently generalizable to be of interest to any agency responsible for training Americans for overseas assignments.

This presentation is in three parts: First, a statement of the need for research in cross-cultural training and improvement of training programs; second, a description of the total research effort in the area by the Aerospace Medical Research Laboratories, and finally a report of our laboratory experimentation on a new training technique.

In the past, the U. S. military overseas contacted the local population only in sharply limited ways, the foreign persons were either refugees, an occupied people, or allies. In any event, the American military tended to live quite apart from the local inhabitants, isolated by the PX, the commissary, the language barrier, and by cultural differences. The American was self-sufficient, his supplies coming either from the U. S. or indirectly from the local residents. Our GI could concentrate on his hardware and the business at hand of fighting a war across well-drawn battle lines.

His modern role is markedly different. He is expected to work directly and individually with a native counterpart, who may be somewhat opposed to his presence (although the American was requested to be there by the native's government). The American's counterpart may be equivalent to him in prestige and rank in the local military structure, which means the American cannot enjoy the status of occupier or badly needed ally. Further, the American finds that, although trained to "do", he is expected to teach and advise, a switch in his roles which can prove frustrating. This new role strongly underlines the importance of solidly based and effective interpersonal relationships between the American and his counterpart. (Reference 6).

2. NATURE OF THE PROBLEM

Various government agencies and research organizations were visited and were asked what problems they have in preparing Americans for contact and work with native personnel overseas. Each agency was asked for information regarding the goals of their culture-training program, the kinds of things taught, the methods used, and the problems faced by the training groups in achieving their aims. Two general findings came out of the survey. First, there is a definite requirement for rapid and effective training in cross-cultural skills. "Ugly American" incidents continue to damage American prestige and the U. S. image abroad. The standard programs of intelligence briefings, remote area orientations and lectures on customs and habits are inadequate. In short, knowing what to do is not equivalent to doing what you know. Giving a man a lecture on do's and don'ts in a foreign country is equivalent to giving him a lecture on how to fly a B-52; in each case he might easily get a passing grade on a written test, but his actual performance would be unacceptable.

Language barriers are not the only problem; lack of cross-cultural knowledge is a critical factor. One study showed that American officers trained intensively for a year in the Turkish language made a poorer adjustment than those who went directly to their Turkish overseas assignment. (Reference 1) The supposition was that the Turks expected the Americans to be as conversant with Turkish customs as they were with the Turkish language. The disparity between language and cross-cultural skills got the Americans into trouble.

The second general finding is that the American does not recognize his need for cross-cultural interaction skills. He feels competent at instructing and socializing here in the U. S.; consequently he sees no reason why he should not be equally successful with his indigenous counterparts. By the time he learns through bitter experience, his tour of duty is usually finished.

Edward Hall, a noted anthropologist, states: "We have to learn to take foreign cultures seriously. The British are ahead of us on this, and the Russians so far ahead that it isn't even funny. We, in the United States, are in the Stone Age of human relations in the overseas field." (Reference 2) The American's failure lies in his propensity to culture-shock and in the meager repertoire of interaction skills. Most Americans sent on overseas assignments experience culture-shock to some degree and all the government agencies visited reported this phenomenon high on their list of training and orientation problems. "Culture-shock" as a term was popularized by Dr. Kalervo Oberg, (Reference 3) an anthropologist with the State Department, who describes the phenomenon in this manner:

> Culture shock is precipitated by the anxiety that results from losing all our familiar signs and symbols of social intercourse. These signs or cues include the thousand and one ways in which we orient ourselves to the situations of daily life: when to shake hands and what to say when we meet people, when and how to give tips, how to give orders to servants, how to make purchases, when to accept and when to refuse invitations, when to take statements seriously and when not. Now these cues which may be words, gestures, facial expressions, customs, or norms are acquired by all of us in the course of growing up and are as much a part of our culture as the language we speak or the beliefs we accept. All of us depend for our peace of mind and our efficiency on hundreds of these cues, most of which we are not consciously aware. Now when an individual enters a strange culture, all or most of these familiar cues are removed. He or she is like a fish out of water. No matter how broad-minded or full of good will he may be, a series of props have been knocked out from under him. This is followed by a feeling of frustration and anxiety. People react to the frustration in much the same way. First they reject the environment which causes the discomfort: "the ways of the host country are bad because they make us feel bad." When Americans or other foreigners in a strange land get together to grouse about the host country and its people you can be sure they are suffering from culture shock. Another phase of culture shock is regression. The home environment suddenly assumes a tremendous importance. To an American everything American becomes irrationally glorified. All the difficulties and problems are forgotten and only the good things back home are remembered. It usually takes a trip home to bring one back to reality. (Reference 4)

A clear picture of a pressing requirement for applied research emerged from the literature survey, visits to operational commands, and to other government agencies. The need for new and better methods of cross-cultural training is broad in scope and applies to every organization, government or private, which send American advisors abroad. This discussion, however, narrows the concern to the needs of the Air Force in general and to the training requirements of the USAF Air Commandos and area survey teams in particular. In brief, these are the lessons learned from the study: The most important and immediate problem is that Americans are inadequately prepared for contact and work with people in other cultures. USAF personnel have received little or no background in the language, customs, traditions, attitudes, and behaviors of persons in the countries they enter. The typical Air Force officer or airman is nauseated by foods commonplace in the Near East. He is offended by the rank body odor of his native counterparts and is repelled by differences in toilet behavior. He becomes irritated and distracted by oriental fatalism and lack of punctuality. Communication failures, bureaucratic ineptitude and elaborate concern with face-saving frustrate the American advisor all the more. He is consequently unprepared for interpersonal relations with people other than fellow Americans.

Another problem is preparing USAF personnel for a training role in other societies; especially in COIN and pre-COIN operations. The essence of USAF participation in COIN is that we not do the fighting directly. Our main role is to guide, train, advise and instruct. In the past, the USAF relied on skill proficiency and high motivation to assist the airman in his teaching role (primarily in giving on-the-job training to fellow airmen); these qualities are not enough to overcome the cultural barriers present in most COIN situations. The situation is worsened by the failure of instructional techniques to work effectively in the foreign setting. An informal briefing style enjoyed by trainees in the U.S. can be both threatening and insulting in the Middle East.

The third problem is that American AIR Force personnel come into direct, personal contact with the local military personnel they are advising. In many cases they work, eat, socialize, and risk their lives with these counterparts. This relationship places critical importance upon the rapid establishment of rapport, the maintenance of mutual respect and the effective exchange of ideas. Hall (reference 5) argues eloquently for training in cross-cultural communication: ". . . formal training in the language, history, government and customs of another nation is only the first step in a comprehensive program. Of equal importance is an introduction to the nonverbal language which exists in every country of the world and among the various groups within each country. Most Americans are only dimly aware of this silent language even though they use it every day. They are not conscious of the elaborate patterning of behavior which prescribes our handling of time, our spatial relationships, our attitudes toward work, play, and learning. In addition to what we say with our verbal language, we are constantly communicating our real feelings in our silent language - the language of behavior. Sometimes this is correctly interpreted by other nationalities, but more often, it is not."

In brief; the special character of training requirements for culture contact and interaction skills poses a problem of critical import for the United States military. The cultural training required differs significantly from the usual technical training now provided. COIN operations require training concepts and training research to develop these concepts which have been unavailable in the Air Force. The traditional emphasis on hardware is inappropriate for this new form of warfare as is the traditional emphasis on propaganda and psychological warfare.

3. RESEARCH APPROACHES

A program of research and development in cross-cultural training has been established at the Behavioral Sciences Laboratory, a division of the Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base. This program attacks the problem of cross-culture contact on a number of fronts. This is necessary because of the multifaceted and complex nature of the subject.

Briefly, the research effort is in four segments. First, the identification in the field of critical incidents and observation and analysis of interactions between Americans and native persons. Second, the development, testing, and evaluation of means of obtaining cultural information, and of sources of pertinent data on other cultures. Third, development in the experimental laboratory of new, improved training methods - vehicles for imparting the appropriate cultural information and skills. Fourth, experimental training and evaluation programs, employing Air Commandos in actual operational contexts.

Any training program for cross-cultural interaction can be thought of as consisting of two interrelated parts; the substantive content, or informational material, and the method or technique used to convey the material.

A crucial and complex problem is the identification of the behaviors and skills most necessary for interaction within a given culture. Researchers from our Behavioral Sciences Laboratory have and are now participating in Mobile Training Team missions, to carefully record the types and frequencies of contacts, both on and off the job, between the American advisors and their local counterparts. Of special interest is the recording of "critical incidents", occurrences between Americans and native persons which have a distinct effect - either positive or negative - upon the desired rapport and mutual trust between the two peoples. This empirically gathered field data is being analysed and from these analysis will ultimately come an organization of the currently chaotic and anecdotal culture-contact information into a meaningful framework.

Two methods employing secondary sources for the acquisition of information on other cultures are being researched. The first of these involves the development of survey instruments such as questionnaires and interview schedules, for use with foreign citizens and with servicemen returned from the foreign countries of interest; and content analytic systems for the searching of written materials. Information gathered in this manner will be brought together in the form of a "cultural atlas," the substance of which could form the basis for the content of training programs.

The second method currently being evaluated involves obtaining relevant cultural information through the resources of the area study institutes, such as the South East Asian study centers at various universities. This mode of attack relies upon the professional community of anthropologists and scholars of foreign societies to a large extent.

One of the main questions that the first mentioned of the two studies will answer, when completed, is whether meaningful information of a cross-cultural nature, suitable for inclusion in training programs, can be obtained using essentially untrained laymen (military personnel); or whether this data is of such a complex and equivocal nature that only well-trained experts with years of study of and participation in a specific culture are able to obtain and interpret it.

Development of a new technique for training cross-cultural interaction skills has been underway for some time. This technique, involving the phenomenon of self-confrontation, will be discussed in a moment.

In the near future an experimental training program will be conducted, employing Air Commandos home in the United States between foreign assignments. Designed to augment and to fit in with other pre-deployment training, the experimental program will make use of the information and techniques described elsewhere in this report. It will take the research in cross-cultural training out of the laboratory and put it in an applied operational situation. A group of Air Commandos whose next overseas destination is known will serve as experimental trainee subjects. It is then planned to accompany the trainees into the field and compare their adjustments in the foreign culture and performances as advisors with that of Commandos who have not received the special training. From this evaluation will come an identification of remaining problem areas and information necessary for modification of the experimental training regimen into an efficient operational program.

4. RESEARCH IN SELF-CONFRONTATION

Research on new training techniques, to complement traditional methods of lectures and manual reading, has centered on the phenomenon of self-confrontation. Self-confrontation is a term describing the presentation to a person, via videotape recording, of a complete visual and aural record of his performance on a given situation. Used in conjunction with role-playing, self-confrontation provides a dramatic and effective mode for the training of appropriate cross-cultural interaction skills.

A typical training session procedes as follows: The subject (trainee) is given a straightforward explanation, demonstration or illustration about a given culture or aspect of the culture, desired general behavior of an American in a particular situation, and specific behavioral requirements for the situation. He is then required to play the role of an American advisor in the foreign country, beset with the problem stated in a given set of instructions, and in so doing to fulfill as many of the behavioral requirements as possible. The trainee plays out the role, interacting with a person or persons preferrably from the other culture but where not available ostensibly from the other culture - actually confederates of the trainer. The trainee has no script and must therefore extemporize his conversations. All of the trainee's actions are recorded on videotape. Immediately at the termination of the role-play, the trainee sits down in front of a T. V. monitor and views the tape of his performance, simultaneously receiving verbal critique of his performance from the trainer. Satisfactory and inadequate aspects of the performance are pointed out, the tape being stopped and rerun where appropriate for emphasis.

Following this self-confrontation treatment, which lasts on the order of twenty minutes, the trainee returns to the role-play, where he performs a second time. This procedure, alternating role-playing with videotape feedback and expert criticism, can be repeated until a criterion level of performance is attained. Selection of a representative sample of role plays, encompassing a range of likely interpersonal situations one would run into as an advisor in another country, provides training of a participatory, real life kind that will enable a trainee to experience in advance the "foreign environment." Mistakes committed will be corrected and eliminated, rather than the mistake being commitied in an actual foreign culture and causing a negative "critical incident."

An initial experiment with the self-confrontation phenomenon demonstrated that subjects, trained in the manner just described, improved significantly in their performance after a 20 minute intertrail self-confrontation session. Quantitative data on the adequacy of the subjects' performances was obtained by having judges view the tapes and rate the presence or absence of some 34 distinct, identifiable behaviors. (Reference 7).

This result was encouraging, and so a more elaborate experiment was then designed. This experiment used a role-play in which the subject, playing the role of a USAF captain, advisor in country "X", was required to report in to his counterpart (a Country "X" Colonel) reprimand him for one aspect of his behavior, commend him for another aspect, and report out. This interaction was to take place in a highly proscribed and ritualistic way, appropriate to the culture, with 57 different behaviors being required of the subject. These involved everything from gross motor movements to such subtle behaviors as tone of voice and direction of gaze. Before participating in the role play, subjects were given a 5 page "cultural description" of Country "X" to read. This description was in three versions, one loaded with favorable statements about the culture, one with negative statements, and a third with mixed positive and negative attitudes toward the culture of Country "X." The hypothesis under test was that the more favorable the attitude, the quicker the learning of the requisite interaction skills. (Reference 8).

One group of subjects received 3 role play trials, with a 20 minute self-confrontation session in between trials 1 and 2 and again between trials 2 and 3. Another group did not receive the self-confrontation feedback training, but instead received an equivalent time of other training - intensive study of the behavioral requirements of the role-play as set forth in the "training manual." The question being asked here was: Does self-confrontation training result in better performance of interaction skills than the traditional manual-reading methods? Finally, subjects returned to the experimental setting either 1 day, 1 week, or 2 weeks following their initial training session. At this time, without being allowed review of any kind, the subjects were asked to go through the role-play again, from memory. This provided a test of the retention over time of interaction skills learned through self-confrontation.

The results of the experiment were very informative: Three trained judges viewed the videotape record of each subject-trial and independently rated the presence or absence and quality of each of the 57 required behaviors, on a 0-5 point scale. Spearman rank order correlation coefficients were obtained to access the degree of agreement or reliability among the judges. For the three possible judge pairings, the r's were .89, .89, and .94. This high level of agreement confirms the validity of the judging procedure as a data-generating device.

The self-confrontation group attained a performance level on the final acquisition trial that was significantly higher than the level of the manual-reading group. The latter group started at a higher level, due to their extra 40 minutes training time; but the self-confrontation group surpassed them on the second trial, and far exceeded the manual group on the third trial. (See Figure 1).

The positive attitude subjects improved in their performance over trials at a more rapid rate than either the neutral or negative attitude subjects, and reached a final performance level that was higher than the other two groups. Terminal performance levels for the positive, neutral, and negative attitude groups were 204, 192, and 179 respectively. (See Figure 2).

Subjects returning cold to the role play after a lapse of as much as two weeks performed fully 94% as well as on the terminal acquisition trial of their original training. The one-day retention group actually performed slightly better than on trial 3 of the previous day, indicating that the retention trial acted as a fourth learning trial. The two-week group retained essentially the same percentage of their interaction behaviors as the one week group - there was no retention decrement between one and two weeks. (See Figure 3).

Several conclusions can be drawn from this study. First, self-confrontation in conjunction with role-playing, was demonstrated to be a significant improvement over standard, passive means of learning interaction skills such as reading of training manuals. Second, it appears that attitude toward the culture affects the rapidity with which interaction skills appropriate to that culture are learned. This could be due to the greater motivation of the positive attitude group to perform well in the context of the other culture, or, to the inhibiting effect of the anxiety or conflict felt by the groups with more negative attitudes. In any event, the creation of positive attitudes looks to be an important part of such training.

The high performance of subjects on their retention trial after two weeks indicates that skills learned through self-confrontation training hold up at least long enough for the trainee to actually arrive in the foreign environment, where such skills would then be maintained by day-to-day social reinforcement.

Currently we have in progress an experiment designed to further optimize the utility of closed circuit T.V. and videotape equipment in conjunction with role playing. This experiment will compare the effectiveness of self-confrontation with that of viewing a tape of a model's criterion or "perfect" performance. Also compared will be verbal criticism from the experimenter with review of written materials, as an adjunct to the videotape feedback, and the relative contributions to learning of role-play practice and videotape feedback. With the completion of the current experiment, enough will be known of the self-confrontation and modeling-imitation techniques as training devices to enable their use with relative confidence in the previously discussed experimental training program. Only then can its true effectiveness be assessed, as the American personnel trained in this manner go about their jobs in the foreign cultural environment.

In closing, I would like to state the firm conviction of all of us working on this program of research, of the crucial importance of effective interpersonal relationships between Americans and citizens of countries in which civic action and technical training programs, and insurgency-counterinsurgency activities are ongoing or likely. It is becoming a hackneyed phrase by now, to "win the minds of the people," but it is none the less true. Effort in making a friend for America now through a little understanding and sensitive treatment is easily preferable to the effort, tanks, planes and ammunition necessary to hunt down the same individual, turned insurgent, five years from now.

ACKNOWLEDGMENTS

The ideas expressed in the introduction and "nature of the problem" sections of this paper are those of [redacted] The self-confrontation study reported was designed and executed primarily by [redacted] provided valuable suggestions and criticisms of the manuscript.

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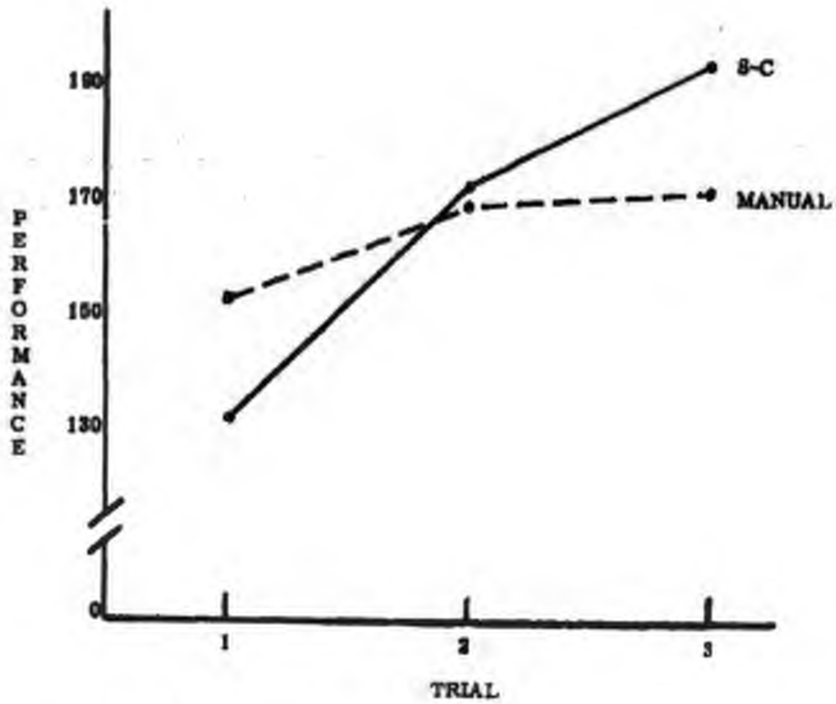

FIGURE 1. ACQUISITION BY TRAINING METHOD

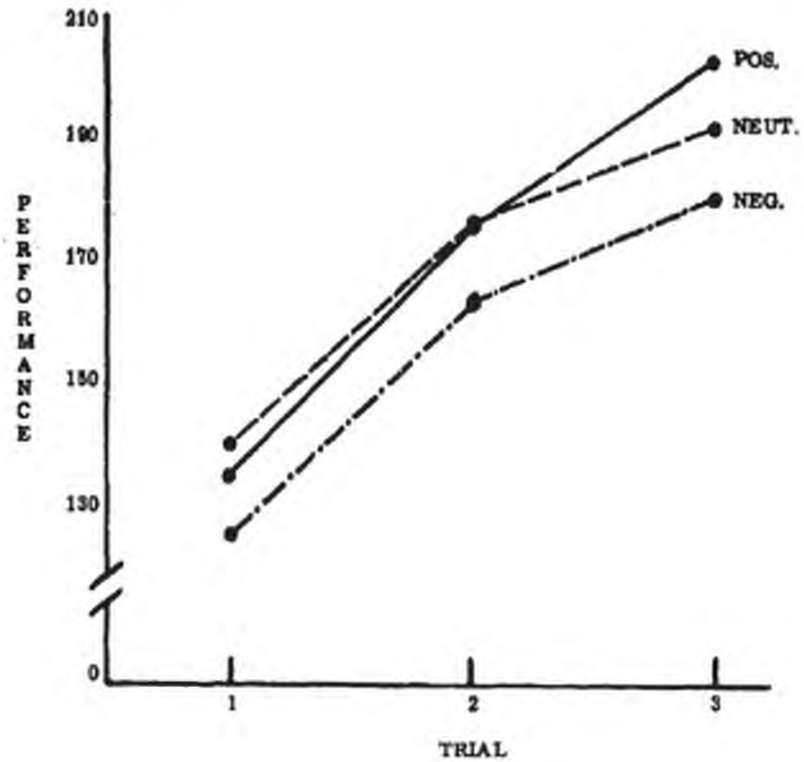

FIGURE 2. ACQUISITION BY ATTITUDE GROUP

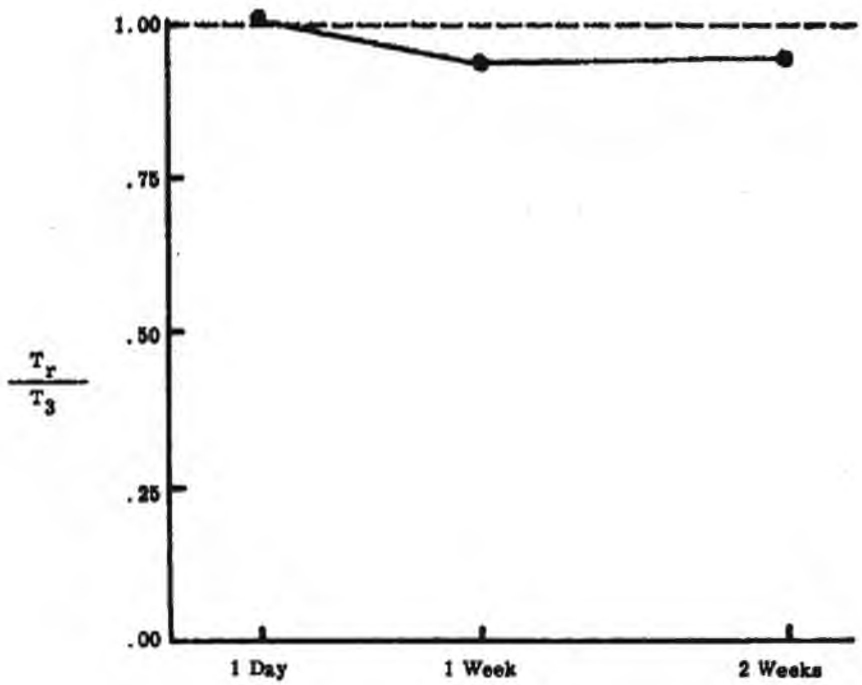

FIGURE 3. RETENTION OF INTERACTION BEHAVIORS

(b)(6)

[redacted]

SOME RELATIONS BETWEEN URBAN AND RURAL INSURGENTS

~~(Confidential)~~

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ABSTRACT
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On the basis of studies on Venezuela and Guatemala, sixteen relationships between rural and urban aspects of insurgency are pointed out. Most of these apply also to South Vietnam, but there are important differences. Doctrinal influences on these relationships, and on the probable significance of urban insurgency in a given conflict, are discussed.

Research in the last few years has shown that insurgency only rarely occurs in cities on such a scale and with such affect as to bring to completion the insurgent aims. It has also become clear that few insurgencies are successful without at some point utilizing the opportunities provided by the urban situation. Attacks in either milieu--rural or urban--pose serious control problems which are compounded when both types of action must be faced simultaneously. Clearly one of the most significant problems in learning to control modern insurgency is to understand the nature of the relationship between the two scenes.

This paper considers some of the dimensions of this inter onnection and illustrates their significance by reference to conditions which have prevailed in Venezuela[1] and Guatemala.[2] The framework so developed is then applied to seek an understanding of the urban insurgency situation in Vietnam.

At least eleven points of view suggest themselves on the basis of which the insurgent leadership in the countryside relates to the movement on the urban scene. There is no intention here to claim that all these conditions exist in each insurgency; only that several or all may be found in any given situation.

1. URBAN AREA AS A SOURCE OF INCITEMENT AND INTELLECTUAL LEADERSHIP

Rural dwellers may be frustrated and may protest against existing power arrangements in their national society, but their normal level of political sophistication is too low to instigate and maintain a serious insurgent movement without outside help. It is in the urban sector of society, particularly among intellectuals, that both political awareness and organizing skill are sufficient to found and push such a movement. Disciplined rural violence rises and falls in intensity and extent with the level of agitation which is carried on mostly by people of urban origin.

2. RECRUITMENT

At least the cadres for early development and command of a guerrilla movement in remote areas may be recruited from among city activists. Such was definitely the case in Venezuela from 1962 to 1965. At a later stage of development of the insurgent movement the peasantry may be more deeply involved.

3. CONTROL AND LIAISON

A variety of factors favor the maintenance by the insurgents of command and liaison headquarters in a major urban center. Of course that may be impossible for security reasons; nevertheless it is preferable.

4. INTELLIGENCE

The fact that government, and the societal decision-making machinery associated with it, is centered in the city gives the insurgents access to more intelligence here than anywhere else. The anonymity of city social relations, furthermore, allows infiltration and subversion on a much larger scale than in more intimate settings.

5. SUPPLY

Arms, radio equipment, uniforms, medical supplies, money, and even food may be carried from city to rural areas in volume.

6. CONTACT WITH FOREIGN ASSISTANCE

The assistance reaching the countryside from abroad is usually financial, although printed propaganda materials also are shipped. It enters the country through smuggling or through trade or diplomatic contacts in the commercial centers.

7. REST AND RECUPERATION

The rigors of operating in remote areas with a few of the amenities of life point up the desirability of an alternative location for rest purposes. To the degree that the guerrillas have been recruited in the city they are even less able to put up with the rough life than peasants would be. As long as they are not too notorious individually, they may be returned for brief or long periods to relatively safe areas of the city, particularly in slum zones.

8. PROPAGANDA OUTLET

Since insurgents ultimately hope to gain increased support from the public, it is important to them to reach the public. Clearly the production and distribution of propaganda of some kinds is easier in urban circumstances. At the same time city people are more heavily politicized, thus perhaps more receptive to propaganda than the cautious peasantry.

9. POLITICAL IMPACT IN THE CITY

The mere fact that insurgent activity is going on in the densely populated urban areas cannot help but affect the political forces at play in the nation. Public support for or opposition to the insurgents results in changes in the political influence of partisan groups either associated with or against the rebels.

10. STRATEGIC INTERPLAY

The insurgents may force concentration of government strenth in either milieu to relieve pressure on the other. If too much damage is being suffered by the city-based units, a compensatory rise in guerrilla operations may make the situation more bearable as counterforces have to be shifted about in adjustment.

11. RIVALRY

A certain degree of rivalry may arise between rural and urban activists if the two forces continue for long. The differences in operational nature, problems, and hardships which the two offer make it likely that the rural fighter will look down on the value and bravery of the urban units.

Rural insurgency as viewed from the city involves some mirror-image, and some new, types of relationships compared with those just offered.

1. POLITICAL IMPACT ON THE NATION

The threat posed by control of a remote-area guerrilla movement which cannot be fully dislodged by the government gives the insurgent leadership, based in the city, considerable bargaining power. Alliances may be formed on that basis with other political sectors, or concessions may be procured in the political arena by reducing, or promising to reduce, the threat.

2. STRATEGIC INTERPLAY

The diversion of government forces by emphasizing either the rural or urban front works in this direction as well as the reverse.

3. PROPAGANDA OUTLET

Certainly the city insurgents are concerned with influencing the rural population and consolidating the movement in those areas; hence they utilize the rural units to pass on ideas and materials normally phrased by city-based theorists and writers.

4. REFUGE

If all fails in the urban action, the redoubt of mountain or jungle remains. The die-hard little enclave of Malayan guerrillas still existing on the Thai border is a good example of this refuge function of a rural base.

5. CONTACT WITH FOREIGN ASSISTANCE

When aid from abroad can be landed in isolated areas beyond government control, the city activists may actually depend to some extent on supplies of arms or other crucial supplies brought into the country via such locations.

Most of these points apply both to Venezuela and Guatemala (and of course in part to other situations--such as Algeria, Palestine, and Cyprus--which are not treated in this paper). The FALN, the communist-led movement which has been active in Venezuela for the last four or five years, began as a purely Caracas-based activity. When a policy decision was made to implement rural operations, urban dwellers went out into the mountains to establish camps and bases, some of which remain today the centers of such rural strength as they command. The most stable source of recruits was always the universities. The control apparatus was clearly centered in the capital city until the imprisonment of many of the movement's leaders in 1963. Until then some had held immunity from arrest by virtue of their elective positions in the government itself. Even after their detention, liaison was carried on out of Caracas as much as possible, and still is. There is no question that a good deal of intelligence reaches the FALN from agents infiltrated into government and military positions which are concentrated in the chief city. Supply in the first two or three years was very heavily dependent on city aid, and the failure of that system to continue operating has caused the guerrilla bands some of their greatest difficulty. Likewise rest and recuperation amidst the bright lights was possible in the earlier days of the insurgency for some rural fighters, but today increased difficulty of internal movement without capture has limited band members mainly to their mountain areas, to their distinct hurt. The MIR and Communist party leaderships have been extremely active in attempting--not without some success--to ally their political strength to other parties, and to exploit several propaganda lines simultaneously, with all these efforts centering on the capital. More than once failure to make progress on one front (as for example with the initial guerrilla debacle in 1962) has led the Communists to shift emphasis to the other to keep up pressure on the government. Finally there are indications that during the strains of late 1965 and early 1966, some guerrilla leaders saw themselves as brave martyrs and the city softies in the movement as too anxious to negotiate for political settlement. They in turn were characterized by some urban insurgents as fools.

Because of the undeveloped nature of the Guatemalan insurgency, fewer of these characteristic relations can be detected clearly. There is, however, not the slightest question that the entire action has taken its inspiration and leadership from ex-military officers and Communist activists who really belong in the city. Students again are recruited heavily, together with some professional and middle-class people from Guatemala City. The structure of control and liaison is not clear, but it is unquestionable that most of the action is correlated through leaders who frequently live in the capital. Intelligence penetration is common enough at several levels so that almost certainly city agents furnish key information to the rural bands. Supply seems not to depend much in this case on shipments from urban sources, but when money was needed late last year, a series of kidnappings, mostly in or around Guatemala City, yielded the insurgent movements as much as $500,000 in ransom. Whether rest for the guerrilla fighters is planned or not, there clearly is shifting of forces back and forth between the eastern lowland rural strongholds and the city for various campaigns, so that the result is the same. Propagandizing and political influence are clearly involved also in the action of the urban insurgent groups.

Inadequate information makes it difficult to be wholly confident that we understand the significance of rural insurgency in these two cases, but few important facets of the situation are likely to have been overlooked. It may be concluded on the basis of these cases that we have identified a number of the relationships which bind the urban and rural facets of an insurgent movement together.

The question may now be asked, do relationships of the same type prevail in South Vietnam? If so, does the analogue provide us with any guidance as to the importance and nature of urban insurgency there?

Our information on insurgent actions in Saigon is severely limited, yet it is possible to make some relevant observations. It is probably true that intellectual leadership of the Viet Cong stems from urban centers in the North, although not from Saigon. Certainly the communists of both North and South Vietnam are controlled and policies set by city-reared people, so the principle holds. Recruitment, particularly among students, is known to have gone on in urban RVN areas, but the presence of a heavy population in the countryside causes Viet Cong attention in the manpower sector to focus there contrary to the condition prevailing in the Latin American cases.

Control is not exercised from the South Vietnamese city, because of the availability of superior locations across international borders and in safe rural areas. Without any question intelligence flows out of Saigon to the enemy camp. Crucial supplies move in the same direction according to many reports.

Contact with foreign assistance is hardly possible in the South Vietnamese cities at present, and in any case is unnecessary because aid is available via other channels.

Whether the rest and recuperation function is served by Saigon is an interesting question, but not a vital one. Since there are sizable areas in secure Viet Cong possession, such rest as may be permitted the guerrilla fighters can be accommodated there. Propaganda certainly is aimed at city dwellers, but it is largely person-to-person, according to a captured document concerning Viet Cong propaganda tactics.[3]

The degree to which urban and rural activity are used as strategic alternatives is not clear. But it is certain that when rioting and political problems occur in Saigon or Hue, a decrease is noted in guerrilla attacks. The nature and dynamics of this interplay are uncertain, however.

Information on what the urban Viet Cong feel toward the rural units is completely lacking, but the strategic interplay, propaganda outlet, refuge, and foreign-assistance contact relationships are all logical and likely.

Upon comparing urban activities of the Vietnamese insurgents with those prevailing in the two Latin American nations considered, one is struck by the relative lack of Viet Cong urban operations and coordination with the rural effort.

Several reasons may be advanced why this is so. For example they may fear US-ARVN ability to hurt their forces in the attempt, yet it is doubtful that the danger to the insurgents is much greater than in Caracas or Guatemala City.

Another possible answer lies in the differing functions, meanings, and histories of city and country, and their relations to each other, in the two areas. "Rural" territories where rice is the staple crop and populaton density very high are dramatically different from the sparsely-settled campos of South and Central America. There cities were functionally peripheral; in Europe, however, the city also developed its own highly-politicized, highly-charged meaning, and this meaning was transferred to the Americas. In Venezuela and Guatemala the city has for centuries been deemed the center, the focus, and the main concern of national life. The way of life that counts and is valued--civilization--has largely been confined to the one true city in each of these countries. If one wishes power there, no one dreams that he has it until after he captures the city; no amount of real estate and no number of peasant followers carries the equivalent power and cultural meaning.

The case of Saigon is completely different. Only a straggling town a few decades ago, it still lacks almost completely the cultural association with power which its outwardly bustling appearance suggests to Americans.

One of the clearest differences between our two regions of concern is that the doctrine of insurgency prevailing has differed sharply. The Latin American movements have been but lightly burdened by formal doctrine, but the main external influence has been that of Lenin. By contrast, the Viet Cong operate under General Giap's, as influenced heavily by Mao Tse-Tung.

The strong emphasis Mao gave to the long war among the peasantry is well known. Good historical reasons for this emphasis derive from the events of 1927 and later in China. Chiang Kai-Shek that year used the Kuomintang and his military forces virtually to wipe out the powerful urban communists in Shanghai and Canton with whom he was nominally allied. The result--a slaughter of perhaps tens of thousands of Reds--destroyed all hope that the Leninist doctrine of seeking power in China via the urban proletariat could succeed. Out of that bitter blow Mao Tse-Tung developed his doctrine which he then proved in practice over the next twenty years. The success of the Viet Minh against the French merely reinforced the emphasis on rural warfare, for they found it quite unnecessary to launch major campaigns against the French-held cities.

Some of Mao's ideas on the subject from the 1948 era of Chinese Communist advance are instructive. They show that he made important distinctions about the cities which may assist in explaining why the Viet Cong have not carried out the damage they surely could have done in Saigon, Danang, or Hue if they had chosen to.

"It is strictly forbidden to destroy any means of production, whether publicly or privately owned,"[4] he noted.

"Precautions should be taken against the mistake of applying in the cities the measures used in rural areas for struggling against landlords and rich peasants and for destroying the feudal exploitation practised by landlords and rich peasants, which must be abolished, and the industrial and commercial enterprises run by landlords and rich peasants, which must be protected. A sharp distinction should also be made between the correct policy of developing production, promoting economic prosperity, giving consideration to both public and private interests and benefiting both labour and capital, and the one-sided and narrow-minded policy of 'relief,' which purports to uphold the workers' welfare but in fact damages industry and commerce and impairs the cause of the people's revolution."[5]

"From 1927 to the present the centre of gravity of our work has been in the villages--gathering strength in the villages, using the villages in order to surround the cities and then taking the cities. The period for this method of work has now ended...The centre of gravity of the Party's work has shifted from the village to the city. In the south the People's Liberation Army will occupy first the cities and then the villages."[6]

The reason for his concern is obvious--he wishes to maintain production, not destroy it. And why?

"From the very first day we take over a city, we should direct our attention to restoring and developing its production. We must not go about our work blindly and haphazardly and forget our central task, lest several months after taking over a city its production and construction should still not be on the right track and many industries should be at a standstill, with the result that the workers are unemployed, their livelihood deteriorates, and they become dissatisfied with the Communist Party. Such a state of affairs is entirely impermissible."[7]

The latest major statement of Viet Cong policy in relation to the cities still reflects the preoccupation with rural action characteristic of Mao's thinking, although it pays more attention to the urban aspect than former VC policy statements. This document, an unattributed article in the People's Revolutionary Party theoretical journal TIEN PHONG, was broadcast by the National Liberation Front radio on 21 February 1966. The emphasis throughout is on "political struggle." It holds that "The...situation once more (reflects) the very basic and decisive role of political struggle and proves that under the present new conditions and situation, there is no change in this role." The chief call is to push such propaganda lines as the high cost of living, house eviction, land confiscation, conscription and wage increase demands, which "must be guided, stirred up, and developed into an extensive, organized, and guided movement." "What is important in the urban movement...is...gradually heightening the movement, and endowing it with a high political content."

Difficulties inhere in this approach, it is admitted. Leadership must be wrested from "reactionary elements" in the various religious organizations and the trade unions. Police action is admitted to have hurt their struggle capabilities in Saigon. "Especially in the cities, it is not possible to organize a huge struggle force in the manner adopted by the rural areas." Instead reliance has to be placed on the main chi bo, or cells, which are to "take advantage of all legal and semilegal organizations of the masses."

Violence is noted in passing as a tactic auxiliary to the political struggle. Forms "may involve revolutionary violence, including such things as demonstrating in the streets, going on strike, occupying workshops, staging market and school strikes, carrying out vanguard propaganda," etc. Also "there will be concentrated large-scale struggles and comprehensive political offensive drives...by the urban and rural people...while being supported by armed activities." Yet even these acts are "to create an opposition opinion in separate wards, quarters, and enterprises," rather than to attempt large-scale violence *per se*.

Thus it appears that no doctrinal basis exists for supposing that the Viet Cong will attempt such tactics as disrupting economic facilities or launching a widespread campaign of terrorism or rioting in Saigon. In addition, of course, there is the practical fact that the insurgent movement is apparently itself economically dependent or parasitic on the urban economy;* they would themselves be hurt seriously by destroying its fabric.

* Cf. Felix Belair, Jr. "Imports of Aid Supplies to Vietnam Outpace Control by U.S.," *New York Times*, May 10, 1966.

In conclusion, it appears that in general there are characteristic types of relationship between the urban and rural aspects of insurgency, but that their expression and relative importance depends on the local situation, on the doctrine held about insurgent operations, and on cultural evaluations of the situation.

In Venezuela and Guatemala, as in some other Latin American nations, the fact that insurgent dissidence is centered in the urban population and particularly among intellectuals, the traditional pre-eminence of the city, and the doctrinal views of the insurgents combine to make the urban aspect of insurgency a very real threat, and an activity likely to be repeated often in the future.

In Vietnam the doctrinal stance and the present force situation combine to de-emphasize the importance of cities to the insurgents. Furthermore the desire to maintain the productive capacity of the urban areas, both for present benefits and in hope of ultimate seizure, discourages any attempt to paralyze urban functions by means of sabotage or terror.

While U.S. counterinsurgency attention is directed to Southeast Asia primarily, we should be cautious about generalizing on the basis of experience only in that area. We have shown that special conditions there make it logical for the Viet Cong not to do their worst to the urban zone, but in other areas, notably Latin America, and perhaps the Middle East and Africa, different conditions prevail. The threat of urban insurgent activities may well be much more significant there.

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ESSENTIALS OF COMMUNIST INSURGENT STRATEGY: ORGANIZATION AND CONCEPT OF OPERATIONS(U)

(UNCLASSIFIED)

(b)(6) [redacted]

Special Operations Research Office

Washington, D. C.

ABSTRACT
(Unclassified)

Schematically, a fully evolved, Communist-directed insurgency movement will consist of three interlocked, parallel hierarchies: (1) the party itself; (2) a complex of civil organizations; and (3) military forces. The present paper analyses the characteristic attributes, both organizational and operational, of each of these structures, relying heavily on the South Vietnamese experience for its data—but drawing from other subversive insurgencies as well—to demonstrate the uniformities which have obtained over some three decades of insurgent activity.

The paper commences with an explanation of the manner in which the Party combines its committee system with its cellular structure at all levels. The Party Youth organization is then related to this highly sophisticated Party design, taking care to differentiate the roles assigned, respectively, to the Party and the Party Youth organizations. In the light of this analysis, attention is then turned to the Party rationale for the establishment of such a complex of command channels in which every Party and Party Youth member is obliged to hold multiple positions and satisfy multiple demands. The inner organizational dynamics that follow from this arrangement is also considered.

Next, the multiple, parallel functions of the Civil structure are examined, drawing a distinction, organizationally, between (1) the mass associations in which the citizenry are enrolled and mobilized to support the insurgency, and (2) the system of "People's Liberation Committees" erected over the mass associations to supervise their activity and provide the substantive base from which a shadow government may arise which seeks to displace the regional administrative organs of the constituted government.

In the context of the Party's organizational work within the civil population and the intent behind this effort, village militia—conventionally viewed as a component element of the military forces—are evaluated as serving an essentially different function from that accredited to them in the past. The members of the militia, the paper argues, are not to be judged as inferior soldiers who work part time, but as members of the village's elite mass association in which they work overtime. Regarding the specifically military echelon of the insurgent movement, a distinction is drawn between the (1) regional and (2) main-line force formations, and particular attention is directed to the raison d'être behind the regional military element, its genesis in the organizational evolution of the insurgency, and its role in the political mobilization of the civil population.

The paper concludes with observations on the historical origins of the principles and practices associated with each of the three hierarchies of the insurgent effort analyzed and a statement on the insurgent's concept of operations. Stress is placed on the totality of the interdependence which obtains between the armed forces and the civil organization, and occasion is taken to identify the respective contributions of each of these components of the insurgency to the social revolutionary content of protracted guerrilla warfare under the guidance of a Communist Party organization.

The genius of the professionally directed insurgency lies in the fact that its command cadre is provided with a body of thought and operational procedures allowing it to give the insurgency direction and purpose corresponding with the interests of no one but the insurgency's own leadership. Not spontaneity, but control is the key word in accounting for the symmetry with which the movement expands in its elements and escalates in its intensity.

Leadership in a Communist-dominated insurgency is lodged with a Party organization irrespective of the level of intensity it may have reached or the sophistication of the organizational complex through which it operates.

Fully elaborated, the insurgent structure will consist of three basic, parallel structures, each of them reaching from the village and the district up through provincial bodies to appropriate national executive offices. The Party apparatus will superintend the growth of a complement of military forces on the one side and a complex of mass organizations and de facto civil administrative bodies on the other.

At the top, the insurgent structure provides the Party with two new agencies through which it addresses the indigenous population and the world at large—its supreme military headquarters and its executive of the national front. Both bodies will be dominated by the membership of the Party Central Committee among whom the assignment of multiple titles and responsibilities will prove to be the rule, not the exception. For purposes of visualizing the structure with which we are dealing here, the following schematic representation may be employed.

1. THE PARTY LABYRINTH

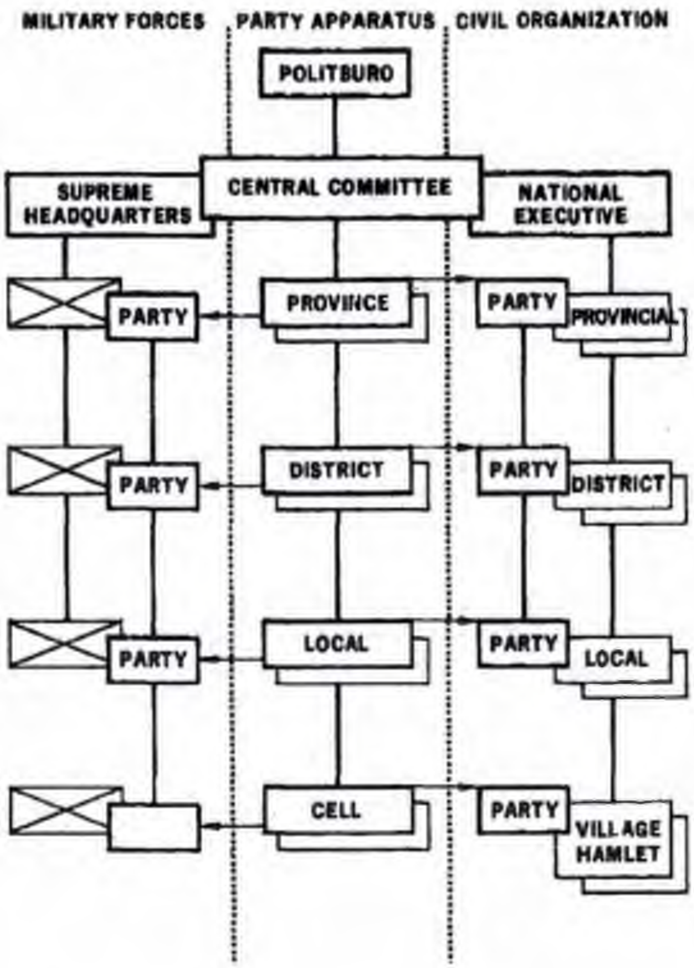
The Party maintains its own independent control and communication channels within the military and civil organization, duplicating the command structure of both of these latter elements. But if extreme efforts are made to dominate, then the Party will concurrently attempt to stay out of the limelight wherever possible. Its members will speak to the public at large either (1) through its dependent agencies or (2) as members of one or the other of the parallel structures, assuming such disguises as are appropriate. Members of the Party command structure may live their daily lives—independent of either the military or civil organization—conducting themselves in accordance with the rules of security traditional to any clandestine group. But they can as well seek security through the cover provided by the civil organization or the physical protection possible within a military unit. The level at which the Party member works, the availability of communications, and the effectiveness of the counterinsurgency are factors that will determine the Party member's whereabouts. Thus Tito and the members of his politburo lived with the main operational forces of the PLA, while leaders of the World War II Greek insurgency could reside for several years in the city of Athens, and many members of the Lao Dong party in Vietnam are hidden within the hierarchy of that insurgency's Civil Organization, the NFLSVN. The physical location of the Party man does not necessarily determine the nature of his work, nor does the body to which he attaches himself always provide a clue as to the authority he exercises in the movement as a whole.

Under the microscope of more exhaustive analysis, this Party apparatus proves to be not simply a vertically ordered system of committees but rather a complex of hierarchies, erected inside one another in accordance with the principle of cellular organization. At the base of the arrangement lies the cell which contains a minimum of three members and must be able to perform a minimum of five tasks. In the order of their importance, these several obligations are: sustained inner cellular discipline for which a designated individual assumes responsibility with the designation of "Cell Captain" or "Secretary"; the maintenance of liaison with superior bodies through which the cell receives its orders, guidelines, and quotas to be filled; distribution of literature produced by higher Party authorities (e.g., newspapers—overtly or clandestinely printed—books, etc.); the conduct of local agitation within the populace to include the fabrication of leaflet and other locally produced printed materials; and, finally, the maintenance of fiscal records (dues, money raised, contributions, etc.). As the cell expands in size, the functions it may assume increase proportionately, with particular attention being given to the conduct of agitation and the closely associated infiltration of popular associations within the populace or the creation of such bodies under disguised Party direction where they have not previously been established. This activity may be referred to as "mass organizational work" and its ultimate payoff—when conducted in an integrated fashion at multiple organizational layers—may be the appearance of prototypes of the "Civil Organization," mentioned here above, even long before anything vaguely approximating a guerrilla band has been activated. Inner cellular discipline, cited as the first priority of the Party, is built through the distinctive Party practices of the struggle meeting, the ideological autobiography, self-criticism, the "democratic" discussion, and vote on proposals on which final and irrevocable determinations have already been made by the Party's national leadership.[1]

Next to identifying the essential characteristics of the cell, it is important to stress that all party members are simultaneously cell members. Each must have his "home," a cell in which he is officially enrolled as a member. At the grass-roots level, this arrangement poses no difficulty. One is a member of a cell and, in the context of the cell's assigned responsibilities, one carries out his specific obligations. But at higher levels in the Party, the member is concurrently a cell member and a committee member. That is to say, one's Party work is not necessarily performed exclusively in the framework of the cell.

A glance back at the schematic structure of the insurgent organization in the chart (Chart I) shows Party committee organizations at the local, district, provincial and national levels. These bodies may develop into a highly sophisticated structure under the direction of a secretary, his assistant, and his executive officer. Under them will function a "Permanent Standing Committee" of perhaps four to ten persons in which the principal executive officers will likewise hold membership. And, subordinate to these larger bodies, a series of branch agencies and subsections may function, engaging the energies of possibly a score or more additional individuals (among whom non-Party fellow travelers are occasionally met in positions of limited responsibility or of a

[1]The present author cannot stress too much the importance of having the counterinsurgent both acquaint himself fully and thoroughly understand the open literature produced by Communists during the last five decades on inner Party practices. Characteristic of this literature are the pamphlets of [redacted] produced in the 1940's and published by Peking's Foreign Languages Press in English by the early 1950's (e.g., On the Party; On Inner-Party Struggle; How To Be a Good Communist). It should be added that none of the three particular documents cited here may be understood narrowly as limited in their applicability to China alone. The principles treated in them are of the highest relevance to the membership of any Communist Party.


MILITARY FORCES
PARTY APPARATUS
CIVIL ORGANIZATION
POLITBURO
CENTRAL COMMITTEE
SUPREME HEADQUARTERS
NATIONAL EXECUTIVE
PARTY
PROVINCE
PARTY
PROVINCIAL
PARTY
DISTRICT
PARTY
DISTRICT
PARTY
LOCAL
PARTY
LOCAL
CELL
PARTY
VILLAGE HAMLET

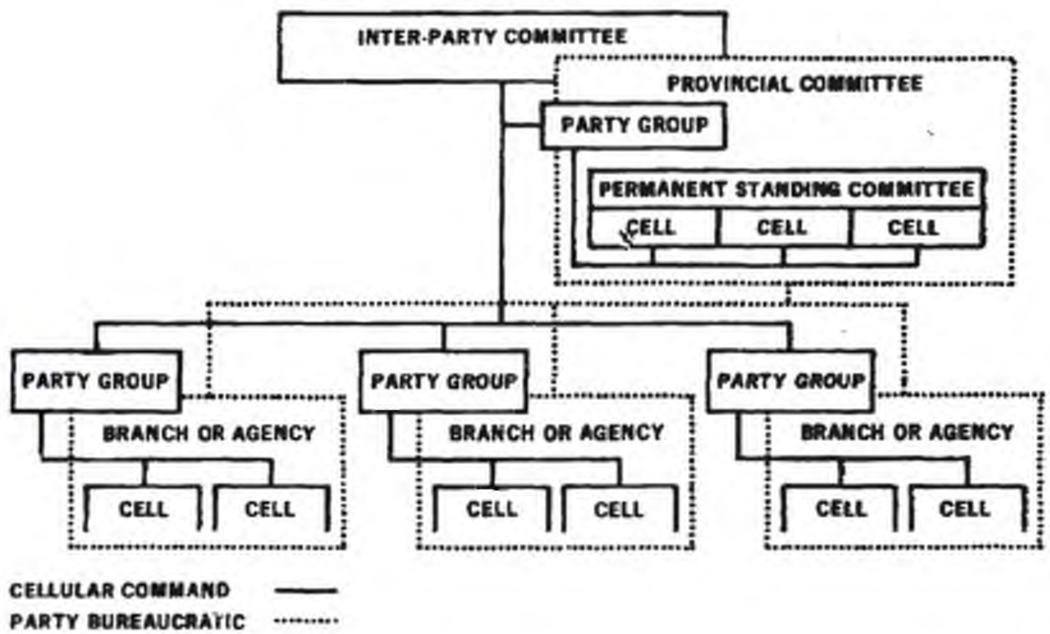
clerical character). This system of committees, together with their specialized elements, structured as a hierarchy, may be conceived of as the bureaucracy through which the Party prosecutes its insurgency. Detailed Party regulations will determine the requirements for membership in the various sections of the committees. Normally, a minimum "Party age" (i.e., number of years since an individual acquired full Party membership) will be fixed for the secretary's and the assistant secretary's positions.

There, where the Party erects this more sophisticated organ, it does not dispense with its cellular structure. Both will exist side by side, and immediately, in the following fashion (see Chart 2). All Party members in a given branch or agency of a committee, including the member of the "Permanent Standing Committee," will be integrated concurrently into one, two, or more cells. In the cellular structure—as opposed to the committee getup—the cell captain is responsible to a new body, known as the "Party Group," which again has its First Secretary, Assistant Secretary, and Cellular Committee (in this case, smaller than the bureaucratic "Permanent Standing Committee"). A "Party Group" will be responsible to yet a third cellular office at the given bureaucratic committee level, the "Inter-Party Committee." It, still once more, will be headed by a First Secretary, Assistant, and Cellular Executive Committee.

The line of command within the cellular structure operating at, as an example, the district and provincial levels is from the supreme agency of the province—i.e., the Provincial Inter-Party Committee—directly down to the District Inter-Party Committee, skipping over the intervening localized offices. In the same fashion, the command channels in the party <u>bureaucracy</u> will proceed from one First Secretary or his Permanent Standing Committee down to the comparable office at the next lower level. Only as one single person controls both supreme offices at his level of organization does he dominate the instruments of power. Where this is not the case, the cellular First Secretary, even when he occupies an inconspicuous position in the bureaucracy, becomes the boss of the Committee First Secretary. The manner in which these two <u>Party</u> structures are related to one another is schematically indicated in the following charts.

One might mistakenly assume at this juncture that the complexities of inner-party organization had now been resolved. This is far from being the case. Yet a third parallel structure is built upon the "Party Youth" organization, an indispensable affiliate of any Communist Party. The youth organization is a halfway house into which likely future Party members may be drawn in their early youth before they reach the required age for candidate membership in the Party proper (varying between 18 and 20 years of age). This body may not be viewed as a mass organization after the fashion of a Women's Association, a Student Organization, a Journalists' Society, and other like bodies. There is a fundamental difference between these latter mass associations and the youth hierarchy. The mass organization is an instrument through which broad elements of the population may be mobilized in support of subversive ends; the Party Youth, in contrast, is a school of training and preparation for the assumption of inner-party responsibilities at a later date. Individuals within mass organizations may indeed eventually become Party members. In principle, the Party encourages just this development, but this is not the primary mission of a Women's Association, as an example. Rather it is to involve substantial portions of the population in activities which at one and the same time enhance the likelihood of an ultimate victory by the insurgents, while making those so involved unavailable for counterinsurgents as a source of support. The Party Youth, on the other hand, does have the primary task of producing the next generation of Party members. Individuals enrolled in this body will be employed, to the maximum extent possible, in a manner similar to their more experienced seniors, for the Party wishes them to acquire that indispensable experience in the multiple phases of Party work which will make it possible to draw them into the hard core of the

INTRA-PARTY STRUCTURE (1)



organization by the time they are of age. Within the Youth Organization, four levels are recognized: sub-cell, cell, youth group, and youth inter-group. The youth in any given area will be incorporated in such an arrangement and will be responsible to a "youth inter-group" committee, hierarchically at the next higher level. It is immediately apparent that this is an attempt to duplicate the Party's own cellular structure, not its bureaucratic structure. And the Party's controls over its own youth structure will proceed, indeed, from its cellular organization, not its bureaucracy. A moment's reflection will make it apparent that no other arrangement is possible if the Party is to maintain its control over the youth apparatus. The Party leadership appreciates that until the closing phase of a successful insurgency, it must ever maintain inner organizational flexibility. It must be prepared—in the face of a sudden increase in the strength or effectiveness of hostile forces—to deactivate with dispatch its more complex organizational arrangements without losing its integrity and thus falling apart in the process. This is one of the essential reasons why the Party's cellular character is maintained in working order at all times. And for this reason the Party Youth will be tied to the cellular structure where control can be sustained irrespective of losses or the level of overt activity feasible.

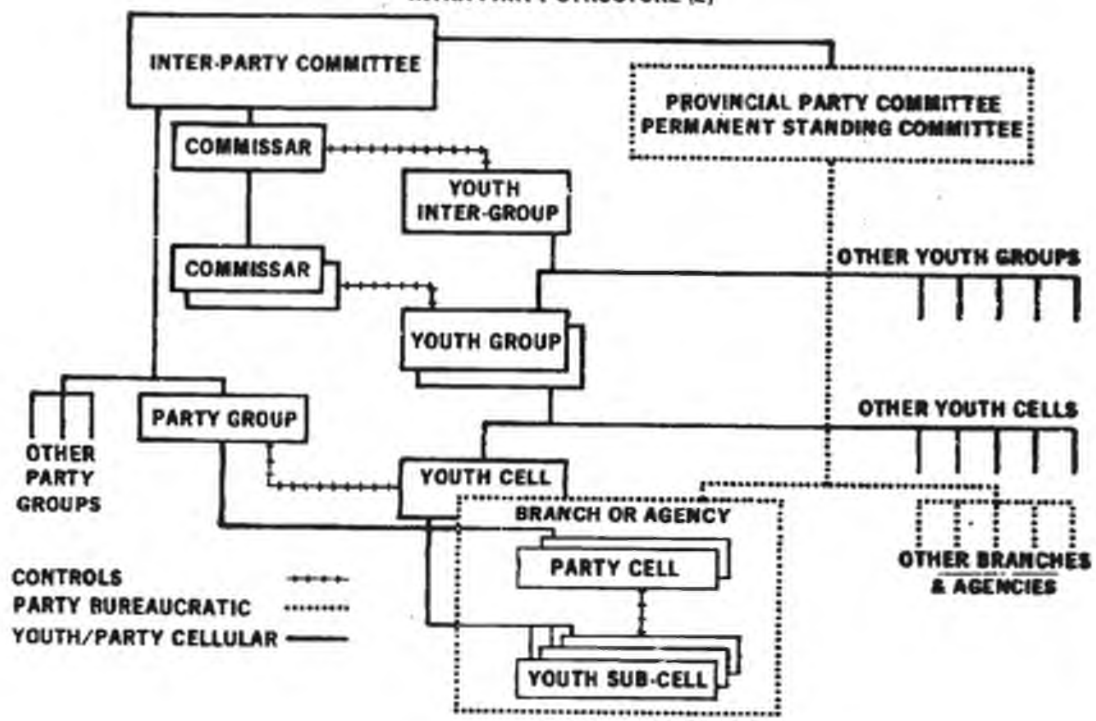
Specifically, control is asserted in the following way: Members of the cellular "Inter-Party Committee," frequently known as "commissars," are attached to the two highest levels of the Party Youth hierarchy (i.e., at the "youth" group and "Youth Inter-Group"), the Party Group is assigned the task of supervising the activities of the youth "cell," and the Party "cell" acquires directing authority over the youth "sub-cell." The Party cell's youth specialist may give orders or assign quotas to his respective sub-cell youth elements, and he exercises veto rights over projects proposed by the latter. A Youth Group or Inter-Group Committee sends orders to subordinate youth elements with the approval of its attached or associated full Party member, i.e., the "commissar." And an inter-group youth committee at the district or higher levels rules over a comparable inter-group at any lower level in complete imitation of the relationship between cellular Inter-Party Committees at dissimilar levels, but with the proviso that the responsible "commissar" approve the proposed action. The relationship between the several Party bodies, including the youth structure, may now be indicated as in Chart 3.

But now the question must invariably arise: "Why?" Why this labyrinth of controls, checks, surveillance systems, etc.? Is there not a simpler means of achieving the essential aims of the organization? The answer is emphatically, "No!" The issue of survival, mentioned above in passing, already constitutes a major justification for such an arrangement, but the raison d'être for the structure goes yet much deeper.

Communism, as a way of life and form of organization, is not realizable in the absence of the cell. The cellular structure of any Communist Party, whether legal or illegal, is its most critical characteristic. Both the mentality of the Party member and the distinctive types of operations pursued by this Party presuppose this principle of cellular construction. Again, "Why?" Because only in the environment of the cell is the party provided with the crucible in which to mold the new recruit into a disciplined Party subject. It is within the cell that the member learns to live with the relentless inner-Party practice of criticism-self-criticism. Here his indoctrination occurs, progressively isolating him—emotionally and intellectually—from the attitudes and patterns of behavior abroad in society at large. These are matters that cannot be effected within a bureaucratic environment.

All of the Party member's activities conducted in behalf of the Counter-Intelligence Section, the Economics Section, and the Administrative Branch make up his job. He may work at these tasks 8 hours a day, 10 hours a day, or more, but his obligations here are finite. In his official position in the territorial Party Committee, he is a bureaucrat among bureaucrats, with obligations of a delimited character which demand less than his total energies.

INTRA-PARTY STRUCTURE (2)



As long as the individual is left with "free time," with his hobbies and private interests, he cannot be provoked into that form of commitment indispensable to the structuring of a disciplined command apparatus intended to supply leadership in the protracted struggle for the seizure of political power in countries like South Vietnam. What cannot be supplied in the system of committees and agencies is provided in the cell which places not finite but infinite demands upon its members.

Among one's fellow Party members within the cell, one finds himself in the midst of an intense, dynamic environment, well calculated to absorb utterly the entirety of one's being. The cell places a claim on the entire energies of the individual—physical, intellectual, and moral—and demands total commitment from its members. Ideal goals are generated through inter-action which at the best can only be approximated by the participating member. Consequently, the individual is left ever in doubt as to the success of his efforts to approach the demands placed upon him, while being encouraged to believe that the realization of the goals set forth for the model cell member accord with his own best interests. As a result, a built-in, permanent sense of insecurity lives in the mind of each member, spurring him on to exert himself with ever greater urgency. Furthermore, the dynamics generated in such a system of cells, integrated at the "Group" and "Inter-Party" levels, necessarily takes precedence over the Party bureaucracy at the same level, particularly in light of the fact that not all of the personnel engaged in the agencies of the bureaucracy will be Party members.

Outside of their daily labors in their various offices and agencies, the cell members are expected to meet at a minimum of once a week for criticism (or struggle) sessions during which both the individual's work in behalf of his cell and his work in his formal office are subject to the searching examination of colleagues. Here, in the cell meeting, the orders received by the "Group" from the "Inter-Party" (which, in turn, receives orders from the "Inter-Party" at the next higher level) are made known to the individual and his work norms are set. In his formal office, he may well receive thereafter a directive encompassing in substance the same determinations established during the cell meeting, but it is the release of instructions among the assembled cell members that counts, and it will be to the end of satisfying the criticism leveled against him by his fellow cell members that the individual will exert himself.

2. THE CIVIL ORGANIZATION

The civil organization in contrast to the Party structure is an implementing body, not an originating one. A considerable effort will be made to encourage the belief that it (1) does initiate action and (2) does so in the interest of the populace at large from which its members are supposedly "democratically" drawn, but in fact it is entirely the creature of the party, subjected to more complete controls than the military forces, since it is the source of much of the movement's supply, intelligence, and recruits, and since, in it, the insurgents see a device through which they may one day win a cheap victory by negotiation or by the default of the adversary who comes to believe that the front genuinely does represent the "wave of the future." Within "civil organizations" are embraced both (1) the mass organizations in which the citizenry are enrolled and mobilized to support the insurgency (e.g., peasant, women's, youth, laborer, student, etc. associations), and (2) the system of "People's Liberation Committees" (PLC) erected over, and drawing members from, the popular bodies established at their respective levels.

The mass organization is the device through which the organically structured populace is committed, at the Party's direction, in behalf of tasks which contribute to the insurgent effort. The PLC, in contrast, is an agency of coordination and administration thrust down over the civil organizations of the local citizenry.

in the eyes of the local citizen, the PLC is a Party means of contact and surveillance. With respect to the outside world, it is the organization which preempts all liaison functions and displaces all other institutions through which the people might articulate their interests and needs. These two bodies, then, differ in their purpose. Still, they must be conceived as interdependent aspects of a single central ingredient of Communist insurgency: The progressive domination of the nation's population and resources.

3. THE VILLAGE MILITIA AS THE INSURGENT'S ELITE MASS ORGANIZATION

Yet a third distinctive element may be treated in the general discussion of mass organizations: the militia elements of the movement. Breaking with the convention of examining all combatant and armed units of an insurgent movement in the context of its military forces, it may be argued that the significance of several of the paramilitary organizations maintained as an example by the Dang Lao Dong at the village or hamlet level can be much more readily grasped if one evaluates them, not as inferior military forces which only work part time, but as the elite formations among the multiple mass associations in which the members work overtime!

There are several peripheral groups that may, from place to place, be identified as genuinely paramilitary elements, e.g., the Veterans (or former Resistance Fighters) Association, the Liberation Red Cross; but more important and more frequently met are the village and hamlet guerrillas or "liberation troops," and the Self-Defense Forces (SDF). Of these, the "Guerrilla" as the Communist insurgent understands this word,[1] is the more important to the Party leadership. It is made up, first off, of relatively young persons who, secondly, joined voluntarily, not in the Western sense of unprovoked and spontaneous identification with some abstract cause but rather as a result of effective Party work which progressively compromised a subject's independence of decision to the point that he throws in his lot with that of the insurgents. The individual enrolled in a guerrilla unit is, to use the Party's terminology, a "receptive male or female youth." The individual may be trained on the spot or concentrated in an area outside the hamlet, where he is trained on military and political subjects. He does participate in combat, but the unit to which he belongs operates only in the local area. Such an individual can have only a minimum of professional military training. Equally important, he has his abode within the local population, where he is subject to the fluctuating influences prevalent among the people. His basic interests remain those with which he concerned himself previously as a full-fledged civilian.

Joining a village or hamlet guerrilla or SD force is not conceived as enlistment in the armed forces. In stepping up the rate of recruitment into the army, Party leaders at the local or chapter level are encouraged to draw those who do not want to enlist in the "regular army" the Quan Doi Chanh Quy, (see note above) into SDF or guerrilla units first from where they may then be persuaded in time to actually "enlist." If the village guerrilla's status has been altered and he finds himself engaged in new kinds of activities, then this is likewise the case with his neighbor who has joined the Peasant, Youth, Workers', or other mass association in the same

[1]In Western parlance it is customary to refer to the entirety of the insurgent combatant forces as "guerrillas," including under this label elite, professionally trained forces as well as local paramilitary or part-time fighters. If it is recognized that substantial differences exist in armament, training, and unit competence between varying units, then the proclivity of all of them to employ guerrilla tactics still serves as a justification for the general use of the word "guerrilla." This is not the case in the Dang Lao Dong's own terminology for referring to its military forces. For the Vietnamese Communist, a "guerrilla" is exclusively a member of a village or hamlet militia formation, the Dan Quan Du Kich. Regional (Po Doi Dia Phuong) forces and main-line (Quan Doi Chu Luc) forces are separately conceived as constituting the Regular Army (the Quan Doi Chanh Quy).

village.[1] Strikingly new in the lives of both individuals is not so much the fact that they have or have not been issued distinctive equipment or commenced training for some specialized role, but that they have been absorbed into organizations for which there are no precedents, and subjected to controls and social pressures forcing their conformance to alien patterns of behavior. The distinction between the members of the "Liberation Peasants' Association" and the Village Guerrilla unit is simply one of degree, following from (1) the greater prestige and (2) the heavy demands placed upon the personnel of the latter body. The guerrilla's weapon, if he is armed with a modern firearm, is a status symbol as well as an instrument with which to kill government security personnel.

And in both types of mass associations, guerrilla as well as straight civilian, the Village Party Local or Chapter is completely in control—not the full-time military force—whether it be a regional unit in the local environs or an infiltrated main-line force. The formation, training, and utilization of SD and guerrilla forces is handled entirely through Party channels. In this area, the Party chapter answers to District and Higher Party Committees, not to military commanders. Main-force units are forbidden to indiscriminately induct personnel enrolled in village political or militia bodies into combat units. This is as much the case in Vietnam now as it was in the Chinese mainland insurgency of the 1930's, the Yugoslav insurgency of the World War II period, or the Malayan affair of the late 40's and early 50's. The determination of who shall go rests with the leadership of the Party Local and, for each individual incorporated in an operational unit as a replacement, the main-force unit must issue a written acknowledgement to the local Party authorities.

Fully alive to the nature of the distinction at play between the mass and the guerrilla body and well aware of the fact that the prestige associated with guerrilla status can be exploited to intensify mass work among the yet unorganized, the party assigns indoctrination an even more important role in the guerrilla unit than in the other mass organizations. Through indoctrination, the influence of popular opinions adverse to the insurgent movement on the unit member can be reduced, and the guerrilla organization can be utilized as an additional device through which the local population is systematically propagandized. To maintain the paramilitary organization's prestige and hold its members together in an increasingly tight-knit operative group, military actions are undertaken in conjunction with regional or main-force units, but ultimately this structure must have a greater impact on the ambient population than on government security personnel.

Throughout all of these elements of the Civil Organization, the mass organizations, the administrative/executive liberation committee (PLC) and the militia, the Party's committees and cellular structure at the local, district, etc., levels will be unobtrusively inserted. The branches, agencies, and sub-sections of a "Permanent Standing Committee" may be constituted as the administration offices established under the "elected" officials of a PLC, or the locally elected "Peoples' Court," may be found to consist of the party's terrorist and proselytizing cells in a Village complex. Great variety is possible, and within the Party's general guidelines extreme forms of opportunism are permitted the imaginative Party cadre.

[1]The controls exercised over the rural peasantry under the ancient Pao Chia system, which once functioned under various guises in Indochina as well as in China proper, have been equated with those evolved through mass organizational work. Arguing from this premise, it is concluded that the Pao Chia system (1) set the precedent for the later Communist control technique, and (2) that reliance upon such means to establish order within the population is consequently distinctively Asiatic. (See (b)(6) [redacted] Control of the Population in China and Vietnam: The Pao Chia System Past and Present, U.S. Naval Ordnance Test Station, China Lake, California, November 1964.) This thesis is unacceptable on two counts. A close comparison of the two systems of control actually reveals greater dissimilarities than likenesses between them and, second, the Communists' ability to erect mass organizational controls among peoples with no cultural precedents comparable to those of the Orient has been, historically, repeatedly demonstrated, e.g., in Cuba, Yugoslavia, Greece, European Russia, and the entire satellite system in Eastern Europe, etc.

4. THE MILITARY FORCES OF THE INSURGENT ORGANIZATION

Finally, the military forces are the insurgent's cutting edge, the catalyst provoking the mobilization of the masses. In South Vietnam, currently, they are to be understood as that element of the total movement which provides the Party with the ability to contend with security forces where the latter would operationally disrupt the progressive mobilization of the population in behalf of the insurgency. Fighting is no end in itself, but one of a series of means to an end; the determination of which means will be utilized at any given juncture or in any distinctive locale is a matter for Party decision. The military services participate in making such determinations quite simply because they are commanded by high-ranking Party members who exercise influence as a consequence of their positions within the Party itself. To attempt to understand the relationship between the Dang Lao Dong and its armed forces in any other context is to attempt to grasp the reality of the situation from a frame of reference which is essentially alien to it.

Tactical commands, inserted between the several echelons of military command (see Chart 1) and responsible to the higher of the two relevant headquarters in each case, will coordinate operations involving the use of multiple units controlled by party committees at two or more hierarchical levels. An extensive literature already exists on the larger main-line forces, operating under the direction of the higher offices of the Party, the so-called Quan Doi Chu Luc in current Vietnam; less exists in print accounting for the origins and purposes for the lesser military units operating in restricted areas under the control of district and provincial Party headquarters—the Bo Doi Dia Phuong in the Vietnamese context. Because of the great strategic importance of this lesser regional force in the insurgent's picture, and its criticality to counterinsurgent planning, a word on this matter should be incorporated here.

Broadly, the regional Guerrilla exists to effect two goals. On the one hand, his operations oblige the counterinsurgents to decentralize elements of their own forces, prohibiting maximum concentration of force upon major armed forces once identified. At the same time, the presence of a disciplined fighting force locally, strengthens the hand of the Party organizer in the village engaged in mobilizing the population in mass organizations or in executing a work program or people's drive via the associations already established. While the first of the two functions performed by the regional force may not be underestimated in its consequences, it is this second role with respect to the local peasantry that deserves careful attention.

Upon the determination of the Party to commence a protracted social revolutionary war, the very first body to be activated is this one, the regional unit. That is to say, the organizational effort starts neither with the village militia, nor with the main-line force. Both of these latter bodies appear later, and in part, as a result of effective work with regional units. If the importance of the body is indicated by the priority attention it receives, once the Party commences the structuring of its insurgent organization, then the reasoning that leads the Party to initiate its effort specifically at this point is even more important. The Party does not propose to fight guerrilla war with the regional band. To the maximum extent possible, indeed, the Party will restrain the unit's members from engaging in any but the most marginal small-unit operations, just enough so that the local population will know of its existence. For the insurgency's leadership, the importance of the organization is primarily political, not military, and its primary mission from the outset is to support organizational efforts among the peasantry. They provide the terror which convinces where the words of the Party's agitation/propaganda cadre fail to accomplish this. And later, after the initial mass organization effort has gotten off the ground, the regional unit provides the local Party committee with the means of punishing opposition groups in the village who were provoked into revealing themselves as increasing pressure is placed upon the peasants to satisfy the insurgency's expanding requirements. The regional unit is the Party's instrument of retribution, building in the populace the belief in the movement's omnipotence and omnipresence. As the population accommodates itself to the fact that opposition is hopeless, the regional unit's utility declines with respect to the peasantry, allowing it to assume an increasingly military role; but it will remain ever ready to conduct demonstrations of strength to guarantee the Party members, lodged within the village's own associations, an overriding voice in local affairs.

5. THE TACTICAL ADAPTATION OF THE STYLIZED MODEL

If this constitutes a generalized model of a fully evolved Communist insurgency model under conditions of protracted revolutionary warfare, then its precise form in any one single instance will vary necessarily in detail. In Malaya and in the Philippines—where the insurgent effort failed ultimately—the intermediate echelons (District and Province) never materialized. In the latter case, the local civil organization assumed the formal character of Barrio Committees. In the present setting of South Vietnam, the model must be modified by inserting an additional vertical echelon of organizations across the board at the interprovincial level, directly beneath the Central Committee. And that latter body, together with its direct dependencies, the supreme military headquarters and the national executive of the civil organization (i.e., the NFLSVN), must be understood as functioning from north of the 17th Parallel or up against the Cambodian border in relatively secure areas.

If such an insurgent organization seems highly distinctive from a Western point of view—with its parallel Party, civil, and military echelons, each, in turn, recognizing further structural bifurcations—then it is a matter of importance to stress that when the current model operative in South Vietnam is compared with the other Communist insurgent organizations which have preceded it during the last thirty years, it is found to have contributed nothing new to the Communist storehouse of experience above the most trivial tactical level. The Vietnamese experience is not distinctive from the Communists' point of view. Neither the Party organization itself, the distinctive inner organizational practices it follows, the subsidiary organizations it has set up, nor the conceptual framework it has pursued in evolving its forces and contending with the constituted government of Vietnam for the political control of South Vietnam may be understood as unique in any sense. In prosecuting its subversion of South Vietnam, the Dang Lao Dong has introduced no combat technique, operational procedures, or political concept which is not already known from previous Communist ventures into the export of subversive insurgency. An investigation of the open literature produced by Communists during the first six decades of our century will provide the investigator with the precedents and rationale for all of the activities promoted by the current insurgent organization. Vietnam, then, is not the occasion for the commencement of a new type of warfare; it is rather a classic synthesis of a system of organizational principles and operational procedures evolved prior to the 1960's.

6. THE INSURGENTS' CONCEPT OF OPERATIONS

The building of this structure is a function of the reciprocal underpinning which the armed unit provides for the civil organization and which the latter associations, in turn, provide the former. Without the sting supplied by the rebel band at the outset of the process—to provoke cooperation in the village where the agitation and threats of the Party representative alone fail to convince—the building of mass organizations would, at the best, be inadequate. But at the same time, the strength and number of rebel bands will remain sharply curtailed until the Party organizer can dispatch personnel from the ranks of the peasant, youth, student, etc., associations to guerrilla assembly areas. For this reason, the task of the insurgent military force is not so much the destruction of opposing security forces, rather it is first, survival, and second, the support of the Party's organizational effort among the civil population. It is in this context that one should understand Mao Tse-tung's assertion in 1929 that "the Chinese Red Army is an armed body for carrying out the political tasks of the revolution"[1] or his declaration of 1938 that "political power grows out of the barrel of a gun."[2] On neither occasion may his words be understood as the vocalization of a militaristic attitude, of a readiness to surrender the fate of a cause to the successes of brute force on the battlefield. Military strength remains one of the instrumentalities available to the party through which it seeks to achieve independently determined, preconceived goals which may not be confused with military ends. Mao follows up his above statement of later 1938 by continuing, "Our principle is that the Party commands the gun, and the gun must never be allowed to command the Party. Yet, having guns, we can create Party organizations... we can create cadres, create schools, create culture, create mass movements."[3]

There is yet another point which deserves considerable attention in conjunction with the interrelated activities of the mass organizations and the military or paramilitary elements. It is precisely their concurrent efforts that convert the guerrilla war into a protracted social or class revolution. The task of the armed units, the terrorist bands and the assassins, is destructive with respect to (1) the nation's administrative executive machinery; (2) its class structure; and (3) the disposition of its wealth and political dynamics. These elements of subversion are charged with tearing down that which provided stability and generated support for the constituted authorities of state. But the genius of insurgent strategy will not permit it to stop at this point. If it did, then the combatting of insurgency would be a relatively simple task and the techniques we are employing in Vietnam would indeed be adequate to end the emergency. Concurrent with the destruction of what is, the insurgent provides the populace at large with the prototype of an alternate national administration which claims their loyalties and is specifically charged with aggressively winning adherents and provoking open support, not simply relying upon voluntaristic acclamation. It is the combination of these efforts, at one and the same time constructive and destructive, carefully substituting alternatives as it destroys that which exists, which lies at the heart of protracted revolutionary warfare and bestows upon it its distinctive character.

In implementing its controls over the population of a village, as an example, the Party will approach the peasantry through parallel avenues. On the positive side, it brings to the people (1) an ideology, tactically adapted to determined local needs and interests; (2) locally feasible action programs which would channel the activity of the people along lines desired by the insurgents and which can be justified—and this is a matter of importance—in terms of the ideology; (3) organizational forms, likewise derived from the ideology within which major categories of the local population can be integrated into corporate bodies under Party surveillance and

[1] "On Correcting Mistaken Ideas in the Party," Selected Military Writings of Mao Tse-tung, Peking: Foreign Languages Press, 1963, p. 52. This passage, perhaps one of the most decisive in all of Mao's writings, continues: "...The Red Army should certainly not confine itself to fighting; besides fighting to destroy the enemy's military strength, it should shoulder such important tasks as doing propaganda among the masses, organizing the masses, arming them, helping them to establish revolutionary political power and setting up Party organizations. The Red Army fights not merely for the sake of fighting but in order to conduct propaganda among the masses, organize them, arm them, and help them to establish revolutionary political power. Without these objectives, fighting loses its meaning and the Red Army loses the reason for its existence." (Italics added.)

[2] "Problems of War and Strategy," in Selected Military Writings of Mao-Tse-tung, p. 272.

[3] Ibid., pp. 272-273.

committed to the achievement of the advertised action programs. Negatively, the Party introduces terror, compromise, and the threat of large-scale retribution in order to stop short the faint of heart who might otherwise object in order to liquidate the pronounced maverick and to root out the agents of local, district, and provincial government. The regional forces of the insurgency become the principal instrument for the execution of this phase of the civil effort. To the maximum extent possible, these two efforts will be jointly undertaken. If it is correct to assert that the Party does not rely upon spontaneous cooperation from a population where its armed strength can be committed, then it will likewise avoid exclusive dependence upon brute force since, through its "message," it provides those who capitulate under duress with a means of justifying in their own minds their submission. But beyond this, within the mass organization, there is a distinct possibility that the movement can positively generate a vested interest in an insurgent victory among its captive supporters as they progressively compromise themselves by doing what they are told.

But if the orientation of the insurgent military unit is first of all toward the civil population and the overriding criteria in determining priorities for military units are local mobilization activities within the civil population, then it still remains a matter of the utmost importance to stress that the center of gravity in the insurgency as a whole lies with neither the military nor the civilian element, but with the party command structure itself, which, in its corporate personality, is the physical embodiment of the insurgency's ideological justification for taking place. If military forces and civil organization are indispensable to protracted revolutionary warfare, then they are not synonymous with "the insurgency" even when considered jointly as an integrated entity, for an insurgent condition may be said to have existed in the country in question long before either of these latter bodies was activated, back at a time when only the cellular party structure alone could be organizationally identified in the body politic. And this highly disciplined association of men engaged in subversion "as a profession"—to borrow a phrase from Lenin—will retain its strategically all-critical position during all of the later stages in the process.

Session 5
RESEARCH AND ANALYSIS - II

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COUNTERINSURGENCY SYSTEMS RESEARCH IN THAILAND:

CT, AND HOW TO FIND THEM (U)

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ABSTRACT

This paper illustrates the processes of systems analysis by describing the research design and results of a two-year investigation of requirements for surveillance systems for use in counterinsurgency operations in Thailand. The methodological difficulties which called for particular design consideration stem from the fact that requirements (in the cost/effectiveness sense) call for estimates of value, and the conflict process involved forces a mingling of political and military kinds of value at nearly every stage of analysis. The project sought to care for this by focusing on a few insurgent activities in one region, southern Thailand, and emphasizing qualitative rather than quantitative methods of analysis.

Estimates of the values of various systems -- if they were effective, their probable degrees of effectiveness with and without R&D, the extent to which each might be unique in performing its main surveillance function, and the dollar cost of each were considered in estimating the degree and kind of requirement for each system. The results of that analysis are summarized in this paper. It was not possible to conduct initially-planned comparative research in other conflict settings, so the results presented here apply only to present and near-future conflict settings in southern Thailand.

I. INTRODUCTION

This is a report of some of the main problems encountered and results achieved during two years' work in Bangkok by about seven men from SRI. We were working on an ARPA project, tasked to bring analysis to bear on the determination of requirements for surveillance systems for use in counterinsurgency in Southeast Asia, and in Thailand in particular. The requirements in question were to be operational ones, and not mere equipment specifications. The characteristic question was, "Of the systems which seem to be feasible, which would be sufficiently useful in practice to justify expenditure now?" --for procurement, development, or further analysis by someone.

It turned out that three interlocking kinds of systems[1] had to be considered if that objective was to be honestly serviced. The three systems to be analysed were: 1) the research process and the set of task interrelations needed to pursue our particular objective; 2) a selected conflict process within which to judge the feasibility and significance of surveillance; 3) a set of surveillance systems, each consisting of some way of getting data (a sensor) and associated methods or equipment to help in discriminating between useful and useless data.

This paper takes up those three kinds of systems serially.

1. <u>The Methodological Problem and Its Solution in This Case</u>

The first step in any systems study is to set the system boundaries--to estimate the size and disciplinary limits of the minimum field of investigation which can safely be treated in isolation. This always involves surgery, since no events are truly and completely isolated. If the ' .d is left too large, it becomes that much more difficult to determine the structure within it and the effects upon all other elements when one element is "improved." If really significant elements are cut away (in the process of trimming the problem to a workable size), utterly false conclusions may be produced.

We all know that military, political, and socio-economic problems are entwined within the study of problems of internal defense. It is only occasionally legitimate to separate those components, even for analytic purposes. There is no need to argue this beyond pointing out that internal defense might just as well be called violent politics, with murder as the tactical objective of many "political" rallies, and the changing of on-looker attitudes the real purpose of many a fire fight. This leads to the almost trite conclusion that this kind of work calls for team study by a group commanding widely different skills.

Having said it, the question is how to do it. Most who have tried have failed, and even the relatively successful tries have all fallen short of their designers' hopes.

The first demand upon our analytic design, therefore, was that it accommodate a full spectrum of disciplinary skills and that it provide natural pressures inducing such skills to <u>converge</u> on the issues pertinent to surveillance. Such convergence cannot be ordered to occur, since research is a discovery process.

[1]Each of us may have his own working definition of what a system is. I hope that no one is offended by mine; a system is a complex whole that is organised around a purpose and is sufficiently self-contained so that it may be studied fruitfully as a separate entity. Systems analysis involves learning enough about the interior workings of a system so that favorable changes may be designated.

A second demand was born of the need for evaluation, essential in any systems analysis intended to help authenticate requirements. That, in turn, implies finding some basis for asserting that one system is more "effective (i.e., has more advantages in practice)" than another and/or "costs" less (has fewer disadvantages). In analysis of regular war operations it has often been possible to relate both effectiveness and cost to dollars. Where political and physical parameters are equally important in a process, however, it rarely is possible to measure either advantages or disadvantages in terms of any common denominator. Except in those cases where analysis indicates that it is safe to treat these immiscible values separately, then, systems evaluations in the field of internal defense analysis ordinarily will have to be qualitative rather than quantitative. The design of a research program in this field, therefore, must make some specific provisions for facilitating such qualitative evaluations.

Thirdly, operations analysis and systems analysis earned their wartime reputations and their role in OSD budgeting by being practically useful, but most of the analyses completed in the field of internal defense have been regarded as impractical by operators in the field. That is, results of analysis have too often been informational, without showing how such information might be put to work. And, in reading many reports, it is hard to believe that the authors themselves could have pointed to the action (even if that action were further analysis preparatory to an actual decision) which should have been induced by their results. A research design, therefore, should include structural characteristics designed to impose responsibility upon the analysts involved.

We tried to accommodate these three demands in the following ways. The matrix layout of Fig. 1 shows the design concepts intended specifically to help induce disciplinary confluence, sound evaluation, and responsibility; such primary reasons for each concept are indicated by cross-hatching. Each concept, however, had collateral advantages, as indicated in each case by a cross.

The idea of focusing the attention of each team member on the conflict in a single area did, indeed, have its hoped-for effect of causing the results, by analysts who sometimes did not really talk to each other, to be functionally related. As indicated by the crosses, this idea also made it easier to deduce values by founding each separate effort in the same general conflict setting, with the same implicit definitions of victory and defeat. Finally on this point, our focus of attention on one area let us get personally acquainted with the officers and men of the Thai

Research Demands	Design Concepts		
	Study One Region	Study a Few Insurgent Operations	Work on All Stages in a C.I. Subject Slice
Multi-Disciplinary Confluence		X	
Basis for Value	X		
Practicality, Responsibility	X	X	

FIG. 1 RESEARCH DESIGN MATRIX

Border Patrol Police whose capabilities would (insofar as we might be successful) be enhanced through our efforts and whose corpses might mark our errors.

As indicated, the decision to focus on one or a few insurgent operations[2] was intended to help especially in the comprehension of the advantages or disadvantages consequent upon one or another modification of the conflict scene. Values then could be estimated in terms of the insurgent purposes interdicted through some particular enhancement of counterinsurgent surveillance capability. The effect upon practicality, however, was at least as great, and the chances of disciplinary confluence also were enhanced by this kind of focus. As regards practicality, the possession of a sensor able to tell if some sign of enemy activity were present would be trivial unless the surveillance system were to include means of estimating the meaning of the detected sign. It seemed imperative that we learn enough about particular insurgent activities so that we could decide on the significance of one or another manifestation of the activity in question. Before a hunter can judge the meaning of a tuft of fur caught in the brush, he must know the height, seasonal coloration, and habits of the animal for which he hunts; we had to learn corresponding things about insurgent operations, and it seemed clear that we would have a better chance to learn such details if we considered one operation at a time.

The third main design concept, of working on a set of linked tasks which were to carry the study of each surveillance system all the way from initial concept through practicality analysis and testing, was intended chiefly to induce analytic responsibility. The idea was (and we think that it worked as expected) that a formally designated set of reasons for performing each component analysis would help to prevent the kind of isolated, futureless results which have cut so deeply into the reputation of internal defense analysis. Also, we thought it less likely that one member of the team would be impractical in his recommendations if he realized that he or one of his teammates would be called on to implement such recommendations. "You think that these tests be undertaken? Okay, what test design did you have in mind?"

The foregoing has listed the main design concepts used in putting together the work program for our project and the advantages anticipated from each. All of the expected advantages emerged, to some extent at least, but there were attendant disadvantages to be considered by anyone who might want to adapt our design to his needs--and that includes SRI in its follow-on work.

[2]Those chosen were CT logistics, CT camp activities, and ambush.

First and most important, it is impossible to authenticate a requirement for any costly innovation based on operational needs in just one area. This was anticipated in the program design by allocating a full third of the total effort to comparative research, intended to check on the general validity of locally-based results. Second, and closely related, any surveillance system that works at all is likely to be useful for the detection of more than one insurgent operation, and again, the demonstration of utility in one application does not adequately reflect the value of the system in question.

The latter disadvantage was relatively well-cared for by treating several different operations during the course of the research, but we never were able to find the time or make the arrangements for the comparative research needed (as in Vietnam for instance) to overcome the parochial effects of the regional focus. As a result, while we think that several of our results are generally applicable to regions of Southeast Asia other than south Thailand and have doubts about some others, we cannot present firm grounds for that belief since we have made no careful study of the environment and operational differences involved.

In summary, then, as regards the research design itself, we feel that the design concepts employed proved themselves well enough in practice to justify their use singly and in concert in other projects of this sort. In particular, the idea of assigning a "subject slice" to one group--of having one study team responsible for all steps between concept and field application for particular systems--seems to have been highly advantageous and to have had no serious disadvantages.

2. The Conflict in South Thailand

a. Regional Considerations

It was decided after a few weeks' survey that our project should chose as its area focus the region just north of the Thai/Malaysian border, in which a small but excellent Communist politico-military movement has entrenched itself and in which it seemed possible that improved surveillance might make a significant difference in counterinsurgent capabilities. That region is shown heavily shaded in Fig. 2. The lightly-shaded region running up to the Kra Isthmus also was studied, but far less intensively.

The Malayan Communists (called "Communist Terrorists"--CT--by the British) were defeated in all levels of conflict during the Malayan Emergency of 1948 to 1960. As early as 1949, they seem to have perceived the probable future, at least one unit was ordered to leave

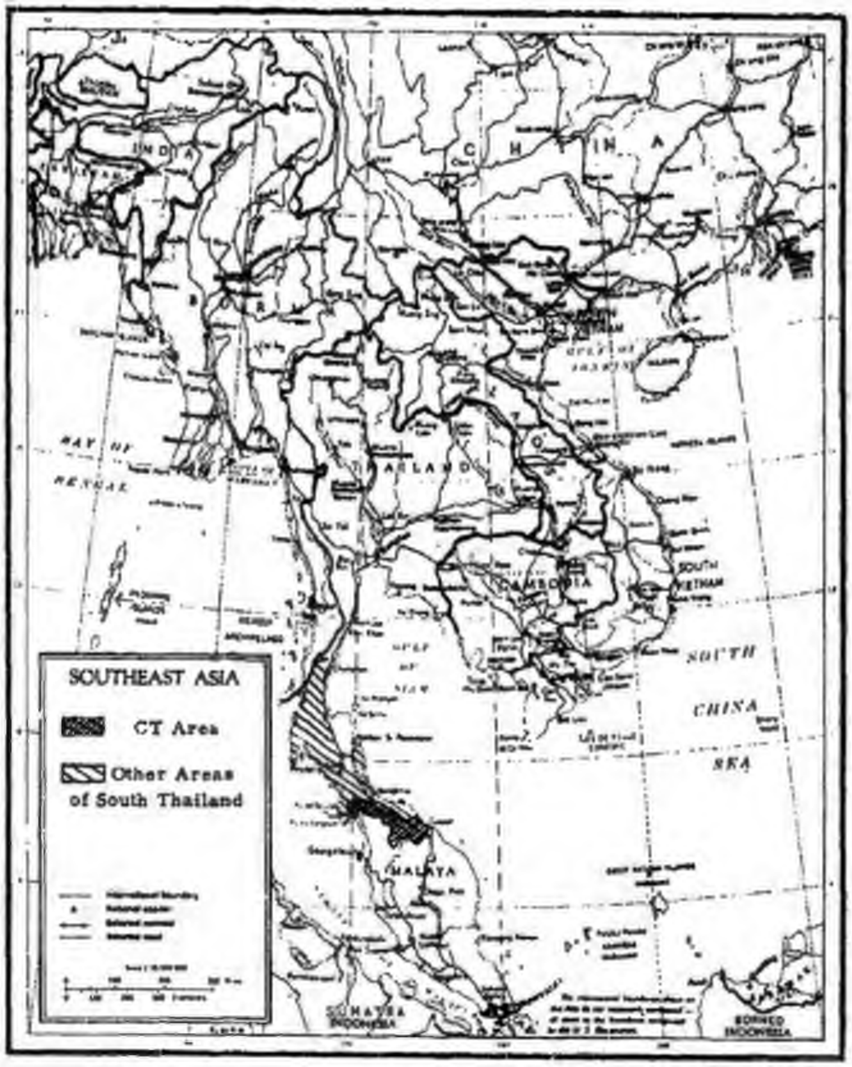
SOUTHEAST ASIA
CT Area
Other Areas of South Thailand
INDIA
CHINA
THAILAND
CAMBODIA
SOUTH VIETNAM
MALAYA
SOUTH CHINA SEA
BAY OF BENGAL

FIG. 2

southern Malaya and go directly to Thailand. In 1953 their commander moved his headquarters into south Thailand, and it has remained there ever since.

The strength of the CT is uncertain, but it seems generally agreed that something in excess of 500 trained graduates of the Emergency (and what a training that was!) were in Thailand just after that condition was declared ended in 1960. After a deliberate culling operation, in the course of which the CT offered its more faint-hearted members the chance to get out with some severence pay and without reprisals, the 1962 strength probably was down to something like 300. Since that time of minimum strength, recruiting has been going on, certainly in the Chinese enclaves and probably in the Muslim areas around them; most estimates of CT strength now run between 400 and 800.

The CT almost always go armed and are often found in uniform; they all are well-disciplined, and a high proportion appears to have had combat patrol experience. More than 260 of their jungle camps have been found in south Thailand. They have adhered to a strategy of avoiding armed conflict with security forces or of using more than a minimum of violence in their dealings with the local population. This seemingly "peaceful situation," as they call it in those of their internal papers which have been captured, has been maintained since their first organized appearance in Thailand. The emphasis during this time has been on the organization of support among the "masses," improvement of the internal coherence and politico-military quality of the CTO itself, and the development of a balanced and comfortably redundant system whereby village support can be transformed into effective logistic support for a guerrilla army in the forest.

These particular Communists are thorough Maoists, as proved by bales of training texts and other documents captured over the last six years. They apparently expect one day to have to turn to violence before attaining their objectives. The maintenance of a disciplined fighting force, therefore, is important to them. They draw detailed comparisons between their history and that of the Chinese Communist revolution; their trek from southern Malaya into Thailand is their "Long March," for instance, and the present phase of passive renewal and consolidation is their "Yenan" period. Their stated objective is to return to Malaya (having never really conceded that Malaysia exists) and conquer that country for Communism. It is quite possible, however, that the CTO may have better chances of success if it reverses its field and puts emphasis on operations against Thailand. In any case, it is in a geographical and organizational posture such that it may do so.

What then of the region where the CT live, and the people there?

Very briefly, the hills and forests look much like those south of the border in Malaysia. Off-trail movement is difficult, hiding is easy, the jungle itself would not support a CT army. The local ecology is one in which food is imported, bought with the proceeds from cash crops and mining. Rubber is the local king, and the pattern of cultivation is one in which the rubber groves lie adjacent to the jungle. The rubber tapper works by himself and often at night; he and the owner of the grove (who often is the tapper himself) obviously are vulnerable to pressure. Since they also are the ones most likely to have at least a small surplus of money on hand, it is no surprise that most CT fund-raising contacts seem to be made with such people.

The CT, thus, parallel the local ecology in their logistic pattern, drawing money from the rubber business and using it to buy supplies, many of which are imported from outside the region.

There are three local ethnic groups whose character and distribution are important to the conflict. The first of these is the Chinese, distributed in several enclaves. The groups near Betong and Sadao now seem to provide most of the tangible support and probably most of the recruits for the CTO. These people have lived in the area for many decades, and we know of no reason for thinking they have any basic ideological affinity for Communism. They just adhere, as does each isolated group of Chinese, to the local Chinese clique which can run things. In south Thailand, that clique is the CT.

The second is the Muslim/Malay community. These people are indigenous to the area; they are of Malay stock and culture and are almost uniformly followers of Islam. They form a local majority in each of the five southern provinces (four of which are adjacent to the border), and most of them surely do not feel any sense of primary identity with the Thai State. Neither, it seems clear, do they feel any affinity with Communism, but there are lines of affection leading toward Indonesia; the concurrence of objectives between the CT and the "Crush Malaysia" movement (in which Indonesian Communists seem to have had such an important part) may have opened bases for association between the CT and some of the more restless members of the Muslim community. More recent events in Indonesia have, we hope, had the opposite effect.

The third group, of course, consists of those who are ethnically Thai, most of them Buddhist. There are relatively few villagers of this type in the area, but among the ranks of the security forces and government officials of all sorts, the Thai form the elite. Only a few of the BPP, for instance, can speak or write Malay or Chinese, although one or the other of those languages is native to almost all people with whom they come in contact during their patrols.

To complete this hurried account of the overall conflict pattern in south Thailand, some comparisons are in order.

1) The mountain area in which CT camps have been discovered is about the size of the Sierra Maestra of Cuba; maneuver room is important to a guerrilla force, and that much room proved sufficient in at least one case.

2) As regards number of forces, Mr. Baxter of our research group commanded a force of about 350 guerrillas on Mindanao during WWII, again in an area about as large as that of the south Thai mountains. With those men, he was able to control effectively most of the out-of-town regions against a force of about 1,000 good Japanese regulars. The CT almost certainly have more than 350 trained members and more likely twice that many; there are evidently enough of them to constitute a dangerous force.

3) Furthermore, they have been in place long enough and were well enough trained by their prior experience so that we must expect them to have a soundly-developed support base.

Finally,

4) they are aptly located so as to threaten either Thailand or Malaysia, two of the very few firmly anti-Communist countries in Southeast Asia. It is doubtful, as far as is indicated by our work so far, that the CT could seriously jeopardize the government in either of those countries unless something else were to weaken them first, but the CT could be very damaging if either Malaysia or Thailand were to be seriously engaged in other internal defense operations. Our study included investigation of cases when one or the other were so engaged, and the CT elected to turn to guerrilla war.

The work of our research team focused on two insurgent operations within this conflict field, namely the logistic and camping activities of the CT. These are being reported in detail and must be briefly treated here. In each case, however, I want to try to lay out for you the basic pattern of activity, the importance of interrupting that pattern to the CT, and some of the opportunities for surveillance presented.

b. <u>CT Logistics</u>

The two key items here are: 1) the interface between the uniformed CT in their jungle camps and the population on whom they depend for supplies and whose attitudes and loyalties form the main CT targets at present, and 2) the management and transport systems within the forest.

The interface problem is being solved by the CT along the same lines which worked in Malaya (until extreme pressure had been brought to bear). Small cells live along the edge of the jungle and maintain contact with trusted individuals in the villages and rubber groves. The members of the cell (called an AWC--Armed Work Cell) can apply some pressure themselves, and if more "muscle" is needed, they can call on a heavily-armed group named the Mobile Unit, at least one of which is available in each of the three "regimental" areas into which the CT have divided the border region. Service is as important as force, however, and the AWC dispenses medicine and engages in a variety of "civic action" projects.

Orders for supplies are assigned to different AWCs by those higher in the CTO in a manner such as to randomize procurement insofar as possible. The AWC further assigns the procurement and either gives or promises the necessary funds to its trusted village agents (called Masses Executives), who then go and buy the supplies or have them bought. No one outside of the forest knows enough about the transaction to betray anything very important, and even the destruction of an AWC leaves many others like it to serve the procurement function.

Once procured and delivered to a temporary cache near the edge of the forest, the supplies are picked up by regular members of the CTO and portered either to more permanent caches or directly to consumers in the camps. Even within the forest, however, cellular subdivisions are used to insure against betrayal.

Communications seem still to be accomplished almost entirely by courier, so that corrective messages travel almost as slowly as the supplies themselves. The courier system is protected by cellular divisions, with redundancy to help minimize the chances of disruption.

Under the present level of stress, this system functions excellently, but its present strengths might turn to weakness at higher levels of pressure. As addressees are forced to move, supply shipments have to be redirected, and if such moves are frequent it is easy for confusion to grow. Correspondingly, the emphasis on secrecy and the limitation on knowledge allowed to any one person makes it relatively difficult to reestablish broken lines of association between the AWCs and the village supporters and to find caches after the few who knew their location have been forced to leave the area.

Pressure on the logistic system, therefore, (and the surveillance systems to aid in bringing such pressure to bear) are of little use unless pushed to levels where disruption starts to set in. After that point, however, it can be vital, contributing to the sort of overall system collapse experienced by the CTO during the last years of the Emergency. The threshold beyond which such saturation may be expected is not known and surely depends on the way in which pressure is brought to bear.

An exhaustive study was made of the kinds of materiel used by the CT and the criticality of each item, the kinds of people used to help buy and transport the different items, sources of funds, kinds of transportation used, and the type and characteristic locations of caches. The study of logistics has proved to be an excellent way of getting an understanding of how the CT live and how the logistic activities which are detected may be used to infer strategic intent.

The most important finding as regards logistics surveillance is, however, that no breakthrough is to be expected in the detection of the basic logistic processes of procurement, transportation, and storage of CT materiel. The insurgent system is well designed to minimize vulnerability to detection, and is masked by the flow of non-CT commodities to such an extent as to make it unlikely that any new sensor or data-handling trick will make a big difference. Reliance still will have to be placed on sound intelligence and police work within a balanced, many-sided attack. Analysis must make its contribution by helping to make small improvements in existing processes.

At least until effective civic regulations have been applied so as to make CT commodity movements more easily discriminated from innocent ones, nearly all of the opportunities to make such improvements seem to lie within the forest. Some of the more notable opportunities are shown in Fig. 7. The most promising item probably is the use of seismic detectors to monitor traffic along selected jungle trails[3], both to help predict the places and times for ambushing porters (and other CT) and for inferring the general locations in which strategic caches might be located. Such monitoring would, over time, permit formation of a more accurate picture of the whole CT pattern of life. It also would generate data on innocent living patterns for those who plan civic action projects.

The study of logistics led to the study of the consumption pattern centering on the CT jungle camps. It soon became apparent that camps were worth finding for reasons other than the interdiction of logistic operations, and a separate study was begun of that topic.

[3] Study and the construction of an experimental prototype have indicated that it is possible to develop a modular, wireless seismic system which can perform this monitoring function and serve as well as an improved aid to offensive ambush operations.

c. CT Camping Activities

This study can be summarized under the following heads: the character of CT camps found so far, the kind of camp system which may exist now, the value of detecting camps, and the main ways in which camp detection might be improved.

First, some 260 camps of various sizes have been found since the beginning of 1960. As of the time when we last worked over the statistics, data were available on 191 of them, indicating their map coordinates, estimated capacity in number of CT, date of discovery, and estimated period of occupancy. Those 191 camps are shown mapped in Fig. 3, with the crosses showing camps of estimated capacity greater than 24 CT, and the dots corresponding to capacities less than 25. Figure 4 shows the apparent shift toward short-term occupancy in recent years, a phenomenon which seems to indicate a basic shift in purpose of the CTO from rest and recuperation after its Malayan defeat to active subversion of local villagers. A number of particular camps have been visited by members of our group soon after their discovery by the BPP, but there is not time to say much about them here.

As regards the system as it may exist now, we think that the hypothetical layout shown in Fig. 5 gives about the right number of camps and has them distributed in a reasonable way. Indeed, a few of the symbols on this chart have been displaced slightly so as to avoid coming too close to some actually-suspected points. On this map, we have shown one camp for overall command, three for regimental command, two district command posts per regimental command, two training camps, and about 60 smaller camps to accommodate the AWCs and the command echelon just above them (the Armed Work Force). This then, or something like it, is the target system for surveillance systems intended to help find CT camps.

It would be desirable for many reasons to be able to find these camps, especially under conditions of surprise. Most of the documents captured from the CT (and on which so much of the current picture of the CTO is based) have been found in camps which were hurriedly evacuated. Additional knowledge of CTs has been gained by inspection of the living patterns evidenced in these camps. Relatively few have been found except by patrols which almost stumble onto them, however, and under such conditions, very few CT have been killed or captured. Furthermore, except, perhaps, for one period in 1961 (when 84 camps were found in one year), the rate of discovery and the intensity of associated pressure has not reached the point where the CT system of logistics or command-control was severely strained.

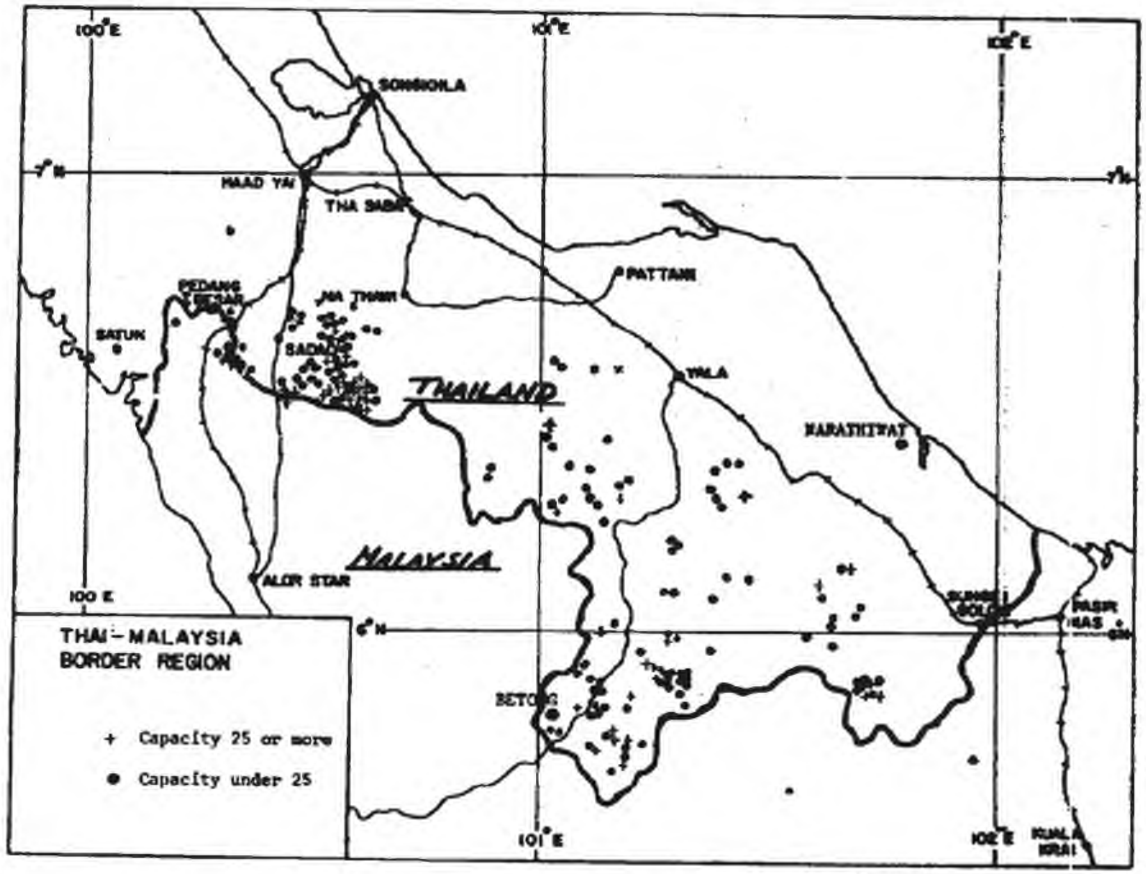

FIG. 3 DISTRIBUTION AND SIZE OF 191 CT CAMPS DISCOVERED IN SOUTH THAILAND

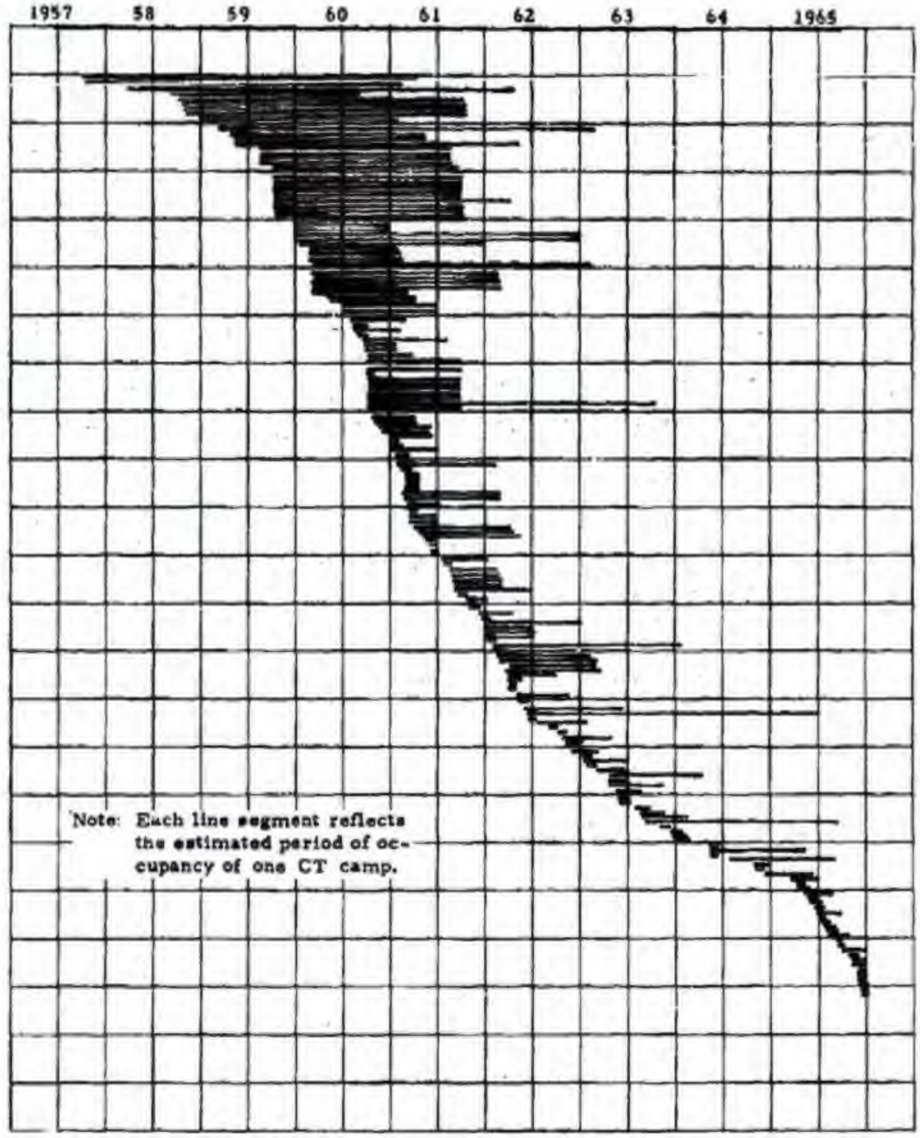

FIG. 4 LENGTH OF OCCUPANCY OF 191 CT CAMPS DISCOVERED IN SOUTH THAILAND

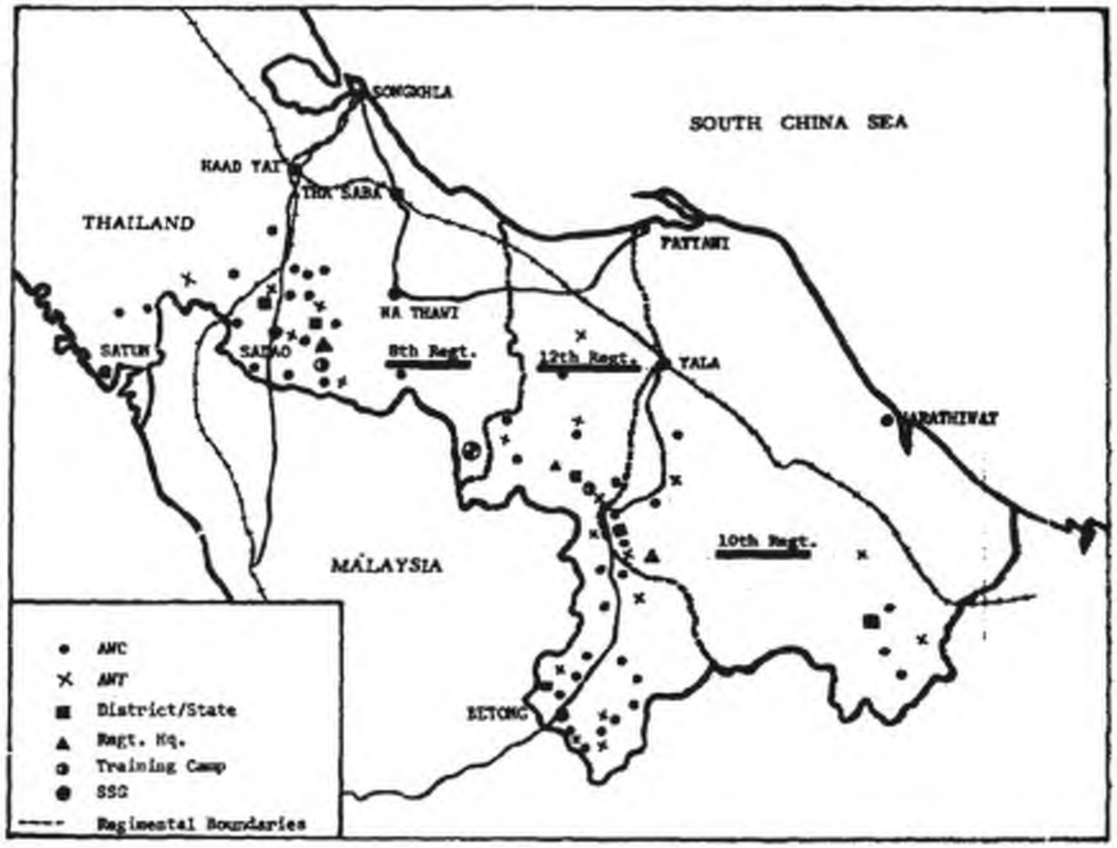

FIG. 5 HYPOTHETICAL DISTRIBUTION OF CT CAMPS IN SOUTHERN THAILAND

If the discovery rate and the conditional probability of surprise can be significantly raised,[4] however, camp discovery could have two very important advantages. First, such discovery might drive the CT into abandoning their uniformed, organized army, which (we have argued in the published material from this project) would cut severely into the CT image in south Thailand and into the insurgent potential of the movement. Second, combined with other suitable forms of attack, it would contribute to the collapse of the logistic and command-control systems, and inducing such collapse probably is the only way in which to defeat the CT without going through the desperate business of killing most of them.

There are five kinds of detection to be considered in connection with camp surveillance, namely the establishment of general location, of pinpointed location (essential to surprise and pre-planned ambushing), determination of camp size, and the post-discovery surveillance activities, search for caches, and the "bugging" of camps which may be reoccupied by CT. Fig. 6 outlines possible methods of accomplishing each of these, along with other surveillance functions pertinent to the conflict in south Thailand.

Which brings us to the consideration of the third kind of system which was investigated under this project, namely particular surveillance systems that we have tested against the criteria (notably, value if successful, feasibility, number of substitutes, and vulnerability to countermeasures) usually used in judging whether a system is worth buying and/or studying further.

3. Requirements

Surveillance systems employing magnetometric, IR, and seismic sensors were studied in detail during the 18 months or so of effective work spent in the field. The entre to each of these was different, but for each we were able to reach supported[5] opinions as to whether or not particular systems are sufficiently promising to merit expenditure now for procurement of existing equipment, development or tests of particular variants of existing gear, and/or analysis.

[4] A detection rate of 100 per year now would, we think, begin to strain the CTO.

[5] We certainly do not claim that any of these assertions of requirement have been "proven." We would argue that numerical proof of any of them is intrinsically impossible, and that our conclusions have the kind of logical and qualitative basis which we can defend before those who have the power and duty of decision.

The same kind of estimates were made for other systems which were studied by us in a much more cursory way; in each of these, the operational and technical data at hand were so limited as to preclude any really detailed analysis, and it was, correspondingly, impossible to support a requirement for anything very expensive. In several cases, however, the operational need and scarcity of alternatives seem to demand development work and further analysis by someone.

A number of systems for which requirements of some kind exist were left unstudied because of shortage of time. Among them are night vision devices and air pollution surveillance systems.

In addition, it was possible to reach conclusions concerning two kinds of supplements to surveillance systems which, while not systems in themselves, are nearly essential to effective surveillance in south Thailand. One of these is the photomosaic and the other the class of civic regulations used to moderate the socio-economic background against which many CT activities will have to be perceived and discriminated.

It would be unsatisfying, however, to leave the problem after considering only isolated surveillance systems. Each system could accomplish at best a part of the overall surveillance job against the CT and a set of systems will be needed. Some surveillance systems have many competitors, while others are unique in their function, and the value of achieving one kind of surveillance may be far greater than is the case with other kinds. These aspects of matter are reflected in Fig. 6, where an array of desirable surveillance functions are shown together with ways of accomplishing them.

Figure 6 deserves more explanation than we will have time to give to it.

First, there is the matter of relative value of surveillance functions. The ranking of importance of surveillance functions is highly subjective, but it has been possible to find some consensus among people familiar with the southern Thai conflict situation. The functions shown in Fig. 6 are ranked, as best we can, in terms of decreasing value, moving from left to right. The double vertical line divides those of particular value from those that seem to be of secondary importance, at least for the present and near future. Some example of our reasoning must suffice. The determination of the exact location of CT camps is vital since on it depends the chance of effective surprise attack, with the attendant advantages of increasing casualties and disruption among the CT as well as increasing the intelligence "take" from the camp and the trove of captured materiel. Knowledgeable members of the anti-CT forces of the Malayan

SURVEILLANCE SYSTEMS	Exact Camp Location	Detect Small Ambush	Attitude Measures	Concealed Weapons	Lay Ambush	Monitor Trail Traffic	Approximate Camp Location	Intruder to Fixed Install.	Camp Size	Final Search for Cache	"Bug" Cache	Detect Large Ambush
Magnetometer												
Varian Rubidium Vapor										S		
Other				M		M				M		
Seismic Detectors												
TI/Elliott					S			S				
Wireless..ambush/monitor					Y	Y	M	S			Y	
Depot Defense								Y				
IR Scanners	Y						Y					
Photo recce...direct observation	S						S		S			
Photo...CT cultivation							M		M			
Sonic Telescope		M									M	M
Water pollution measures							M		M			
Microwave scanner	M						M		M			M
Anti-ambush "radar"												M
Pupil-size measures			M									

FIG. 6 SURVEILLANCE OF CT

Emergency period have stated that possession of a capability for determination of camp location to about 50 meters accuracy, such as that proved for the IR scanners (during the November 1965 tests) might well have shortened the Emergency by as much as six years.

As other examples, surveillance in support of small-unit ambushes may be vital in any period of heightened activity in south Thailand, and it is listed accordingly. Detection of CT ambush, however, is less doubtful, since security forces may be expected to suffer heavy casualties and loss of weapons to such ambushes following any decision by the CT to abandon their present "seemingly peaceful" strategy in favor of active attack or defense.

Finally, action agencies in the field, both U.S. and Thai, have emphasized their present lack of any means of finding attitudinal targets for such counterinsurgent operations as psywar and civic action, especially where there are cultural and linguistic bars to communications. This item was judged worthy of first mention to us by spokesmen for the Royal Thai Army, the Thai Supreme Command, and the U.S. Special Forces at Okinawa.

Of the various surveillance systems which might help to accomplish the functions indicated, some clearly are applicable and are reasonably reliable in such cases, the word, Yes, or the letter, Y, is entered. In other cases, the surveillance system is known to work, but opportunities for observation or discrimination are doubtful; in such instances, we have entered the word, Sometimes, or the letter, S. In still other cases (in general, those where initial indications are favorable and further R&D are needed), the usefulness of the system for the function in question is doubtful; for these cases, we have entered the word, Maybe, or the letter, M.

Surveillance entries for the more valuable functions are especially sparse. Only one surveillance system now offers to pinpoint the locations of CT camps with even reasonable frequency (the IR scanner) and only one follow-on system (the microwave scanner) appears to offer a promising substitute for the IR if it were to be defeated by countermeasures or continuing problems of discrimination between friend and foe. Correspondingly, only the wireless seismic monitor system (with possible back-up from later kinds of magnetometers) seems likely to "hack" the job of road and trail monitoring. A sonic telescope may help a skilled woodsman in detecting small-unit ambushes in the forest, but the chance is slim.[5] Existing seismic detection equipment can and is being used to help out in offensive ambush situations, but its dependence on wires precludes its use in many especially promising, operational situations; a wireless version to meet this disability is feasible. Finally, there are some promising possibilities of field measurement of attitudes of approval and disapproval using nonverbal responses as indicators, but we were unable to find any other means by which surveillance could aid in the task of selecting and assessing civic action projects.

Related questions of technical feasibility and "signal/noise" relationships are treated in our detailed reports. Here, it must suffice to record our main conclusions as to the priority requirements for procurement or R&D of particular surveillance systems for use in the near future in south Thailand. Estimated requirements (ranging from essentially none, shown by a dash, and very high, shown by three crosses) are shown in Fig. 7 for each of the surveillance systems studied under this project. The first-priority list is shown in Fig. 8.

[5] Since this research was completed, the testing of instruments which sense human presence by detecting atmospheric pollutants has indicated the feasibility in many operating conditions of an ambush detection system using such a sensor.

Surveillance System	Value if Effective	Effectiveness Now	Effectiveness Potential, R&D	Uniqueness	Cost	Procure, Use	Develop	Research & Tests
	Assessment Parameters					Requirement for:		
Magnetometer								
. Varian Rubidium Vapor	x	x	x	xx	x	-	x	x
. Other	x	-	x	xx	x	-	x	x
Seismic Detectors								
. TI/Elliott	x	x	-	x	x	x	-	-
. Wireless - Ambush	xx	x	xx	xx	x	-	xx	x
Wireless - Monitor	xx	x	xxx	xx	x	-	xx	xx
. Fixed-base Defense	xx	x	x	[illegible]	xx	x	-	x
IR Scanners	xxx	xx	xx	xxx	xx	xxx	x	xxx
Photo Reconnaissance								
. Direct Photo	xxx	x	-	xx	xx	x	-	-
. CT Cultivation	xx	x	x	x	x	x	-	x
Sonic Telescopes, Scouting	xx	-	x	xx	x	-	x	xx
Water Pollution	xx	-	x	x	x	-	-	x
Anti-Ambush Radar	xx	-	x	x	x	-	x	x
Microwave Scanners	xxx	-	xx	xx	xx	-	xxx	xx
Nonverbal Attitude Measures	xx	-	xx	xxx	x	-	x	xx
Photomosaics	xxx	xxx	-	xx	xx	xxx	-	-
Civic Regulations	xxx	x	xx	xxx	xxx	x	-	xxx

FIG. 7 SURVEILLANCE REQUIREMENTS, FOR USE IN SOUTH THAILAND

Pinpoint CT Camps

1. IR Scanner

   (Min. procurement for tactical use)

   (Analysis of discrimination problem)

   (Regular production of mosaics)

2. Microwave Scanner, follow-on to IR

   (R&D)

Trail and Road Monitoring

1. Wireless Seismic Systems, long-duration

   (Develop and test)

Laying Ambushes

1. TI or Elliot (procure minimum quantities, and test)

2. Wireless Seismic System, short-duration

   (Develop and test)

Defend Against Ambush

1. Woodsmanship Extension with Sonic Telescope

   (Procure and field test with woodsmen)

Rapid Detection of Villager Attitudes

1. Nonverbal Attitude Measures

   (Experiment with pupil dilation)

FIG. 8 FIRST-PRIORITY SURVEILLANCE REQUIREMENTS, SOUTH THAILAND

(b)(6)

[redacted]

VIET CONG MOTIVATION AND MORALE STUDY (U)
~~(Confidential)~~

[redacted]

The RAND Corporation
Santa Monica, California

ABSTRACT
(Unclassified)

This paper describes major procedures and some findings of an ongoing study of Viet Cong Motivation and Morale being conducted by The RAND Corporation in Vietnam, chiefly on the basis of extended interrogations of personnel formerly in the Viet Cong, or under its control, or in the North Vietnamese Army. Commencing in June 1964, Phase I of the study dealt with subjects with experience prior to the major escalations of 1965. Phase II of the study, commencing in January 1965, emphasizes the effects of weapons systems on motivation and morale, and probes for motivational vulnerabilities.

In the spring of 1964, [redacted] asked The RAND Corporation to undertake a study of the Viet Cong--who is he, why does he join, how is he motivated, and what is his morale? In May, [redacted] and [redacted] of The RAND staff were able to make arrangements with the Government of Vietnam (GVN) for RAND personnel to interrogate persons formerly in the Viet Cong, or under its control, under conditions permitting fruitful and objective work.

During the summer of 1964, two RAND consultants, [redacted] and [redacted] assembled a staff of Vietnamese interviewers, drew up an appropriate questionnaire, made detailed arrangements with GVN agencies for access to subjects, and began trial interviewing and revision of the questionnaire.

As initially drafted, the questionnaire included nearly 500 questions since we intended to do far more than simply to ask our respondents what their morale was; what they thought the morale of their units or their superiors was; and what their motivations were to join the Front, to stay in it, or to leave it. We asked all these questions, but also probed deeply into the context of environment and action within which morale played its role, and motivations could be seen in action. The questionnaire explored the subject's family status and history, education, religion, economic status and function, political role and attitudes, main characteristics of his village (defense and security, economics, educational and medical facilities, organizations), circumstances of joining the insurgents, use of information media, participation in self-criticism sessions, political perceptions and attitudes toward the GVN, the Liberation Front, the French, the Americans, the North Vietnamese, etc.; the subject's combat experience; his life in the VC (including food, rest, health, relationships with women, awards and citations, letters, leave). The questionnaire also explored the subject's manner of leaving the Front, whether by capture, desertion or rally; and, finally, his evaluations and comparisons of the Front and the GVN.

The first interview is dated in September 1964; during the six months ending December 1964, 147 interviews were produced. These 147 interviewees fell into the following categories:

Prisoners		65%
Southern	36%	
Regroupees	29%	
Defectors		21%
Suspects		11%
Infiltrators		3%

About one-third of the sample were Party members; somewhat more were cadres (i.e., assistant squad leader or higher in military formations; equivalent civilian ranks).

This group of subjects, with its strong representation of prisoners, Party members, cadres and regroupees, provided us with important clues to the motivation of relatively hard-core VC to join and stay in the movement in the period prior to VC efforts to increase their forces drastically, prior to substantial involvement of regular PAVN formations, prior to the commitment of U.S. combat troops, and prior to the bombing of North Vietnam. The older revolutionaries saw the struggle as a continuation of the war for independence from the French, and the regroupees, in particular, combined such nationalist motivations with resentment toward the GVN for its failure to permit reunification of the country and thus allow them to return home to their families. The younger interviewees joined for a mixture of motives, including protest against social injustice at the village level, lack of educational and career opportunity under the GVN, antipathy to the GVN draft, adventurousness, desire to escape from unpleasant personal circumstances, admiration for older Viet Minh members of the family, all intermixed with a desire to "chase out the American imperialists and their lackeys," and thus to liberate and reunify the country.

This early group also pointed clearly to the effectiveness of VC political control mechanisms, such as the three-man cell, the frequent criticism or

Kiem Thao sessions, the watchfulness of the Party, and the intimate and sustained control exercised by the cadres. Many of these subjects recognized that their immediate material life was miserable, but responded to the call of idealism as well as the hope of personal advancement. They expected a long war that might not be ended by a VC victory, but by exhaustion of the enemy.

These positive motivations were unfortunately reinforced by VC propaganda that the GVN would certainly beat, torture and eventually kill any ralliers or prisoners after all useful information had been extracted from them. The all too frequent cases in which the GVN did treat its suspects or prisoners severely gave some grounds for these charges.

Nevertheless, defections did take place, and our subjects attributed them to their inability to stand hardships or prolonged separation from home or family. While defectors sometimes attributed their defection to dissatisfaction with their personal roles in the movement, they did not usually disavow VC political aims. The second generation of VC, interestingly enough, did not show any deep comprehension of Communist doctrine; they envisaged VC goals as "peace, independence, democracy and neutralism"; socialism was vaguely held to be a good thing, but not clearly related to Communism. The early group characteristically underplayed Hanoi's role in the movement, tending to regard the struggle as by and for Southerners. Many were unaware of the role played by the outside Communist powers; they were seldom aware of the Sino-Soviet split, or of the extent of Chinese aid.[1]

In December 1964, the project passed into a second phase as [redacted] and a team of four or five RAND personnel replaced [redacted] and [redacted] in Saigon. Phase II called for more emphasis on the impact of military operations and weapons on the Viet Cong and the civilian population, with increased attention to VC vulnerabilities, both to conventional weapons systems and to psychological warfare. We continued to rely on the extended interview as our major data source. We shortened and sharpened our questions on the subject's judgments of attitude and affect, and added questions of an operational nature, of interest to our sponsors and to field agencies. This shift was compatible with the project's underlying method: to test subjective judgments against operational evidence emerging from largely unstructured accounts of personal experience.

We not only revised our general questionnaire, but prepared several specialized questionnaires, while maintaining flexibility to add new topics as the

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[1]These findings are reported in [redacted] Viet Cong Motivation and Morale: A Preliminary Report (U), Confidential, RM-4507-ISA, March, 1965.

developing situation required. The general questionnaire provided an opportunity to explore the subject's observations and experiences prior to joining the VC, the manner of joining, life in the VC (with attention to his experience of ground operations, air operations, and defoliation and crop destruction); and the circumstances of capture, desertion or rally. Examples of topics added in view of the developing situation were bombing of the North, increased U.S. participation in in-country air operations, and the increased U.S. combat presence. The special questionnaires dealt with the situation in Dinh Tuong Province (where we were especially interested in data useful in improving psychological warfare), with refugees, and with herbicide operations. The Dinh Tuong schedule provided additional probes into the communications environment; the authority structure in VC areas, formations, or in contested areas; the composition of VC leadership; attitudes toward civilian and military cadres; career opportunities, fulfillment, and frustration; attitudes of villagers toward military formations and activities; battle experiences; differences in weaponry between the VC and ARVN formations; observations of morale; responses to VC control and morale-building techniques; family contacts and conditions; expectations of victory; and exploration of the conditions and act of rallying.

Our current practice is essentially the same. Interviews are administered chiefly by Vietnamese personnel; occasionally, the RAND supervisor conducts the interview, using the Vietnamese as an interpreter and recorder. Choice and phrasing of questions are left up to the interviewer in the interview situation. Occasionally the entire questionnaire is administered, but more often the interviewer asks only those questions that seem appropriate to the interviewee's experience. If the interviewee proves to be an unusually good source of information on an important topic, the interviewer may explore this in detail, at the expense of other parts of the questionnaire. In most cases, the interviewer covers a large part of the questionnaire. Interviewers give a brief assessment of the interview situation, reporting anything that might affect it seriously, and commenting on the veracity, the responsiveness, and the _bona fides_ of the interviewee. The interviews are written up in Vietnamese either from handwritten notes or from tapes, and then translated into English (sometimes via French). After preliminary review by a RAND supervisor, they are revised. The final texts reproduce the questions actually asked, and either a verbatim report or a near-verbatim summary of the respondent's answers.

Most of the subjects have been quite candid and willing to talk, and even willing to express opinions or attitudes, or to report occurrences that would be displeasing to the interviewer. A few hard-core VC took the interview as an opportunity to propagandize the interviewer. Others expressed firm faith in the Front, its aims and its practices, while asserting a robust confidence that the

VC would win, despite an admitted superiority in men and weapons on the U.S./GVN side.

Time spent on each interview varied markedly. A few interviews had to be terminated in an hour or so, because of tight transportation schedules; some valuable material has thus been lost. Others were short simply because the informant had little to contribute, or because adequate translation facilities were lacking (for some Montagnard subjects). Most interviews take several hours to complete. Others last through several days. Since the chance for call-backs is rarely good in the field, we have had to be content with what we could get at the first interview. In Saigon, the opportunity to call back is better, but the number of interviews made there is necessarily limited.

Our sample has provided a rich store of data, much of it unique, but posing difficult questions of validation and generalization. A rigorously representative sample is an impossibility today; Vietnam does not have comprehensive or reliable enough census information to permit the creation of a model to which a sample should conform, and even if the model were feasible, the opportunity to select the sample, given the conditions under which Vietnamese prisoners of war, refugees, ralliers, or villagers are held or housed, is absent.

Our intention has been to create a data base that includes substantial representation of all major segments of the social and functional groups in which we are interested, with appropriate geographical distribution of places of origin and of experience in the VC. For the VC, our subjects include both military and civilian personnel; rank and file and cadres; Party members and non-Party members; personnel from hamlet and village guerrillas, Local Forces and Main Forces; regroupees, infiltrators, and Southerners who did not regroup; members of the PAVN serving both as members of PAVN units, or as cadres or support personnel for VC formations. We have geographical representation from the various operational regions into which Vietnam is divided, i.e., the former Annamite provinces in the North, the Central highlands, the Central lowlands, the jungles of Zone C and Zone D, and the delta regions from Saigon to the Southwest.

We have adequate representation from all four Corps Tactical Zones. We have some representation of the major Montagnard tribes, along with representatives of religious sects. Our respondents range in economic status from very poor farmers to rich farmers or their military equivalents, with emphasis on the lower end of the spectrum. In terms of social status, we have strong representation of the poorly educated and lower occupational ranks. We do have a few district or provincial civilian cadres, with more village and hamlet cadres although most of our civilians are rank and file. In the military hierarchy, our highest rank is senior captain, with a sprinkling of lieutenants, aspirants, and senior sergeants--all considerable ranks in the Front, where a squad leader is a respected cadre in the eyes of the rank and file. Again, most of our respondents are lower cadres or rank and file.

In raw results, the project has produced, up to 1 June 1966, nearly 800 finished interviews as follows:

147 Z series (Phase I, prior to 1 January 1965)
400+ AG series (Phase II, general, after 1 January 1965)
60+ AGR series (Phase II, refugees, May, 1965)
120+ DT series (Phase II, Dinh Tuong ralliers and prisoners, May, 1965)
30+ H series (Phase II, herbicide effects, February, 1966)

Project leaders periodically provide short, comprehensive briefings to top officials in Washington and the field.[2] These presentations cover not only assessments of continuing trends, but also clues and implications emerging from the more recent data that are of special interest, and that may prove on more intensive analysis and after further data collection to form important elements of the assessment of vulnerabilities and estimates of the situation. Characteristically, they cover effects of GVN/U.S. military operations (air power, artillery, ground forces, defoliation, impact on Viet Cong operations, reactions of the population); Viet Cong vulnerabilities (failure to make major gains, plus declining faith in VC victory; effects of increased U.S. participation in military operations); problems of VC recruiting and force composition; problems of performance and morale among lower ranking VC cadres; problems arising from continuing VC defection and desertion; bombing of North Vietnam; the North Vietnamese soldier; VC problems of controlling population and resources; VC and North Vietnamese weapons; expectations about duration and outcome of the war; and suggestions for U.S./GVN actions.

Some of our more interesting interim results deal with refugees, with B-52 attacks, with cadre relations in Dinh Tuong Province, and with crop destruction and defoliation. As for the latter, we have found not only the expectable expressions of resentment of the damage inflicted, but also a somewhat surprising willingness to put part of the blame on the VC for having provoked such measures. More to the point has been the uncovering of an extended, systematic VC propaganda campaign on the subject that opens up some interesting possibilities both for U.S./GVN operations and for psychological warfare, because of the systematic VC falsifications of the deadliness of the threat. These falsifications, when exposed, reduce credibility in VC statements, and the widespread fears lead to odd and clumsy countermeasures that could hamper VC operations seriously.

Our subjects indicated that B-52 bombing faced the cadres with new and difficult problems--how to maintain morale and operational cohesiveness in the face

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[2] The most recent example is [redacted] Some Findings of the Viet Cong Motivation and Morale Study: June-December 1965 (U), Confidential, RM-4911-ISA/ARPA, February, 1966.

of devastating attacks appearing without warning, and often in places the VC had long regarded as safe from enemy attacks.

As for refugees, our materials indicate, inter alia, a very serious impact on the VC supply system of the loss of nearly 900,000 persons to GVN control. VC cadres are troubled about the implications for intelligence and the loss of control over such persons; they are equally troubled over their inability to protect the refugees while still in VC territory, and their inability to keep them from leaving when they find conditions intolerable.

The Dinh Tuong interviews proved to be especially valuable in casting light on the position of the VC cadres. They showed the existence of cliques and favoritism among them and revealed strains and stresses imposed on the cadre structure by a VC program for combing out unnecessary administrative cadres and reassigning them to military duties. They pointed to further strains imposed on lower cadres caught between upper cadres, the villagers, and the rank and file.

A series of more extensive analytical works is in progress. One of the first of these to appear is an extensive analysis of the Chieu Hoi (i.e., defector) program, published in May 1966.[3] Because of the relevance of the act of desertion or defection to questions of motivation and morale, some findings from our Chieu Hoi study may be of interest.

Despite uncertain GVN leadership and frequent administration changes, and notwithstanding the physical dangers of defection and the threat of VC reprisals against the families of defectors, the flow of VC ralliers, though small and fluctuating, has never stopped. Rallying has increased during recent months, reaching 2082 in February, 1966. The chief factors favoring rallying, in our opinion, are:

Military effectiveness of the GVN.

Growing hardships of life in the VC.

War weariness and disappointment in VC policies, promises and actions.

Increasingly ruthless VC recruiting methods.

More favorable perception of the Chieu Hoi program, of the GVN and its promises in general.

Forty-nine percent of the ralliers come from the Delta. Ralliers come from all major components of the VC, and from North Vietnamese units, too. They include military and civilian cadres, Party members, and regroupees, many with long-term service in the VC. The proportion of military ralliers is increasing.

In the opinion of our subjects, the main reasons for rallying were these: physical hardships, economic needs of the family back home, escape from criticism

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(b)(6) [redacted]t Cong Motivation and Morale: The Speci[redacted] RM-4830-ISA/ARPA, May 1966.

or punishment, fear of death in battle, and homesickness. Less frequently mentioned were a desire to escape from enforced service in the Front or to escape from U.S./GVN air attacks. Others mentioned loss of faith in VC victory, resentment because a relative had been killed by the VC, or revulsion against VC terrorism. Other motives cited were grievances, denials of home leave, quarrels with superiors, objections to puritanical controls over personal behavior, restrictions on personal freedom, or failure to be promoted. Surprisingly few interviewees cited VC defeats or losses as reasons for their own rally, although they more frequently attributed the rallies of others to such reasons.

Personal, rather than ideological factors seem to motivate most ralliers. Hence it is not surprising that some persons who rally continue to express full or partial approval of VC aims, although some ralliers reject them in toto, in the light of their experience of life in the Front. The interviews show that in many cases indoctrination is not sufficient to overcome personal disappointment, fear, or weariness, and that once the immediate interests of the individual predispose him to rally or desert home, the belief in VC aims and other ideological factors apparently play little or no role in his considerations. This is borne out by the current expectations and behavior of many ralliers, who seem to have no difficulty in accepting service in the GVN as soon as the GVN will take them, and to turn both psychological and hardware weapons against their former comrades.

Deterrents to rallying included fear of mistreatment by the GVN, the difficulty of getting away from one's unit; the fear of reprisals; inability to go home to an area controlled by the Viet Cong; tight supervision over VC personnel; and ignorance of the terrain. The Viet Cong recognize the Chieu Hoi program as a serious threat and take elaborate measures to anticipate, prevent, and offset the effects of rallying. Ignorance of the Chieu Hoi program plays some role in depressing the rate of rallying, but this factor is diminishing in importance.

We have examined the communications channels by which VC learn of the Chieu Hoi program, and have made some judgments about the conditions favoring persuasiveness and credibility of Chieu Hoi appeals. VC learn of the program through many channels, the most important of which are word-of-mouth communications, especially via family or close friends. Leaflets and airborne broadcasts play an important role, as do the conversations of villagers, especially during the period prior to joining the VC. As for credibility, the reinforcement of appeals through various media seems to enhance it; the single most persuasive and trusted channel is the family. Next is the appeal of a former colleague who has rallied and by leaflet or airborne broadcast calls on his former comrades to come out and reassures them about the kind of treatment he has received.

We have made numerous suggestions about how the content, timing, and targeting of Chieu Hoi appeals could be improved, with special reference to cadres, to regroupees, and to PAVN personnel. We are also hopeful that the Chieu Hoi program can play a role in the long-run political reorientation of the GVN, and can exercise full pressure on the VC by helping to demonstrate that a VC victory is not essential to the achievement of Vietnamese personal or national aspirations. Hence we have proposed more vigorous and better sustained support for the program, both from the GVN and from U.S. government agencies.

Work in progress includes an intensive examination of our data for implications concerning changes and stresses in the position of the middle and lower VC cadres, especially as they are revealed by our intensive interviewing in Dinh Tuong Province. We expect shortly to publish a profile of the PAVN soldier, as he is revealed by our interview data. We are completing studies on the political motivations of the Viet Minh regroupees, and on the recruitment of VC cadres. Two specialists are preparing a profile of the typical VC cadre. Two others are studying both interviews and captured documents to make a better assessment of the role of the Party in the VC. We also have under way studies of VC operations and policies at the village level, and of VC control mechanisms at that level and elsewhere. The project is open-ended and continuing.

Session 6
SPECIFIC APPLICATIONS OF TECHNOLOGY

(b)(6)

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(b)(6) [redacted]

CLOSE AIR SUPPORT AVIONICS

FOR

COUNTERINSURGENCY APPLICATIONS (U)
~~(Confidential)~~

(b)(6) [redacted]

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ABSTRACT
~~(Confidential)~~

The problems of realizing an effective close air support capability for counterinsurgency operations are reviewed. A selected set of close air support avionics packages which might be suitable for use in an aircraft operated by indigenous forces is discussed. It is suggested that invocation of fairly sophisticated weapon system concepts in conjunction with relatively simple avionics equipment can yield a system which is effective in terms of tactical responsiveness, precision of weapon delivery, and which can function with an acceptable burden in terms of training requirements, maintenance, and cost. A system (and tactics for its use) is described which purports to realize these goals; comparisons are drawn with a number of alternate configurations.

I. INTRODUCTION

This paper describes a relatively simple avionics system for close air support in counterinsurgency operations. Two basic ground rules were adopted* in developing the rationale for equipment selection:

(1) It is likely that the systems will be used by indigenous forces.

(2) The targets are people (with simple weapons) who will try very hard to remain hidden in the terrain.

The first rule has several important implications. First, the aircraft used for close air support (and its avionics complement) must be as simple as possible, consistent with adequate mission performance. This requirement stems from the need to minimize training and maintenance requirements, while obtaining the earliest possible operational proficiency. A design goal would be to achieve the close air support weapons system on the basis of a

*At the suggestion of (b)(6) [redacted] of the Institute for Defense Analyses.

twin-engine aircraft with an empty weight of 6,000 lbs., carrying a two-man crew and an ordnance load of 1500 to 2000 lbs., at a speed of 225 knots. In the considerations leading to the conclusions reported here, it was assumed that U.S. advisory personnel would be available to assist in training and maintenance, however.

With regard to the second ground rule, the inference drawn is that the likelihood of target acquisition by the aircrew can be discounted completely. Both analysis and operational experience indicate that acquisition (e.g., visual detection and recognition) of close air support targets is quite problematical even for conventional warfare. As far as the present discussion is concerned, target acquisition by the aircrew is a bonus factor, but the system must be specified to function without it.

The role of close air support in counterinsurgency by indigenous forces has certain implications in itself. First, the mix of preplanned versus unplanned strike missions will shift its proportions strongly toward the latter, in contradistinction with the use of close or direct air support in conventional warfare. The availability of more effective reconnaissance and a stronger intelligence base (and better counterintelligence) in conventional war permits a preponderance of close air support operations to be carried out on a preplanned basis, with the capability for unplanned strikes being maintained to handle unforeseen contingencies, which are hopefully few in number. In counterinsurgency, the unforeseen contingency is practically a rule of the game. Ambushes and surprise attacks are typical; conversely, contact with the enemy during sweeps and other planned movements cannot be guaranteed because of the shortcomings of counterintelligence.

Accordingly, the emphasis of the considerations of the present paper has been on achieving responsiveness of the close air support weapons system to the immediate and urgent needs of a relatively small ground party, and on achieving the coordination and selectivity of response to those needs required for effectiveness. In this regard, it should be noted that the classical criteria for effectiveness (such as the fraction of targets killed per sortie, or the probability of achieving a specified damage level on a single pass) appear to be less relevant for counterinsurgency operations than for the planned strikes of sustained conventional warfare. In part for these reasons, no attempt has been made to develop quantitative measures of effectiveness, which must account for the value of harassment, and the value of disrupting an attack or facilitating escape from an ambush. The qualitative criteria that have been adopted as guide-lines include day-and-night, nearly all-weather operational capabilities, and reasonably small weapon delivery errors.

The desire for an operational capability under nearly all environmental conditions stems from the need for timely responses; the delivery error criterion stems from a need to avoid saturation bombing tactics whenever possible, because of the cost of such operations and because of the danger to friendly troops in close proximity with the enemy.

In the light of this discussion, the specific requirements on the avionics system begin to appear. The standard functions of flight control, navigation, communication, and weapon delivery are of course required. The most important function, however, is one that has not been emphasized strongly in system designs in the past, with the result that users are forced to adopt procedures and techniques that get around the shortcomings of the avionics. This function might be called designation, and relates to the process whereby the ground unit and the aircrew establish a common spatial frame of reference, and in which the target location in that frame of reference is communicated to the aircrew. One can illustrate the frustrations of trying to use modern attack aircraft for close air support by asking what good is a mortar-fired smoke shell to an aircraft with a high-performance, sophisticated, multi-function radar; or, conversely, why is the radar needed when the target has been marked with a smoke shell? This is not to say that smoke shells are the answer to the designation problem, but rather to illustrate the gross disparity between the needs for counterinsurgency close air support and the capabilities of our modern weapon systems.

The approach adopted in writing this paper was not one of achieving the greatest possible total mission capability, but to attend strictly to the needs of the counterinsurgency close air support mission. The result is a configuration that has been qualitatively optimized for this mission, by meeting the requirements at minimum cost, as measured in terms of dollars, maintenance and support burden, and training requirements.

A word is in order with regard to the matter of combat attrition. When an effort is made to rescue an ambushed unit by means of ground forces, a known risk must be taken that the rescuing party will itself be enveloped in a larger ambush, but the risk is taken. Even if the rescuing forces do join with the ambushed unit, the possibility exists that they will be collectively defeated, but the risk is taken. The position taken here is that in view of the second ground rule stated above, the responsiveness, mobility, and fire-power of the close air support system minimizes the risk that must be taken for a given investment in deployed forces.

II. MISSION AND EQUIPMENT CONSIDERATIONS

A. Qualitative Mission Analysis

As a basis for discussion, it will be assumed that the counterinsurgency close air support mission is unplanned, and that the strike aircraft is operating out of a fairly primitive forward-area base within 100 nautical miles of the zone in which support operations are to be carried out. The sequence of events that occur during the mission are as follows:

(i) The request for close air support is communicated to the base and the aircraft takes off.

(ii) The aircraft flies to the strike zone and establishes contact with the ground unit that made the request.

(iii) The target is designated to the aircrew and the strike is carried out.

(iv) The aircraft returns to its base and lands.

(v) The aircraft is refueled, reloaded with ordnance, and checked out in preparation for the next mission.

There are, of course, several variations on this theme: the aircraft may be in the air (loitering) at the time the request is transmitted; the aircraft may return to a different base; repairs may be necessary at the end of the mission, and so forth. It must also be recognized that the steps in the sequence may be varied. For example, in conventional-warfare close air support, the request alluded to in (i) is transmitted over a request net, and several links in the chain of command are involved. It is of course desirable that the time involved in processing the request and initiating the mission be minimized, so it will be assumed that the request is transmitted directly to the base.

In any event, the aircraft must reach the strike zone, which is assumed to be one kilometer or less from the ground unit which requested the mission. This can be accomplished in a number of ways, but in view of the discussions of the Introduction, the navigation function must be available on a virtually all-weather basis. At this point, the question must be raised as to the equipment available to the ground unit. It is clear that the unit must possess some kind of communication capability and it is likely that this capability will take the form of radio, because this is the only means for establishing contact with the aircraft on an all-weather basis. Beyond this, the ground unit must know where it is located; how well it knows this has a bearing on the specification of the close-air-support avionics. The view taken in this paper is that the equipment burden placed on the ground unit should be minimized. The assumptions made heretofore have already burdened the ground unit with an HF radio (for communicating the request for close air support beyond line of sight).*

*An alternative is to maintain a communications relay aircraft over the area of operations; lighter-weight and greater-capacity VHF or UHF radios could then be employed.

In any event, it seems doubtful under the postulated conditions that the burden of a sophisticated position-fixing equipment such as LORAN could be tolerated, particularly on a cost basis. As a starting point, then, it will be assumed that the ground unit only knows its approximate location on a map grid of doubtful accuracy; position-location errors of several hundred yards cannot be ruled out.

The aircraft can be aided in locating the ground unit in bad weather or night operations by homing on a communication transmission from the ground unit. This approach is feasible if the ground unit is equipped with a VHF or UHF (two-way) radio, which will also be useful in maintaining the dialogue between the ground unit and the aircraft during the strike itself. Unless both the aircraft and the ground radio are modified for beacon interrogation purposes, however, this approach only provides the aircraft with the bearing of the ground unit.

The next step, designation of the target to the aircraft, is most crucial, because (as was stated in the Introduction), it may not be possible for the aircrew to acquire the target, either visually or otherwise. By means of the designation function, the ground commander tells the aircraft where he wants the weapons delivered. The most natural basis for doing this is in terms of range, bearing, and relative elevation of the desired weapon impact point from a reference point in the area occupied by the friendly ground forces. In good weather and during daylight hours, the reference point could be a panel or smoke signal; in good weather and at night, a flare could be used. In bad weather, it is necessary to employ non-visual techniques. One approach which has been suggested is to provide the ground units (i.e., all ground units which might have reasons to request close air support) with a LORAN set. The target could then be designated to the aircraft in LORAN coordinates. The strike could then be carried out via the aircraft's navigation system, which would include a LORAN set. This approach is technically feasible, although the weapon delivery accuracy obtained would be regarded by some as marginal for the intended application. However, this approach is both costly (in terms of the number of LORAN receivers that would have to be provided to ground units) and burdensome to the ground forces, from the standpoints of logistics, training, and maintenance. In the final analysis, the desideratum is a designation capability such that the accuracy of weapon delivery is principally determined by the accuracy with which the ground commander knows where he wants the weapons to fall.

The solution to the designation problem which is recommended here is to provide the ground unit with a small, low-power radar beacon, and to equip the aircraft with a radar which has been specialized to the task of interrogating such a beacon and tracking its replies. The beacon serves as a reference point for designation purposes. Locating it in the aircraft spatial frame of reference can be done with such good precision that the data can be used as a basis for an accurate offset-aimpoint weapon-delivery solution.

The remaining steps in the sequence of events during the mission: return to base, landing, and maintenance operations, are relatively straightforward in the conventional warfare context, but the constraint of operating out of a primitive base raises important questions. It is assumed that installation of a conventional instrument landing system to facilitate bad-weather and night landings at such a base would be undesirable. Further, it is assumed that the maintenance facilities at such a base would be severely limited. The solution referred to above provides for this need as well.

Finally, it must be recognized that the cost and timeliness of providing a nation with a capability for close air support in counterinsurgency operations is dictated in part by the requirements for training the aircrews. In this regard, the system synthesis philosophy has not been to minimize avionics costs so much as to insure that their use and maintenance imposes a minimum training burden on the users and maintainers. The offset-aimpoint weapon-delivery technique using the radar/beacon combination can be implemented in such a way that the training required to achieve proficiency is minimized. The same philosophy can be applied to other weapon-delivery techniques.

With this setting for the mission context, it is now appropriate to examine the resources available to meet the requirements and goals which have been set forth above.

B. Avionics Equipment

Table I lists some candidate equipment packages and their general characteristics. The data are not intended to describe any particular equipments, but are representative of what can be achieved in the near future. The weight values listed are, in most cases, black-box weights, and do not include the weight of cables, installation hardware, and antennas. In many instances, however, the weights listed are for equipment with built-in test features. The MTBF's listed are IDA's current estimates of near-future values, for equipment developed, produced, and maintained according to normal military standards, and installed in light, short-range aircraft. The cost figures are black-box costs, and do not include RDT&E, installation and similar costs; performance figures are generally representative of what will be available in the near future on an off-the-shelf basis.

The role of HF radio in close air support is ambiguous. In the conventional war situation, the HF radio plays a secondary role, because the aircraft is not ordinarily directly involved in the request net. Accordingly, the HF radio is included to facilitate communications during long-range missions (e.g., ferrying) and as a back-up communication link. In this role, it would be appropriate to consider using HF radio in a pod installation, to be installed on the aircraft only when the character of the mission indicates that it might be needed. In counterinsurgency operations, however, it may be desirable to retain the HF radio on all missions, and as a working communications facility at the forward base.

TABLE I. CANDIDATE CLOSE AIR SUPPORT AVIONICS PACKAGES

I. COMMUNICATIONS

A. HF Radio

Function: two-way communications beyond line of sight

Weight: 50 lbs — Input Power: 1200 w

Cost: $6000 — MTBF: 250 hrs

Output Power: 400 w

Remarks: Operation in restricted band to simplify antenna

B. VHF Radio/Homing

Function: two-way line-of-sight communications and homing

Weight: 24 lbs — Input Power: 200 w

Cost: $6500 — MTBF: 900 hrs

Output Power: 10 w

Remarks: FM or AM; compatible with ground units

C. UHF Radio/ADF

Function: two-way line-of-sight communications; automatic direction-finding

Weight: 50 lbs — Input Power: 500 w

Cost: $7000 — MTBF: 330 hrs

Output Power: 20 w

Remarks: Voice/cw only

II. NAVIGATION

A. Inertial Navigation Set

Function: point-to-point navigation; attitude reference for weapons delivery

Weight: 20 lbs — Input Power: 200 w

Cost: $30,000 — MTBF: 300 hrs

Accuracy: 1-2 mi/hr

Remarks: Carry-on platform; alignment prior to take-off outside the aircraft

B. TACAN

Function: determine range and bearing of aircraft relative to TACAN station

Weight: 20 lbs — Input Power: 100 w

Cost: $18,000 — MTBF: 250 hrs

Output Power: 500 w

Accuracy: ± 0.6 degree, 250 ft.

Remarks: Amortized cost of ground stations ($100k each) not included.

C. LORAN

Function: determine location of aircraft in LORAN grid

Weight: 20 lbs — Input Power: 200 w

Cost: $20,000 — MTBF: 200 hrs

Accuracy: 150 feet

Remarks: Realization of stated accuracy requires INS and computer for airborne application; no amortization of cost of ground stations ($3-5M) included.

D. Altimeter

Function: measure altitude of aircraft above terrain

Weight: 15 lbs — Input Power: 100 w

Cost: $5000 — MTBF: 450 hrs

Accuracy: 10 ft; altitude rate 0.5 ft per sec

Remarks: Altitude rate needed for bomb-delivery solution

III. TARGET ACQUISITION AND WEAPON DELIVERY

A. Radar

Function: locate and track ground beacons

Weight: 60 lbs — Input Power: 400 w

Cost: $30,000 — MTBF: 200 hrs

Output Power: 2 kw peak, 6 w average — Range: 10 miles

Accuracy: 5 ft. in range, 1 ft/sec in range rate, 1 milliradian in azimuth, at data rate of 10 per second

Remarks: K_a-band; 10-in dia., 4-horn monopulse; beacon interrogation transmission

B. Beacon (to be used by ground units)

Function: provide reference point for airborne radar target designation and landing aid

Weight: 8 lbs — Input Power: 40 w

Cost: $3000 — MTBF: 1000 hrs

Output Power: 200 w peak

Remarks: K_a-band; 16 coded interrogations, single-pulse reply

C. Display

Function: display beacon replies

Weight: 25 lbs — Input Power: 200 w

Cost: $15,000 — MTBF: 150 hrs

Type: 5-inch PPI; 2-mile, 10-mile range sweeps

D. Laser-Ranging Visual Weapon Delivery Equipment

Function: continuous-solution weapon release for visually-acquired targets

Weight: 150 lbs — Input Power: 1200 w

Cost: $40,000 — MTBF: 150 hrs

E. Weapon-Release Equipment

Function: selective control of weapon release sequence

Weight: 10 lbs — Input Power: 20 w

Cost: $2500 — MTBF: 600 hrs

F. Driven Optical Sight

Function: designate weapon impact point for visually-acquired aim points

Weight: 18 lbs — Input Power: 100 w

Cost: $5000 — MTBF: 800 hrs

G. Computer

Function: weapon release solution; interface

Weight: 20 lbs — Input Power: 50 w

Cost: $30,000 — MTBF: 500 hrs

Type: GP or Hybrid GP/DDA

Remarks: 10 solutions per second

Some improvement in the HF weight, cost, and power drain penalties could be realized by reducing the output power to, say, 20 watts, which might be quite acceptable for the counterinsurgency application.

The next two items refer to the primary means of communication between the aircraft and the ground unit: VHF and UHF radio. At the general level of detail of this paper, there is little basis for a firm choice between them. There is, however, some preference for the use of UHF, because of the availability of a greater frequency spectrum (225 to 400 mc, as opposed to 30 to 70 mc) than is realizable at VHF. VHF sets with homing features are available, but it is to be expected that accurate direction-finding at UHF would be somewhat easier because of the shorter wavelength. The reason for emphasizing accuracy is that the UHF ADF has growth potential for locating a ground beacon in both range and azimuth; this capability is an essential feature for the strike system to be described.

Another option which has not been listed is a radio operating in the high-HF/low-VHF band. This alternative deserves further study from the standpoint of minimizing cost, weight, and maintenance burden, but has been tentatively rejected because the combination of UHF and HF seems better suited to the communication needs.

The next three items are various means for solving the navigation problem, and provide essentially different functions. The inertial navigation set consists of a computer and a light-weight carry-on platform. The platform can be maintained in an aligned condition in a shed at the airbase until just prior to take-off. At that point, it is connected to a portable power supply and installed in the aircraft. Alternatively, the platform could be retained in alignment in the aircraft via the sight head. The inertial navigation set provides a completely self-contained navigation capability, and the attitude information available from the platform is of value in weapon delivery.

TACAN and LORAN involve the use of external ground stations. In the case of TACAN, a useful navigation capability can be achieved with a single station over a restricted area (i.e., within a 300-mile radius). The TACAN provides the aircraft with present range and present bearing to the ground station, and is line-of-sight limited. In one sense, TACAN position fixes are more accurate than are available from the postulated inertial set, because they are not subject to drift.

LORAN represents a significantly greater investment insofar as the ground stations are concerned. A master and two slave stations are required. but the potential accuracy available from LORAN is substantially better than that of TACAN. The two equipments are quite comparable, insofar as the black-box cost, and weight, power, and maintenance penalties are concerned. Two other important differences are that LORAN is not line-of-sight limited, and that full realization of LORAN accuracy in the airborne application requires that the equipment be used in conjunction with inertial navigation equipment and a small computer. The reason for this is that the aircraft speed and heading can change significantly during the smoothing time required for extraction of LORAN position data, with the result that the LORAN fix will lag the actual aircraft position. By using LORAN and inertial data together, however, the inertial errors can be damped with the LORAN data, and the inertial data can be used to correct for velocity changes during the smoothing time. Neither LORAN (by itself) nor TACAN provide attitude information which is needed for weapon delivery, however.

The final item in the Navigation category is a radar altimeter; the major reason for including it (in addition to a barometric altimeter, for example) is to provide precise altitude and altitude rate data for weapon delivery and instrument landing purposes.

One class of equipment which has been omitted is an instrument landing system. From the standpoint of costs and penalties for the aircraft, the addition of marker beacon, localizer and glide-slope receivers imposes no severe strain. It is clear, however, that installation and maintenance of the requisite ground equipment may not be consistent with the notion of a primitive, forward-area base operated by indigenous forces. In the following section, an alternative to the conventional ILS approach is suggested which is more consistent with this notion.

Many possible candidates could be listed in the next category: target acquisition and weapon delivery. The term target acquisition is a misnomer, because the philosophy employed in the synthesis is that the system must be effective even though the target cannot be acquired from the air. Accordingly, a number of equipments, including television, low-light-level television, infra-red, night-vision equipment, and MTI and synthetic-aperture radars have been omitted for a variety of reasons. In all cases, the contributions that these equipments might make to the effectiveness of the close air support weapon system appears to be far outweighed by th: costs and penalties associated with having them aboard the aircraft. None of them guarantees target acquisition. The electro-optical and infra-red sensors are limited by the weather; MTI radar is not appropriate for the class of targets being considered, and synthetic-aperture high resolution radars are both costly and of dubious value for unplanned counterinsurgency operations.

The radar which is cited is intended solely for beacon interrogation and tracking. The choice of K_a-band for the frequency is fairly arbitrary, but consistent with the use for which it is intended. A short paper design study was undertaken for this equipment; some parameters (in addition to those shown in the table) are:

PRF: 10,000 pulse groups per second

Beamwidth: 2 to 2.5 degrees

Antenna gain: 36 to 40 db (one way)

The transmitted pulse group consists of three 0.1-microsecond pulses which can be spaced at intervals of 1, 3, 5, and 7 microseconds, for a total of 16 possible interrogation codes. The radar interrogates a beacon, which is the next item in the table. It was assumed that the beacon receiver bandwidth is 50 mc (to minimize tuning problems), with a 20-db noise figure. Deducting 10 db for line and propagation losses and antenna inefficiency, the power received at the beacon at 10 (statute) miles is -56 dbm. The single-pulse signal-to-noise margin turns out to be 21 db; beacon receivers with a triggering sensitivity of -65 dbm are available today. Because of the lower power in the beacon, the margins are 10 db less on the reply link, but this is unimportant, because the received replies can be integrated on the display.

This radar is not appropriate for terrain-avoidance flight applications. To modify it for this function would increase its weight, cost, and complexity to a point where it would not be suitable for the problem considered. Under conditions of poor visibility the only course is for the aircraft to fly at a sufficiently high altitude to clear any obstacles (including mountains) that might otherwise appear in its path.

The most critical parameters for the radar/beacon combination appear to be the desired tracking accuracies. Range and range rate data can be obtained from standard analog or digital tracking units; elevation and azimuth angle tracking can be accomplished via conical-scanning or monopulse techniques. Monopulse is simpler from a mechanical standpoint, and is recommended for that reason.

A beacon similar to the one described in the table could be carried aboard the aircraft to facilitate tracking by ground-based radar attack control systems (as currently embodied in the Marine Corps AN/TPQ-10). This method of weapon delivery control will be discussed subsequently.

The display cited in the table is used to permit the operator to put a tracking cursor on the displayed beacon replies.

The next item, laser-ranging weapon delivery equipment, is included primarily to take advantage of actual visual target acquisition; it thereby eliminates target location errors which will be discussed subsequently. The equipment consists of a driven optical sight, a laser ranging device which is slaved to the sight, and a special-purpose computer (or, if the aircraft is so provided, the general-purpose computer to be described subsequently). The computer accepts attitude and velocity data from the aircraft's attitude reference and air data system, and range data from the ranging device. Several modes of operation are possible; in one, the computer drives the sight so as to designate the impact point of the weapon to the pilot. He then flies the aircraft so that the sight dot crosses the target and releases the weapon at that point. In another mode, the pilot (in effect) designates the target to the computer during a dive, and the computer releases the weapon at the appropriate point during pull-up. In this mode, the effects of timing error on the part of the pilot are eliminated. The principal reasons for including this item are that the training required to achieve accurate visual weapon delivery could be greatly reduced, and that it provides significant growth potential for use of the aircraft in planned strikes against easily-acquired targets (as for interdiction missions) which are not close to friendly ground units.

The next item, weapon release equipment, is a standard item at the present time, and facilitates the use of various release tactics (ripple, salvo). The ripple interval can be varied from 20 milliseconds to 2 seconds. Accordingly, the weapon impact pattern can be matched to the fire support needs of the ground unit.

The driven optical sight is an element of the laser-ranging delivery system described above, and is included separately because it can be coupled into the weapon delivery subsystem in other ways. For example, the radar described above could be modified to provide aircraft-to-target range data, albeit with less accuracy than the laser equipment. Alternatively, the sight could be used without range data, being driven by the computer to designate the estimated weapon impact point from attitude, altitude and air speed data alone.

Finally, the computer is used primarily to effect solutions to the weapon delivery problem. These solutions can be of several types; for example, the computer can take beacon data from the radar for an offset-aim-point solution, using information from the altimeter, an attitude reference or platform, and the air data system to control the aircraft autopilot and initiate weapon release. Alternatively, the computer can drive the sight, as has already been mentioned. More generally the computer is used as an interface between the sources of sensed data (altimeter, air data set, radar, laser, inertial navigation set, manual entry, ADF, LORAN, TACAN, attitude and heading reference, and the display) and the system actuators (autopilot, sight drive, weapon release equipment). In this role, its purpose is to eliminate the need for extensive training of the crew, who would otherwise perform these functions.

Other items of equipment which have been mentioned in passing but are not described in the tables include the aircraft's air data system, autopilot, and the attitude reference. These are not described in detail because they would generally comprise part of the normal aircraft avionics complement, and are not specific to the close air support mission. Included in this category are the intercommunications equipment, and the flight control and engine instrumentation. Many equipments which might have been considered were not, including gun-fire detectors, data link terminals, station-keeping systems, terrain avoidance radar, low-frequency ADF, IFF, contact analog displays, radar warning receivers, and electronic countermeasures. These were omitted because a casual appraisal indicated that either their functions could be better done by the equipment which was considered, or they were not needed in the problem context, or they were not consistent with the notion of a light-weight, relatively low-cost, easily-maintained system. Doppler radar navigation equipment was eliminated on the same grounds. In retrospect, however, the potential role of Doppler radar for weapon delivery (as well as for en-route navigation) indicates that its use in the counterinsurgency application should be examined.

In the next section, the elements which have been described here will be combined into systems, and some features of their operation will be discussed.

III. SYSTEM DESCRIPTION

A. Equipment Complements

In synthesizing an avionics system for counterinsurgency close air support, several alternatives were considered. The preferred choice is termed the basic all-weather system, and its complement of equipment is listed in Table II, along with the complements for the other systems.

TABLE II. SYSTEM OPTIONS

System	Airborne Equipment			Ground Equipment
	Communication	Navigation	Attack	
1. Basic All-Weather	HF Radio UHF Radio/ ADF	Inertial Navigation Set Altimeter	Radar Display Computer WRE Driven Optical Sight	HF Radio UHF Radio Beacon
2. Minimum	HF Radio	LORAN or TACAN	Driven Optical Sight Computer WRE	HF Radio
3. Improved Minimum, Alternate I	Same as (1)	LORAN or TACAN	LRVWDE WRE	HF Radio UHF Radio
4. Improved Minimum, Alternate II	Same as (1)	Inertial Navigation Set	Same as (3)	Same as (3)
5. Augmented All-Weather	Same as (1)	Same as (1)	Radar Display LRVWDE* WRE	Same as (1)

WRE: Weapon-Release Equipment

LRVWDE: Laser-Ranging Visual Weapon-Delivery Equipment

* With augmented computer

With regard to the equipment required by the ground unit, it is assumed in all instances that they have the capability of estimating their position to within a few miles (in the case of Systems 1 and 5) and to within a mile (for Systems 2, 3, and 4). The HF radio carried by the ground unit is a normal tactical ground radio, and is used to request the close air support mission, and for any other beyond-line-of-sight communication tasks that they might require. The UHF radio can be a light-weight set (4 to 9 lbs), and is used to assist the aircraft to approach the target area (except for System 1), as well as for communication between the air and the ground during the strike itself. In the case of Systems 2, 3, and 4, it is assumed that the ground unit has some means for establishing a visual point of reference for purposes of designating the target (panels, smoke, or flares). The beacon employed in Systems 1 and 5 was described in the previous section, and is the all-weather reference point for target designation.

System 1 and the means for its employment will be discussed subsequently. System 2 appears to be the rock-bottom avionics complement to perform any kind of close air support mission, with the exception of the driven optical sight and the computer. The justification for these equipments is that they permit shorter training periods for acquiring weapon delivery proficiency. The computer accepts information from the aircraft's air data equipment (air speed, angle of attack, air density), from the attitude reference (dive angle), and from the barometric altimeter (altitude and rate of ascent or descent). In a level-bombing, strafing, or rocket attack mode, the computer drives the optical sight to indicate to the pilot the estimated point of weapon impact. It is therefore only necessary for the pilot to fly the sight dot over the target. In the dive-toss mode, the pilot places the sight dot on the target during the dive, and initiates the weapon-release sequence (pickling) simultaneously with his planned pull-up. The computer releases the bomb at the appropriate point in the pull-up to place the bomb on the target. The computer performs a similar function when the point of aim is the designation reference point, with the exception that the range from the designation point to the target is entered manually, and the pilot must fly on a heading which is on the bearing of the target with respect to the designation reference point.

System 2 is obviously subject to a number of limitations: visibility must be sufficiently good for the aircrew to find the designation point of reference without ADF assistance; the use of HF for direct communication between the ground and the air is susceptible to overcrowding of the limited spectrum; and the use of air data and flight-control attitude reference information for weapon delivery may be questionable from an accuracy standpoint.

System 3 achieves improved accuracy of weapon delivery by means of laser ranging, which eliminates a number of error sources present in System 2. The UHF Radio/ADF capability has also been added to alleviate the communication traffic problem and to assist the aircrew in finding the visual designation reference point. An additional benefit can be implemented if the UHF radio on the ground and the designation reference point are approximately colocated. Under these circumstances, the ADF can be coupled to the autopilot through the computer to put the aircraft on the proper heading for weapon delivery.

In System 4, the TACAN or LORAN equipment is replaced with the light-weight navigation set. In addition to eliminating the need for ground stations, the availability of more accurate velocity and attitude data improves the accuracy of weapon delivery over that obtainable with System 3.

In System 5, the mission scope of System 1 is enhanced by adding a laser range-finder. That is, the primary mode for weapon delivery in System 1 is based on using the beacon as an offset radar-bombing aim point. Against targets which are not close to such a beacon, the delivery accuracy of System 1 is somewhere between that of System 2 and System 4, because range and range rate to the target will not be known. Adding the laser range-finder alleviates this problem for targets that can be acquired visually. There are two applications for this capability. First, the system can be used in planned interdiction missions under good-weather conditions against targets that are easily acquired. Second, in close air support missions, the ground unit may have imperfect knowledge as to the target location. The bomb run can be initiated under control of data derived from the radar/beacon combination; if the target is then acquired visually, the pilot can revert to the laser-ranging mode of attack with improved delivery accuracy.

B. Tactical Employment of the Basic All-Weather Configuration

The close air support mission begins with the aircraft taking off from its base and flying in the general direction of the strike zone, using the inertial equipment for navigation, e.g., under autopilot control. The aircrew then establishes contact with the ground unit via UHF radio, and obtains a more accurate heading via the automatic direction-finding equipment (if this is necessary). At this point, the target bearing and range relative to the ground beacon are entered into the computer (this information can be subsequently updated if necessary).

When the aircraft is within ten miles of the ground unit, the radar is turned on to interrogate the ground beacon, using the ADF information to steer the radar antenna in the approximately correct direction. (Alternatively, the radar antenna can scan a wide sector

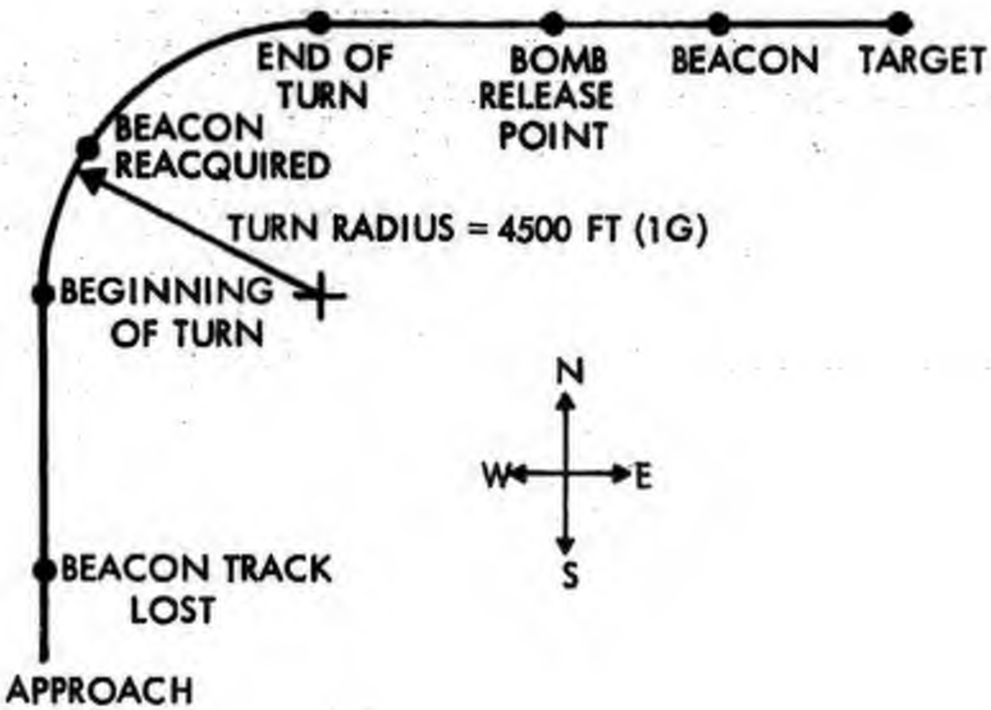

FIGURE 1. TYPICAL ATTACK TRAJECTORY

in the search mode if for some reason the ADF is not functioning.) Once the ground beacon answers the interrogations from the radar, the operator places a cursor over the displayed replies and switches the radar into its tracking mode. The beacon range and angle data are stored by the computer in a fixed coordinate system, using inputs from the inertial navigation set. This is substantially equivalent to updating the inertial navigation data via a checkpoint, and facilitates reacquisition of the beacon during later parts of the mission.

Next, the aircraft descends to the desired bombing altitude and turns so that it is heading toward the beacon in the direction of the target. This operation can be accomplished under computer control of the autopilot, using inertial data. Figure 1 illustrates the maneuver in plan view for a typical approach. The aircraft is flying at an altitude of 3600 feet at a speed of 225 knots (380 feet per second). The target is east of the beacon at a range of 3000 feet. A low-drag bomb will take 15 seconds to fall; the horizontal distance traversed by the bomb is therefore 5700 feet. The aircraft approaches from the south. At the point marked Beacon Track Lost, the radar can no longer track the beacon because the slewing angle is too great (a maximum slewing angle of 45 degrees was assumed for the purpose of drawing the figure), but by this time, the aircraft is under autopilot control from the computer. The aircraft continues on its approach heading until the turn begins. During the turn, the beacon is reacquired by the radar. The turn continues until the aircraft is on the in-run, that is on a course which will take it over the beacon and toward the target. During the in-run (of 10 seconds duration for the situation depicted in the figure) the computer is using the radar tracking data and inertial inputs to correct the heading. The computer releases the bomb at the computed release point and the aircraft is turned over to manual control.

The release point is computed using the specified range and elevation from the beacon to the target, elevation angle to the beacon (as measured by the radar), altitude rate from the altimeter,* and either range rate to the beacon (as measured by the radar) or horizontal velocity data from the inertial navigation set. Wind corrections and aircraft heading corrections can be provided by the computer from inertial and air data.

This mechanization of the attack control has many advantages. First, it is possible to include wind corrections automatically. Second, the accuracy attainable is essentially

*Over rough terrain, it may be preferable to use inertial or even barometric altitude rate data.

limited by the accuracy with which the ground commander can designate the range, bearing, and elevation of the desired impact area, since the tracking accuracy of the inertial and altimeter inputs should be sufficient to insure CEP's (with respect to the designated aim point) of the order of 50 feet under the conditions described.

Concurrently with this operation, the computer can slew the optical sight so as to delineate the designated aim point to the pilot, and he can attempt to acquire the target visually if the weather and illumination conditions permit. If such acquisition occurs, he can switch over to the visual delivery mode, thereby eliminating target location errors. Conversely, the relationship of the sight dot to the target gives the pilot a measure of the error in the designated aim point; if this is satisfactorily small, he can leave the system in its fully automatic mode.

For second and subsequent passes over the target, the inertial navigation set and the computer can be used to steer the aircraft (via the autopilot) on a race-track course, and the sequence of events described above is repeated. Between passes, the ground unit commander can correct the designated aim point, or he can designate aim points for new targets.

A major point of this discussion is that the training requirements for achieving accurate weapon delivery have been minimized, by providing means for steering the aircraft on a correctly-oriented bombing run, and for automatically releasing the weapon at the correct time.

Finally, it will be noted that the equipments specified for the basic all-weather system can also be used for instrument landing purposes, by placing one or more of the ground beacons in a known relationship to the runway. This obviates the need for an instrument landing facility at the airbase.

C. Cost Comparisons

Table III exhibits the cost factors associated with the systems that have been discussed. The cumulative data do not include provision for such elements as cabling and other installation hardware, interface packages, and cooling, but it is felt that the assumed values for the individual equipment packages were sufficiently conservative that the additional penalties imposed by these necessary adjuncts are relatively modest.

The most conspicuous points brought out by Table III are the following:

(i) It is possible to realize a close air support avionics system which provides a useful weapon delivery capability at a reasonable fraction of the cost of the counterinsurgency aircraft (typically, $250,000 to 300,000) within a weight, power, and maintenance burden envelope which is acceptable for such an aircraft.

(ii) There is only a two-to-one variation between the cost factors for a system which is limited to daylight, fair-weather operations and one which can function effectively at night and under nearly all weather conditions.

With regard to the maintenance burden cited in (i), it was noted previously that many of the equipment descriptions listed included provisions for built-in test features. It has been estimated that the maintenance requirements for the basic all-weather configuration could therefore be kept under one maintenance man-hour per flying hour.

TABLE III. COST COMPARISONS

System	Weight (lbs)	Cost ($X)	Input Power (kilowatts)	MTBF (hrs.)
1. Basic All-Weather	268	131	2.8	34
2. Minimum	110	64	1.6	72
3. Improved Minimum, Alternate I	280	71	3.0	62
4. Improved Minimum, Alternate II	280	83	3.1	64
5. Augmented All-Weather	323	136	3.7	31

D. Other Possibilities

The approach adopted in this discussion is not the only way of obtaining the kind of capability for close air support that has been sought. Three other approaches will be mentioned here.

The first is to use LORAN coordinates for the frame of reference for target designation as was mentioned in Section II. The disadvantages cited were that LORAN equipment would add significantly to the burden of the ground units, and that the cost of equipping all such units with LORAN receivers would be prohibitive. Furthermore, use of LORAN data for weapon delivery purposes requires the use of a small inertial-navigation set and a small computer to overcome the lag effects due to the smoothing time required for LORAN position fixes. The viewpoint taken in this paper has been that the basic all-weather system described above is a better way to exploit this combination. Nevertheless, there are definite advantages to the LORAN approach, especially for application with ground units (such as those of the U.S. forces) for which the burden would be acceptable. One of the principal advantages is that with an operating LORAN receiver along, a ground unit will always know where it is with good accuracy. This point may be important for tactical operations other than close air support. That is, if there are other justifications for providing LORAN receivers to the ground units and/or for carrying them on close air support aircraft, it may well be that the LORAN approach is best from an effectiveness-cost standpoint. It is questionable, however, whether LORAN-based weapon delivery can ever be as accurate as the short-range offset-aimpoint bombing technique that has been described above.

The next approach is to employ a UHF beacon, in somewhat the same manner as was described for the K_a-band approach of the basic all-weather configuration. This approach is also attractive, since most aircraft have or will be provided with UHF ADF equipment. For the fullest exploitation of this approach, the aircraft would interrogate the beacon (entailing a significant modification to the UHF transmitter on the aircraft) to obtain range information. The range information would probably not be as good as is available at higher frequencies but would probably be good enough for weapon delivery. (To obtain sufficiently good range rate data for use in the bombing equation solution, however, the beacon would probably have to be a coherent repeater; range rate could then be obtained from the Doppler shift in the reply.) The principal shortcoming of the UHF approach is that in conventional installations, no elevation (or depression angle) data of the beacon with respect to the aircraft would be available. This information is useful in weapon delivery; its availability permits computation of the altitude of the aircraft above the beacon without errors due to terrain elevation variations. About the most that can be said is that the UHF beacon approach deserves further study, to determine whether its shortcomings can be overcome to an acceptable degree.

The third approach which will be discussed here is that of using a third party to control the close air support aircraft. This concept is currently used by the Marine Corps in the form of an Air Support Radar Team. The principal equipment of the ARST is the AN/TPQ-10 Radar Course-Directing Central, which is a combination of a computer and communications complex with a high-precision tracking radar. The location of the target with respect to the radar must be known with an accuracy better than that required for weapon delivery, because this uncertainty is reflected directly into the delivery errors. In operation, the radar tracks a beacon on the aircraft; the resulting position data are fed into the computer, which generates steering commands to the aircraft. The steering commands are transmitted to the aircraft's autopilot via a UHF data link, and serve to place the aircraft on a bombing run toward the target. The computer generates a command, which is transmitted to the aircraft and causes bomb-release, when the estimated release point has been reached. Accuracies (CEP's) ranging from 40 to 70 yards have been reported at control ranges of 20 to 65 kilometers.

This approach has tremendous growth potential from several standpoints. It minimizes the equipment that must be carried by both the aircraft and the ground unit.* In effect, it is akin to LORAN and TACAN navigation, except that it has been specialized to the air support function. Its disadvantage is that because the aircraft must remain within line-of-sight of the radar, certain kinds of attacks (e.g., strafing) are precluded. The accuracy obtained by the TPQ-10 radar is probably close to the limit for such types of control (the radar angle-tracking accuracy is 0.5 milliradian), but is somewhat poorer than can be obtained with the offset-aimpoint approach adopted here. This potential shortcoming could possibly be overcome by means of a base-line technique using two receiving sets for the aircraft beacon replies. Perhaps the most serious problem is the fact that the success of the ASRT concept is due in no small part to the highly-skilled and ingenious Marine Corps personnel who operate the TPQ-10 system. It is not at all apparent that such proficiency could be quickly established with indigenous forces.

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*This statement must be qualified by again noting that the position of the target must be accurately known to the ASRT, which in turn implies that the ground unit requesting support must at least know its own position accurately.

SEYMOUR J. BIRSTEIN

Mr. Birstein has worked as a chemist in the Space Physics Laboratory of the Air Force Cambridge Research Laboratories since 1951. At AFCRL, Mr. Birstein has conducted extensive studies in surface chemistry and condensation physics and is now heading a group engaged in the development of contrail-suppression techniques and devices. Before joining AFCRL, Mr. Birstein was employed by the Air Reduction Company, where he specialized in research on the absorption properties of rare gases and the development of rare-gas separation and identification methods. He holds an MS in physical chemistry from Montana State College and is a member of the American Chemical Society, American Meteorological Society, Electron Microscope Society of America, and the Scientific Research Society of America.

CONTRAIL SUPPRESSION ( )

~~([illegible])~~

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ABSTRACT
(Unclassified)

The suppression of moisture produced contrails associated with high flying jet aircraft, the device used, and the method of inserting the nucleating agent are described. Application and importance to the present operational vehicles in the Air Force inventory are discussed. Future plans and area of required research, with emphasis on potential applications, are examined.

While contrails are an inspiring sight when they are being made by our aircraft over our own territory, they may be the first and sometimes the only warning to an enemy that our aircraft are over his country. This is especially true when we use a vehicle with a low radar cross section.

This presentation describes the development of contrail suppression devices by the Air Force Cambridge Research Laboratories from the initial laboratory concepts to operational hardware now in use in Southeast Asia.

A contrail or vapor trail is produced by the condensation of the water vapor formed by the combustion of a hydrocarbon fuel that forms a visible wake of water particles in an aircraft exhaust.

$$C_n H_{2n} + O_2 \rightarrow H_2O + CO_2$$

When the exhaust gases cool, a certain portion of the water vapor saturates the exhaust envelope and any water vapor in excess of that needed to saturate the exhaust at ambient temperature, pressure, and humidity is available for contrail formation.

Because of strong in-house programs in the area of condensation physics, AFCRL first became involved in contrail suppression in 1955. By 1959 it had been demonstrated that if the amount of hydrogen in a fuel was reduced, the probability of contrail formation was also reduced. While this was an interesting exercise in condensation physics, the approach was unacceptable to the Air Force for two obvious reasons: (a) as the hydrogen content of a fuel is reduced, the heat of combustion is lowered and the aircraft suffers a range penalty, and (b) the logistic problems of utilizing two fuel supplies for aircraft made this solution impractical.

A parallel approach also began showing promise in 1959. The reasoning behind this approach maintained that rather than suppress the contrail by conventional means, it should be possible to make a contrail invisible by reducing the size of the water particles below 0.25 microns, therefore causing the particles to scatter in the Rayleigh region and be invisible.

Various means of achieving the size reduction technique were studied, and the conclusion reached was that the nucleating agent would have to be an extremely hygroscopic gas, since it is impossible to reduce a powder to a small enough size so that final growth on the nucleus will not exceed 0.25 microns.

Sulfur trioxide was found to be the only material which met our criteria. Because of problems involved in the handling of sulfur trioxide, mainly polymerization when it became exposed to either moisture or cold, we decided to develop a means of manufacturing sulfur trioxide directly in the jet exhaust. Chlorosulfonic acid was injected into the exhaust and in the hot environment it broke down to form sulfur trioxide and hydrogen chloride. The sulfur trioxide suppressed the contrail.

This system was demonstrated on both B-47 and B-52 type aircraft and the system was turned over to SAC. The lower half of Figure 1 is a demonstration of the suppression system in operation on the right wing of a B-47.

In the fall of 1963, after repeated failure of the airframe contractor to develop a contrail suppression system for a projected special purpose vehicle, AFCRL was directed to undertake a program to develop a contrail suppression device for that vehicle and the "Blind Alley" program was initiated.

Basic flight testing was performed at Holloman AFB on a Ryan Firebee target drone. As the flight testing progressed, instrumentation was developed to measure all significant variables. These included agent temperature, agent flow, altitude, outside air temperature, and relative humidity. Agent flow could be varied during a flight. A computer program was developed to optimize the placement of nucleating agent droplets in the exhaust. This gave us not only the size and injection point for maximum evaporation, but also considered the chemistry in the exhaust stream and maximized the sulfur trioxide concentration by determining the conditions for minimum thermal decomposition of the SO_3 into SO_2 and oxygen.

of 35,000 to 53,000 ft., the altitude ceiling of the test vehicle. Preliminary test data analysis showed, however, that the relations concerning agent requirements as a function of ambient conditions did not follow the criteria developed during our B-47 test program. As the altitude range of our test program increased, we found that the expected relationships between amount of nucleating agent required and atmospheric parameters did not hold. According to meteorological theory, it should be possible to express nucleating agent requirements in terms of liquid water content of the contrail or the amount of actual water which will condense at any set of atmospheric conditions. We found, however, that as altitude increased, the amount of agent necessary to suppress a contrail of a given liquid water content also increased.

While the "Blind Alley" test program was progressing, we were directed, using the best state of the art, to install a contrail suppression device into an operational vehicle for a flight test program at Eglin Air Force Base. One successful flight was made at altitudes to 59,000 ft. and temperatures to -67°C. Further tests were not made because of the sudden deployment of the operational group to Southeast Asia.

In November, 1964, we were directed to develop and construct an operational contrail suppression system for the vehicle upon which we had run our Eglin tests. During a ten day period, design and flow rate were set, materials were assembled, AFCRL personnel traveled to the vehicle contractor's plant, installed the system, wrote the operating manuals, and were on their way to Southeast Asia with the contrail systems and vehicles.

While the initial operational systems were not the best possible because of the short time for design and construction, they did fill the need and gave a reasonable probability of contrail suppression under all but the coldest ambient conditions.

The "Blind Alley" flight test program was completed on 1 December 1964, and a comprehensive analysis of the "Blind Alley" test was begun.

The analysis showed the following relationships:

SYSTEM EFFICIENCY INCREASES

a) System efficiency is increased by increasing tailpipe temperature insofar as one is concerned only with the evaporation of the chlorosulfonic acid droplets to form sulfur trioxide.

forward position, as close to the turbine as possible; this favors agent droplet evaporation because of the longer time that the droplet remains in the hottest region of the tailpipe.

c) System efficiency is increased as the agent temperature is increased.

SYSTEM EFFICIENCY DECREASES

a) System efficiency is decreased as the exhaust gas temperature is increased insofar as this increase is related to droplet breakup. The density of the gases in the tailpipe is, with increasing temperature, decreased and breakup of the agent stream into droplets increases with increasing, high tailpipe density.

b) System efficiency is decreased as altitude is increased because of the decreased tailpipe density with altitude.

c) System efficiency is decreased as the velocity of the agent stream is increased because stream breakup into droplets is inversely proportional to stream velocity.

If allowances are made for the changes introduced by the droplet breakup mechanism and tailpipe density changes, then the relationships based on nucleating material as a function of liquid water content of the contrail are valid.

During April of 1965, AFCRL was called upon to contribute towards the design of an advanced version of the reconnaissance vehicle which would have a new engine and increased altitude capability. Sufficient time was allowed for flight test and we were given the opportunity to develop a meaningful program based on the "Blind Alley" test results. All significant variables identified during our program analysis were included in the flight test program. An RB 57F was provided as a test bed and the test engine was hung in a pod replacing one of the J60 engines on the aircraft.

The variables chosen were:

a) Agent temperature; this could be varied from 75°F to 190°F.

b) Injection position; two sets of 4 each injection positions were chosen, one at the turbine and the other further aft in the tailpipe.

c) Agent velocity A; a choice of nozzle sizes was provided in order that flows could be compared at differing velocities.

d) Agent velocity B; for any nozzle configuration the flow could be directed through either two or four nozzles.

e) Flow rate of the agent could be varied.

The parameters measured included agent flow, agent temperature, tailpipe pressure, exhaust gas temperature, and outside air temperature.

In addition to the above, an attempt was made to nullify the tailpipe density effects caused by altitude and temperature changes. This utilized a completely new nozzle design in which only the nozzle and injection parameters controlled droplet breakup (Figure 2). The agent was injected through a nozzle and onto a parabolic deflector welded on the end of the nozzle insert. The agent stream was broken up by the deflector rather than the jet exhaust.

These tests confirmed our "Blind Alley" data analysis:

a) System efficiency was increased as agent temperature was increased up to the point where the agent began decomposing.

b) The optimum agent temperature was found to be in the range 135°F to 150°F.

c) System efficiency was found significantly better in the nozzle position closest to the turbine.

d) Within the limits of well defined flow (ignoring the largest nozzle size of 0.017 in. where stream velocity was too low to allow penetration and interaction with the exhaust gases) the larger nozzle diameters were most efficient.

e) Two nozzle configurations proved superior to the four nozzle configurations, and the deflector nozzles were the most efficient of all tested.

All system designs tested worked well within our design envelope of 59,000 ft. and above and the deflector nozzles were approximately 35 percent more efficient than those of our previous operational system.

The above test program, which was conducted at General Dynamics, Fort Worth, Texas, was concluded in July, 1965, and work was immediately begun to translate the data into an operational system. AFCRL personnel working with AFLC and AFSC at the vehicle contractor's plant designed a new system which was incorporated into the advanced reconnaissance vehicle. The criteria used in the design were in order of importance, reliability, weight, and cost. Since previous experience showed that, whenever the people in the field could turn something either by hand or with available tools they did, the system was designed to be completely tamper proof by the personnel in the field and usable by the maintenance crews with a minimum of training. Figure 3 illustrates the first system built in November 1964 and Figure 4 shows the current system.

The system was completed in October, 1965, testing was completed in November, and it is now operational in Southeast Asia.

While work was progressing on the operational system, AFCRL was directed by Hq USAF to initiate a project in the exploratory development area in order that we might develop design data for new generations of vehicles and improve the state of the art. A certain portion of our current work is tied to a specific vehicle which must be ready later this year.

Our present program is divided into three parts: Nucleation Chemistry, Droplet Injection Mechanisms, and Materials Research. In our Nucleation Chemistry studies, work is underway to develop better nucleating materials. We have already developed a variation of chlorosulfonic acid and sulfur trioxide which should be about 20 percent more efficient then our current agent. Other methods of producing sulfur trioxide, new nucleating materials, and the use of fuel additives are under study.

Work on droplet breakup mechanisms involves an attempt to develop droplet breakup theory to the point where we can optimize the injection of a material into an exhaust. Current studies involve both theoretical modeling of the breakup mechanism and experimental verification of the results using high speed photography and a nanosecond light source.

Our materials studies are concerned mainly with the development of better, lighter, more reliable systems for contrail suppression. With one specific vehicle on which we have worked, every pound of system weight results in a 10-ft. altitude penalty.

While it is impossible to discuss the specifics of our operational vehicle, the enhancement in mission capability of a reconnaissance vehicle which leaves no visual calling card to direct enemy fighters for an intercept can be left to the imagination.

Although we have been responsive to the Air Force needs to the extent of the design and construction of operational hardware in the shortest period of time, our mission has not ended with the delivery of the system, but we are striving for the knowledge to improve what we have already built and to respond even better in the future to Air Force requirements.

Figure I. Trails From B-47 Suppressed on One Wing

Figure II. Deflector Nozzle Design

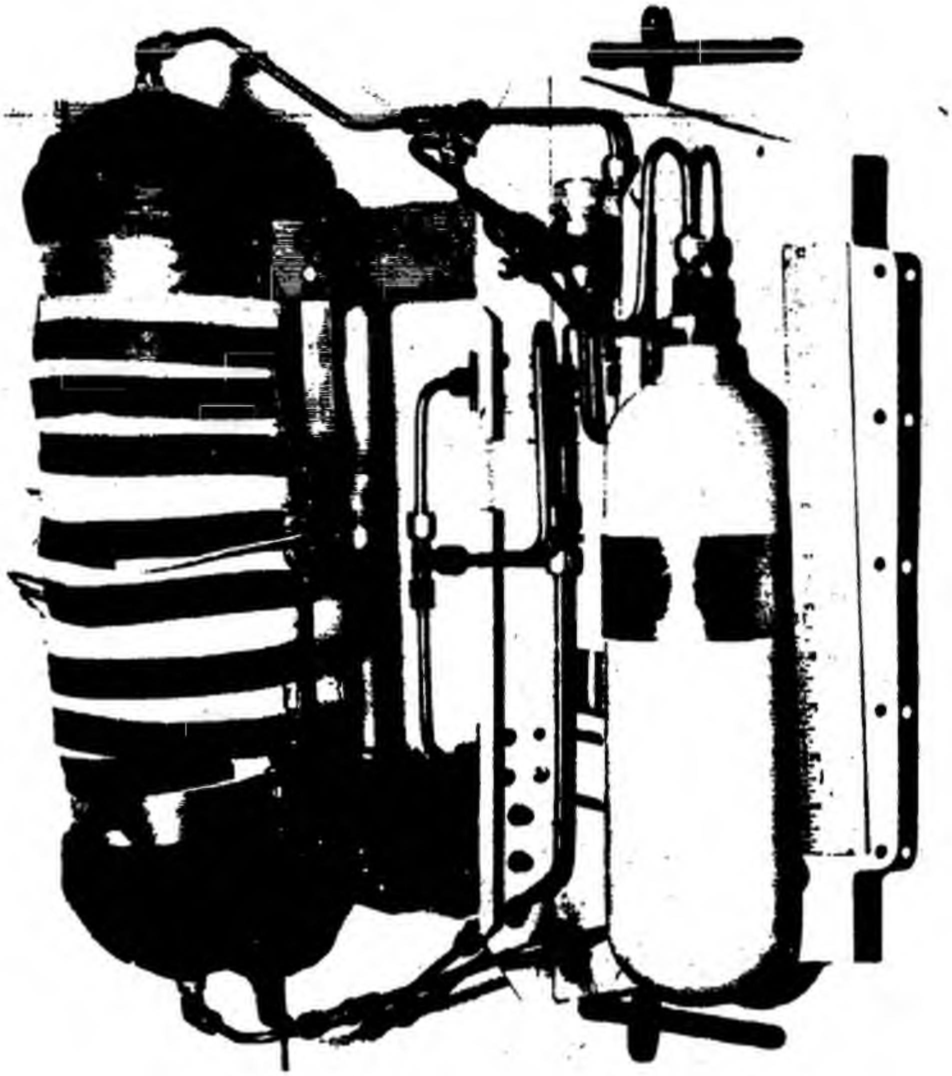

Figure III. First System Built in 1964

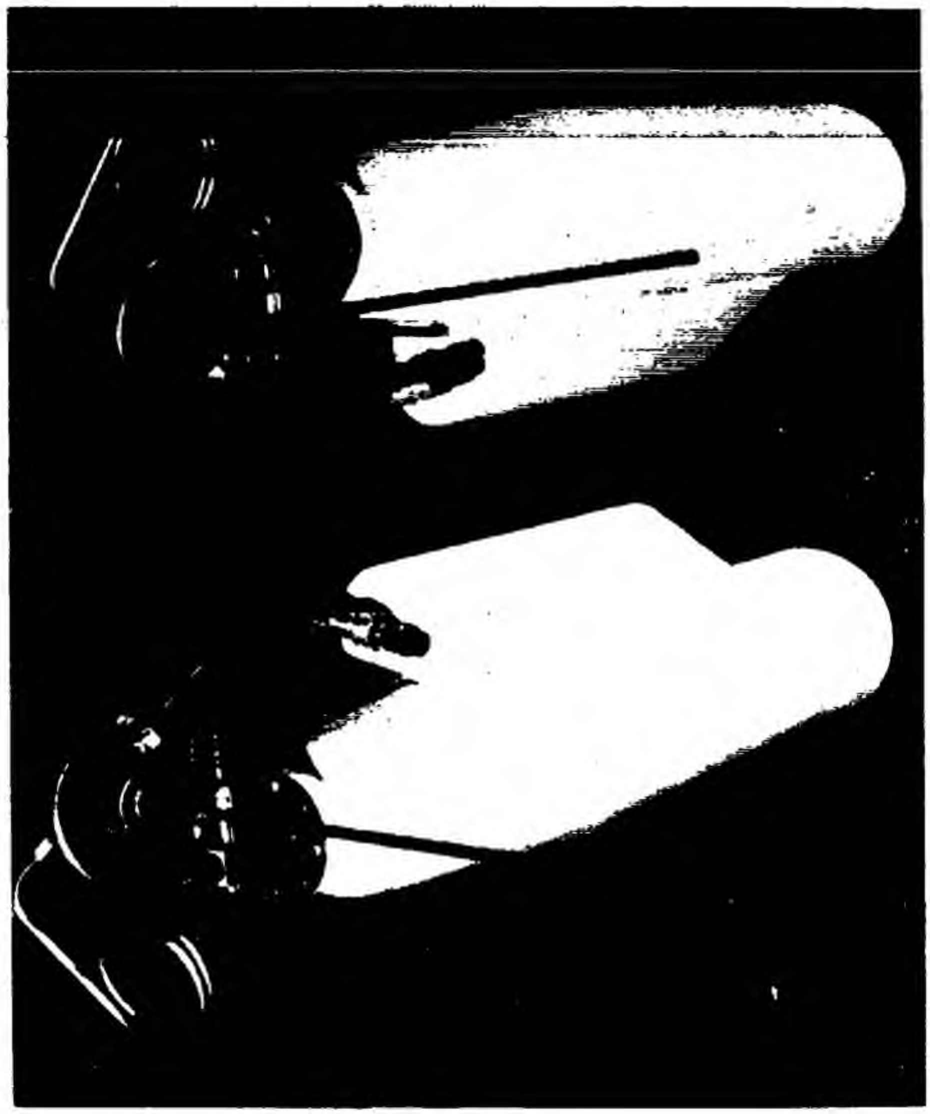

Figure IV. System in Use at the Present Time

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OPERATION OF IMPLANTED-SENSOR SYSTEMS IN REMOTE AREAS (U)
~~(Confidential)~~

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ABSTRACT
~~(Confidential)~~

The detection of guerrilla movement by means of sensors placed beside trails and along borders would have a number of tactical advantages. Such a detection system involves both sensors and communication equipment.

Acoustic, infrared, and seismic sensors are considered. Seismic sensors, with circuits to discriminate footsteps from other earth vibrations appear the most promising. Communication links based on wire lines or ground to ground radio equipment are shown to have significant disadvantages, but interrogation of sensors from aircraft flying over them appears to be feasible.

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1. INTRODUCTION

This paper is based on a short study[1] on the utility of sensors implanted (by air drop or deep penetration patrols) in remote areas with heavy vegetation and rough terrain to detect, store, and transmit intelligence on guerrilla movement. The study was performed for ARPA about a year ago.

During the past few years a number of organizations have considered the use of remote sensors for the detection of personnel and vehicles. Their potential utility is suggested by the analogy of implanted sensors with conventional anti-personnel mines (which also incorporate personnel detectors). The mine and related traps have in many areas been most effective guerrilla weapons, and have been of value in counterinsurgency. It is reasonable to suppose that the reasons for their effectiveness are that they are hidden, patient, and do not require the presence of the implanting soldier. These characteristics, with the possibility that their readout antennas may be more difficult to conceal, are also those of the implanted sensors; the use of such sensors has the additional advantage of not threatening the civilian population, and not alarming a guerrilla band before it has been engaged in combat.

This study was concerned with the cost and utility of systems of implanted sensors to provide military information in an extended region which is not under friendly control. This involved consideration both of the sensors and of the additional equipment necessary to complete an information-gathering system. In this paper we will deal with: The possible military applications of implanted sensors; the possible applicability of known sensors; and some of the problems of deploying a sensor system.

2. POSSIBLE MILITARY APPLICATIONS

2.1 BORDER CONTROL

An important use of remote sensors might be the monitoring of traffic across the boundaries of a country or a limited tactical region. It is clear that in this application such detectors will not be useful in every situation. For example, when normal civilian traffic is heavy, it is unlikely that the movement of insurgents can be detected unless, perhaps, civilian traffic is largely confined to daylight and guerrilla movement takes place at night.

The use of remote sensors for border control has a significant advantage over other methods in that, ideally at least, the existence of the sensors is secret. Thus if sensors are implanted only along portions of the border where heavy guerrilla traffic is suspected, there should be little tendency for guerrillas to avoid this region as they would if fences and patrols were used in such a limited region. Similarly in jungle areas, where progress off trails is slow and laborious, sensors may be needed only on or near trails, and in mountainous regions only areas of easy access need be covered. If it is found that the secrecy of implanted sensors makes a partial coverage effective, the average number of sensors required per linear mile of border is significantly reduced.

Information obtained from sensors along national or regional boundaries can be used in three general ways: immediate response, local intelligence, and central intelligence. In the case of aircraft-interrogating sensors, immediate response involves decision and action by the pilot (or observer) in the interrogation aircraft. The pilot familiar with the normal responses of the sensors over which he flies can respond to an unexpected detection signal by conducting a visual search along the probable path of human beings who might have triggered the sensor, or by notifying the ground by radio so that a patrol can be sent out. The data collected can be used after the interrogation flight by local intelligence to determine the nature of normal and insurgent traffic, and to take action against insurgent groups. It may be noted that because of the slow rate of progress of men on foot, sensor information (particularly if acquired in depth—that is, by successive lines of sensors) may permit contact with insurgent bands even if it is several hours late. Finally, data acquired on interrogation flights can be used in a central intelligence agency to map traffic patterns, determine the correlation of suspected insurgent traffic with insurgent activities, and correlate sensor data with intelligence information from other sources to build a coherent picture of insurgent traffic in the vicinity of the border.

2.2 REGIONAL SURVEILLANCE

In addition to use as an aid in border traffic control, it is believed that an information-gathering system incorporating small emplaced sensors has applications in conducting regional surveillance. Thus sensors implanted along trails and possible guerrilla routes in an area where guerrillas are known to be operating could provide information on routes and habit patterns which would greatly assist in setting up ambushes and in taking other military action against insurgents. The cost of covering an extended area with sensors can be controlled by installing the sensors only along trails and other probable insurgent routes. However, a considerable expense for sensors could be tolerated if they were effective, because of the difficulty generally experienced in making contact with insurgents. It is stated that in Malaya an army or police patrol might spend thousands of man-hours of patient work to get one shot at one bandit.[2] It has also been stated that during periods of reduced or dwindling guerrilla strength it becomes more and more difficult to make combat contact with the guerrillas. Thus, military operations become economically unproductive in simple terms of the dollars spent to support the combat forces in the field compared with the number of insurgents killed or captured.[3] This great expense of manpower might be considerably reduced by employing remote sensors as sentries capable of keeping track of insurgent movements.

A possible variation in the employment of these sensors may be mentioned. It appears possible to make very short range interrogation equipment small enough to be carried by a man on foot. Thus it might be possible for a patrol to interrogate sensors for signs of insurgent movement and activity. For example, if an airplane interrogated and reset all the sensors in an area at dusk, a patrol early the next morning could easily determine whether or not a particular trail had been used during the night; in areas remote from normal traffic, in areas where a curfew has been established, or in areas where there is normally very little civilian traffic after dark, this might provide very valuable information.

2.3 AMBUSH ALERT

It seems that the basic problem in ambush prevention is the detection of guerrillas hidden along the edges of the road. It is suggested that if sensors were implanted at frequent intervals along a road—at least in areas where an ambush might occur—they might provide the required detection capability. For example, an interrogation airplane might fly along the road at night and reset all the sensors. A flight at dawn would indicate which sensors had been alarmed during the night and hence, suggest areas which were probably clear of guerrillas and those where guerrillas might be expected. Another procedure would be to fly along the road ahead of the convoy to interrogate and reset the sensors, and use a truck with interrogation equipment just ahead of the convoy to determine points along the road where human activity had occurred. These techniques require that normal foot traffic along the road be very light at times and places where the insurgents are preparing an ambush. It is believed that in parts of the world where the civilian population is actively cooperating with the government this condition is necessary for a successful ambush, and also in many other regions ambushes must be laid at night when normal traffic is very low.

3. UTILITY OF KNOWN SENSORS

The following assumptions and constraints on possible sensing devices can be inferred from the operational uses discussed above. Due to the operational nature of the problem discussed, the emplacement of the sensors as well as their operation must be covert. The operation of such sensors, especially in remote areas, must be unattended; the sensors must have a self-contained power supply and must operate reliably under variable climatic conditions for long periods of time. It is desirable that the devices under consideration be able to discriminate human beings from other targets (animals, etc.) so that the false alarm rate is low. However, it is assumed that actual identification of detections as enemy personnel can be inferred from other operational considerations such as the known disposition of innocent traffic, time of interrogation, duration between interrogations, site of sensors, and other pertinent intelligence.

Acoustic, infrared, and seismic devices suggest themselves as possible candidates. They are considered, in turn, below.

3.1 ACOUSTIC SENSORS

Two possibilities exist for the detection of human beings with an acoustic device: the detection of human speech, and the detection of other sounds produced by motion or activity. Human speech has a distinctive signature, and it is possible that a simple automatic recognition device might be developed to take advantage of this. This possibility is not considered here, since the dependence on speech for detection appears undesirable because of the likelihood that guerrillas (especially individuals or small groups)may be silent when they cross the line of detectors. Hence it appears that reliance may have to be placed on detecting other sounds of human activity.

No data has been found on the sound levels to be expected from manmade sounds associated with movement in jungles, and so detection ranges are difficult to assess. However, some calculations have been made on detection ranges associated with conversational levels of human speech.[4] It does not appear entirely unreasonable to assume that these two sources are of the same order of magnitude. If this assumption is made then detection ranges of about 75 feet might be expected.* No actual measurements appear to have been published to support or dispute this calculation, although the recently completed ARPA-sponsored measurements in Thailand[5] should provide more precise estimates. During the study no information was discovered to suggest that acoustic devices exist at the present time which embody automatic discrimination techniques for identifying non-speech man-made signatures. Therefore, acoustic sensors without continuous monitoring by human interpreters appear to be impractical at the present time. This implies that they must be provided with a transmitter to relay their data to a monitoring station continuously or with recording equipment which would transfer the recorded information upon interrogation. In both cases because of the continuous nature of the collection information the systems require undesirably large amounts of power.

3.2 INFRARED

Various infrared devices can be considered for intrusion warning; these may be passive or active. Passive intrusion warning systems generally detect the motion of a human being within the field of view of an optical system by responding to short-term changes in the received radiation. They do not appear attractive as long-term unattended personnel sensors for a number of reasons. Changes in the general radiation level from day to night may force rebalancing of the system; such systems cannot discriminate between animals—or sometimes motion of vegetation—and human beings; they are line-of-sight devices and require mounting above the ground, and thus are difficult

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*The 75 foot value arises from speech levels of 65 db at 3 ft., a masking level of 20 db, terrain absorption coefficient of .05 db/foot, and an assumed detection signal-to-noise ratio of 15 db.

to conceal effectively; they generally have limited fields of view; for operation at night the long-wavelength region must be used and the uncooled detectors available for this region are slow and not highly sensitive.

Typical of such devices is the "Turnstile" intrusion detector, originally developed for the Air Force.[5] This detector has a field of view of $6^{\circ} \times 9^{\circ}$. The detector head weighs 1 pound; a battery pack capable of operating the detector for 4 months weighs 8 pounds. Uncooled detectors are used; the maximum range of this device during the hours of darkness is 30 yards for personnel. Because of the various disadvantages enumerated above, passive infrared devices appear to have limited utility as implanted personnel sensors, but perhaps warrant further investigation.

Active personnel detection systems use a transmitter and receiver operating in the infrared region to duplicate conventional "electric eye" techniques. Such systems would be expected to find principal application in regions where traffic is generally confined to trails, although they can be used over greater distances in open terrain, where unimpeded lines of sight exist. Such devices offer the possibility of providing an accurate count of traffic.

The apparent limitations of such devices are the difficulty of concealing two units which must be above ground and of having an unobstructed line of sight between them, and the lack of discrimination capability which may result in counting birds or animals. Also, weather—rain, fog, and perhaps steaming vapor from terrain—may severely limit the operation of such devices. However, some investigation of the severity of these problems appears warranted.

3.3 SEISMIC

Walking sets up vibrations in the earth which can be detected some distance away from the footsteps. The basic problem encountered in personnel sensing by seismic detectors is the discrimination of personnel from animals, vehicles, and natural occurrences such as wind and associated effects of tree roots moving, etc. A signature study conducted by Melpar, Inc., for the Picatinny Arsenal[6, 7] determined that it is possible to discriminate human footsteps at ranges of 30 yards in clay soil by appropriate signal data processing.[7] The main discrimination parameters are frequency, amplitude and time. Field measurements indicated that footsteps generate signals having dominant frequencies in the range of 20 to 30 cps. On the other hand, the dominant frequencies of heavy vehicles are below those of footsteps and light vehicles, although the amplitude of vehicle signatures is 2 to 500 times that of footsteps. However, footsteps produce a characteristic pulse-type signal in contrast to vehicle signals which have relatively constant amplitudes.

A typical example of seismic sensors is one originally developed by Melpar, Inc., as a mine triggering device. It utilizes three discrimination techniques with major emphasis on the pulse nature of the footsteps signature. More study of automatic discrimination techniques is needed to define optimum solutions. The AR[redacted] measurement program in Thailand[8] is expected to provide needed signature, background, and propagation data.

4. IMPLANTING PROBLEMS

Emplacement of the sensors by foot patrols is naturally the most desirable mode. However in cases where an area is completely under insurgent control then access by foot patrols is infeasible.

The only other alternative then is to air-drop the sensors. Air-drop of sensors poses several problems: if the sensor is dropped with a small parachute it may well hang up on the foliage of the jungle canopy, which might not be the most suitable position for the detector; the use of spikes may not be feasible since vegetation will deflect them and cause them to land in undesired positions and not with the proper attitude; impact shock at landing may pose severe structural design requirements for the sensors; even finding the right trails from the air especially at night may be extremely difficult. It is easy to see that air drop poses many potential problems. It is not clear, however, that these cannot be surmounted. In view of its obvious value when planting sensors in enemy occupied terriitory a program to further investigate air drop capability would appear worthwhile.

5. INFORMATION GATHERING CONSIDERATION

The information which is obtained by individual implanted sensors must be made available at a central point for interpretation and subsequent use. Three possible modes of transmission appear possible: wire lines linking each sensor with a relay station or the central; ground to ground radio networks; and airborne interrogation.

Wire lines appear undesirable for a number of reasons. Laying wire networks on the ground in the jungle or in rugged terrain may be difficult. The operation of laying wire from the air and connecting it to sensor and relay stations on the ground would be hard to conceal. Furthermore, discovery of even one wire leg would be sufficient for the enemy to discover and destroy the entire system by following the wire network link by link.

For the ground to ground radio network system, if we assume a 1-watt transmitter and a receiver sensitivity of the order of -70 dbm for an adequate output signal-to-noise ratio the permissible path loss for communication cannot exceed 100 db. Free-space path loss calculations using unity-gain antennas give a working range for this path loss of about 20 miles at VHF. However, recent experimental work by [redacted] in Thailand shows that the path loss under jungle conditions is considerably greater and the corresponding working range therefore drastically reduced. Specifically this data indicates that for vertically polarized antennas, when both the transmitting and receiving antennas are located close to ground level, the path loss may be expected to be 100 db at 0.2 miles. If one of the antennas is near ground (7 feet above) and the other 40 feet above the canopy (for 40 foot canopy) a 100 db path loss is experienced at ranges of 0.35 miles for 100 mc and 0.6 miles at 50 mc. Finally, if both of the antennas are placed 40 feet above the canopy the path loss at 2 miles will be 103 db for 100 mc and 94 db for 50 mc. Thus path losses under, through, or over the canopy are much greater than free-space losses, and communication between points near the ground is much worse than between points above the canopy.

On the basis of these figures, it appears that if the sensor antenna and the receiving antenna are near the ground and are simple enough to be concealed, radio transmission of sensor data is not feasible in forested and rough terrain.

Even if it were possible to locate the antennas on top of the canopy, the use of relay stations at 2 mile intervals results in a great number of relays, greatly adding to the installation and maintenance problem beyond that required for the sensors themselves.

Neither wire nor ground radio networks appear to provide practical and secure communication with distributed remote sensors. A third possibility which offers greater promise of feasibility is the radio interrogation of the implanted sensors from an airplane.

The airborne interrogation of remote implanted sensors requires the addition of a traffic counter and a coded transponder which, when interrogated with the proper code, transmits data concerning the stored count of traffic. The process of interrogation resets the traffic counter to zero. Interrogation is accomplished from an airplane which flies at low altitude along the line of sensors. A record is kept in the airplane of the sensor responses; this information can be transmitted to the ground immediately via the normal aircraft communication equipment, or the record can be analyzed at the conclusion of the flight.

The transmission from the sensors in any such system could be prefixed with a sensor address code so that the sensor which is reporting can be known without ambiguity. For example, if the sensors are located at an average distance of 0.2 miles apart, a coding system with 256 individual codes will place sensors with identical codes approximately 52 miles apart. The transmission range of the aircraft transmitter could easily be restricted below this value to prevent identical sensors from being triggered simultaneously; and yet be adequate to cover aircraft navigation errors.

6. SYSTEM COSTS

The cost of using implanted sensors and an airborne interrogation system includes the cost of the sensors themselves, the cost of the aircraft and airborne equipment, the cost of the manpower (and equipment if necessary) for implanting the sensors, the cost of the crews and operators for the aircraft and interrogation equipment, aircraft operating costs, and the cost of men and equipment for data processing and analysis. In considering the cost of implanting the sensors the nature of the terrain and the tactical situation are critical. These factors determine the number of sensors needed, the distance they must be carried, and the amount of firepower required for the protection by the implanting patrols. The cost of crews and operators for the aircraft and interrogation equipment depends on the design of the interrogation equipment and on the interrogation frequency. The men and equipment necessary for data processing and analysis cannot be determined until the amount of data obtainable from implanted sensors has been analyzed in the field. Therefore, it appears that at this initial stage all that can be done is to estimate on an order of magnitude basis the costs of the individual sensors and the airborne equipment. The best basis for estimating sensor cost appears to be the existing seismic personnel sensor manufactured by Melpar, which costs about $100 in lots of 1000. It is estimated that the three to five times more complicated sensor required for the present system can be produced for about $300-$500 apiece in large quantities. Only a guess can be made as to the cost of the airborne equipment. It would appear simple enough, that the cost of an installation is unlikely to be significant compared to aircraft operating costs.

7. CONCLUSIONS

In summary we can conclude:

1. Implanted sensors will probably prove to be tactically useful in the monitoring of traffic across national borders, in the control of traffic in local regions, in the

detection of insurgent activity within regions, and in the prevention of highway ambushes by insurgents. Their use depends on the level of normal traffic; they may be expected to be of special value in obtaining intelligence in remote areas where there is little or no normal traffic.

2. The most promising sensors at present are seismic detectors which detect and recognize personnel within a range of about 30 yards by the distinctive nature of human footsteps. Acoustic sensors do not appear to be satisfactory because the absence of a distinctive signature requires continuous monitoring of the sensor output.

3. Both ground to ground radio and wire lines present major problems when used for transmitting data from implanted sensors back to a central station. The principal shortcomings of wire lines are the difficulties of laying wire and the vulnerability of the whole system to a single discovery of any portions of the lines. The principal shortcoming of ground to ground radio is the very short ranges that can be achieved with concealed antennas in the jungle. Even under good conditions, rather complicated radio relay nets would be necessary.

4. The interrogation of implanted sensors incorporating a simple counter and memory from an airplane which flies over the line of sensors appears to be a practical data handling procedure requiring relatively simple equipment.

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RUBIDIUM VAPOR MAGNETOMETER

TESTS IN THAILAND

~~Confidential~~

(b)(6) [redacted]

Military Research & Development Centre,

Bangkok, Thailand.

ABSTRACT
(Unclassified)

This paper is a short summary of work completed during 1965 by staff of the College of Engineering, Chulalongkorn University, the Stanford Research Institute's Bangkok Field Office, and the Military Research and Development Center.

The rubidium vapor magnetometer was tested to determine whether its use would enable detection in Southeast Asian areas of:

1. Caches of buried weapons, or other military materials containing steel, and

2. Tunnels in iron rich soils.

In general, it appears that under favorable conditions, the magnetometer will allow search rates of about 16,000 to 22,000 square meters per hour for a detection probability of about 85% against one to six rifles.

Inexperienced personnel have achieved search rates of about 2000 to 3000 square meters per hour against a range of targets varying from a sten gun to a 50 gallon drum and achieved a detection rate of 65%

1. INTRODUCTION

1.1 Background

Insurgent forces have frequently buried weapons, canned food and other military equipment so as to ensure a secure supply for future operations. In other cases, weapons are hidden in the roofs or walls of huts, under the floors, or even in hollow trees.

Weapons are frequently transported by insurgent forces in barges where they might be hidden beneath large quantities of rice, in trucks carrying various materials, or in bullock wagons.

For a counterinsurgency force, the control of weapons and their distribution is of great importance, and so the development of a means for detecting hidden weapons has become a necessity.

It is obvious that weapons contain appreciable amounts of steel. Experience tells us that many food or medical supplies buried underground are usually first placed in steel containers for protection. It thus appeared reasonable to test passive magnetic methods as a means of detecting these target types. However, the degree of background variation which might be present was unknown.

Another problem is that many Southeast Asian soils are rich in maghemite or gamma-hematite which is an iron rich mineral of high magnetic susceptibility. Burying steel in such a material would probably result in attenuation of the magnetic anomaly.

An associated problem is that of tunnels, for which no fast, reliable method of detection exists at the present time. Here, the problem of high magnetic susceptibility has more favorable aspects--a void in such a soil might itself produce a measurable magnetic anomaly and so enable the detection of tunnels if natural spatial variations were not excessive.

With these aspects in mind, Stanford Research Institute made preliminary tests at Calaveras, California, in late 1964. The rubidium vapor magnetometer was used to measure the magnetic anomaly produced by a cache of about 10 rifles at 3 meters depth. The results were quite promising and a proposal to test passive magnetic systems for the detection of tunnels and buried steel was subsequently raised. The project was assigned to the Military Research and Development Center who negotiated a contract with the College of Electrical Engineering, Chulalongkorn University, Bangkok, for data acquisition, reduction, and analysis.

Further analysis has been done by personnel of the Military Research and Development Center.

1.2 Objectives

The objectives of this series of tests were to:

1. Examine the feasibility of using the rubidium vapor magnetometer in Southeast Asian areas for the detection of, firstly, cached arms and military equipment of a ferrous nature and secondly, tunnels in iron bearing soils; and

2. To determine the desirable specifications of an operational version of the instrument.

It was expected that the information gathered would be suitable for the assessment of other passive magnetic detection systems.

1.3 Scope

The scope of the tests included the measurement of spatial variations of the earth's magnetic field over sites scattered through Thailand, and measurement of the magnetic anomalies of what were considered to be typical targets. A simulated search produced indications of the capacity of inexperienced personnel to use the instrument.

2. DESCRIPTION OF THE RUBIDIUM VAPOR MAGNETOMETER

Two versions of the rubidium vapor magnetometer produced by Varian Associates, Incorporated, were used:

1. A modified V-4938 magnetometer incorporating a paper tape analog recorder was used to obtain a permanent record of spatial variations.
Figure 1 illustrates the readout and analog recorder.
Figure 2 illustrates the portable sensor and sensor electronics units which are mounted on a staff and carried over the area to be measured.

2. A portable version using the same sensor and sensor electronics units, but

Figure 1 - Magnetometer Readout and Recording Unit

Figure 2 - Sensor and Sensor Electronics Unit (Stationary Oscillator is visible in the background above the operator's left wrist)

Figure 3 - Portable audio
version of the rubidium
vapor magnetometer

utilizing only an audio output was used during a simulated search. (See figure 3)

2.1 Principle of Operation

The rubidium molecule has a natural frequency which is associated with the valence electron. Changes in the ambient magnetic field produce an interaction effect between the magnetic moment and the angular momentum of the electron. This results in a change of the natural frequency which is measured by means of optical pumping and monitoring techniques. Measurement of the changes in frequency associated with the valence electron, thus gives a record of changes in the ambient total magnetic field.

2.2 Description

The instrument used for data acquisition was the Model V-4938 magnetometer consisting of five basic components. The first two, the sensor and sensor electronics units together comprise the rubidium oscillator and are mounted on a five foot staff and joined by a multiconductor cable.

The output of the oscillator runs to a third component, the readout unit via a 200 foot length of cable. (This cable also carries power to the oscillator.) The output is fed to the fourth component, the analog recorder, which produces a permanent record of magnetic field variations. A four stroke motor driving a generator comprised the power source.

The output of the portable oscillator can be compared with that of a crystal oscillator which is not subject to changes of magnetic field. If this is done, temporal as well as spatial changes in the magnetic field will be included in the output of the analog recorder. The equipment is said to be operating in the direct mode in this case.

Alternatively, the portable rubidium oscillator output can be compared with that of another remote rubidium oscillator which is stationary. Both oscillators are thus subject to virtually the same temporal changes. The difference of these two outputs is thus a result of only spatial changes in the magnetic field. This arrangement is referred to as the differential mode.

The portable audio version used in the simulated search has no readout or analog recorder and utilizes batteries as a power source. The output takes the form of an audio tone (adjustable) which is fed to the operators headphones. The operator must thus interpret changes in the frequency of an audio tone as changes in the magnitude of the ambient total magnetic field. The unit operates essentially in the direct mode.

The weight of the sensor and associated equipment is 11 pounds, and that of the battery pack used to date is 19 pounds, producing a continuous operating battery life of six or seven hours.

2.3 General

It is important to recognize that the magnetometer measures changes in the magnitude of the total magnetic field.

Another point worthy of mention is that the axis of the sensor must be inclined at a vertical angle of 45 degrees to the direction of the field for best signal to noise ratio. However, variations of at least plus or minus 15 degrees are quite acceptable. Also, the axis of the sensor should not deviate from the north-south direction by more than about 15 degrees. These limitations have presented no major problems in tests, but will probably do so when dense vegetation is present.

Most traverses were made in the north south direction as this allows the operator to hold the staff more easily across the body. The staff can be held with the staff axis pointing forwards and so with only little discomfort, traverses can be made in other directions.

3. THEORY

Using the magnetometer in either the direct or differential mode will result in magnetic anomalies, the amplitude of which should bear an inverse cubic relationship to the nearest approach distance for horizontal targets aligned north and south. The shape of the anomaly is shown in Figure 4. Note that the distance between peaks is 2.5 times the nearest approach distance.

When vertical targets are considered, the same sort of relationship applies between signal amplitude and nearest approach distance for traverses along specific planes. This is shown in Figure 5, and the distance between maximum and minimum values is about equal to the nearest approach distance.

It can be seen that the shape of the anomaly is different for both these targets. Further, the distance over which the anomaly occurs can be taken as a measure of slant range to the target, and signal amplitude can give some measure of the magnetic moment of the object.

Tests were carried out using north south traverses and most targets were aligned north south, but some were vertical. Tests on other orientations were not made. Clearly, more work on other target orientations is required, but it seems safe to assume that a north south traverse over a target aligned with the earth's magnetic field should give the largest anomaly.

4. TEST RESULTS

4.1 Buried Ferrous Materials

During tests the sensor staff was held at waist level; however, several operators carried it and so the sensor height above ground level has varied. Essentially, the height of the sensor was about 70 centimeters above the ground and this height has been assumed for most calculations. Figure 6 illustrates some measurements made with a steel rod of 65 centimeters length aligned horizontally, north and south. The vertical strokes indicate the extent of probable error in measurement of nearest approach distance. The measurements of the peak to peak amplitude of the anomaly were made along north-south traverses over a range of nearest approach distances and with three different depths of burial--on the ground, at 75 cm depth, and 125 cm depth.

Readings of anomaly amplitude appear to follow the inverse cubic relationship with distance when each individual test is considered. However, depth of burial appears to have some effect on this relationship. The signals from the rod on the ground seem to be proportionally lower than those of the other tests, implying either that the soil susceptibility has some effect, or alternatively, that the magnetic moment of the bar had changed. The latter explanation is chosen since the soil susceptibility at the test site was very low. Measurement errors cannot explain the differences. No special preliminary alignment of the bar was made prior to the test and so this appears to be a reasonable assumption. Operationally, targets might be assumed to have been in position for long periods and so the largest magnetic moments have been chosen as what might be representative of north-south aligned targets.

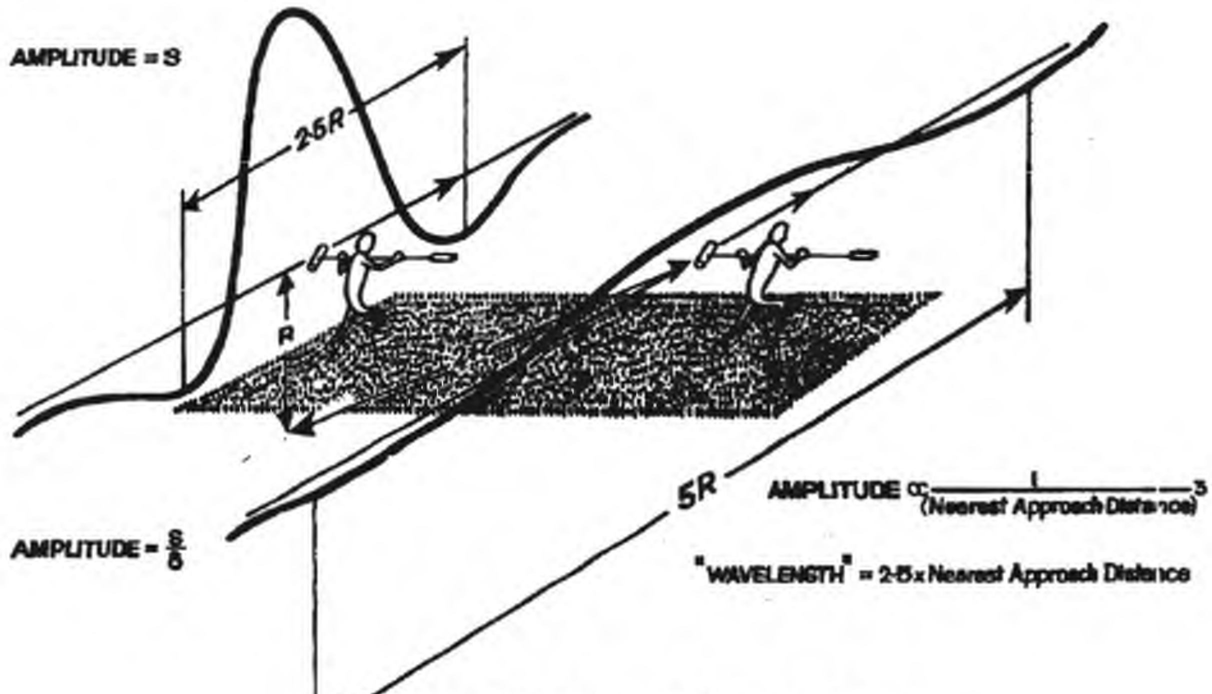


FIGURE 4 HORIZONTAL DIPOLE ALIGNED N–S

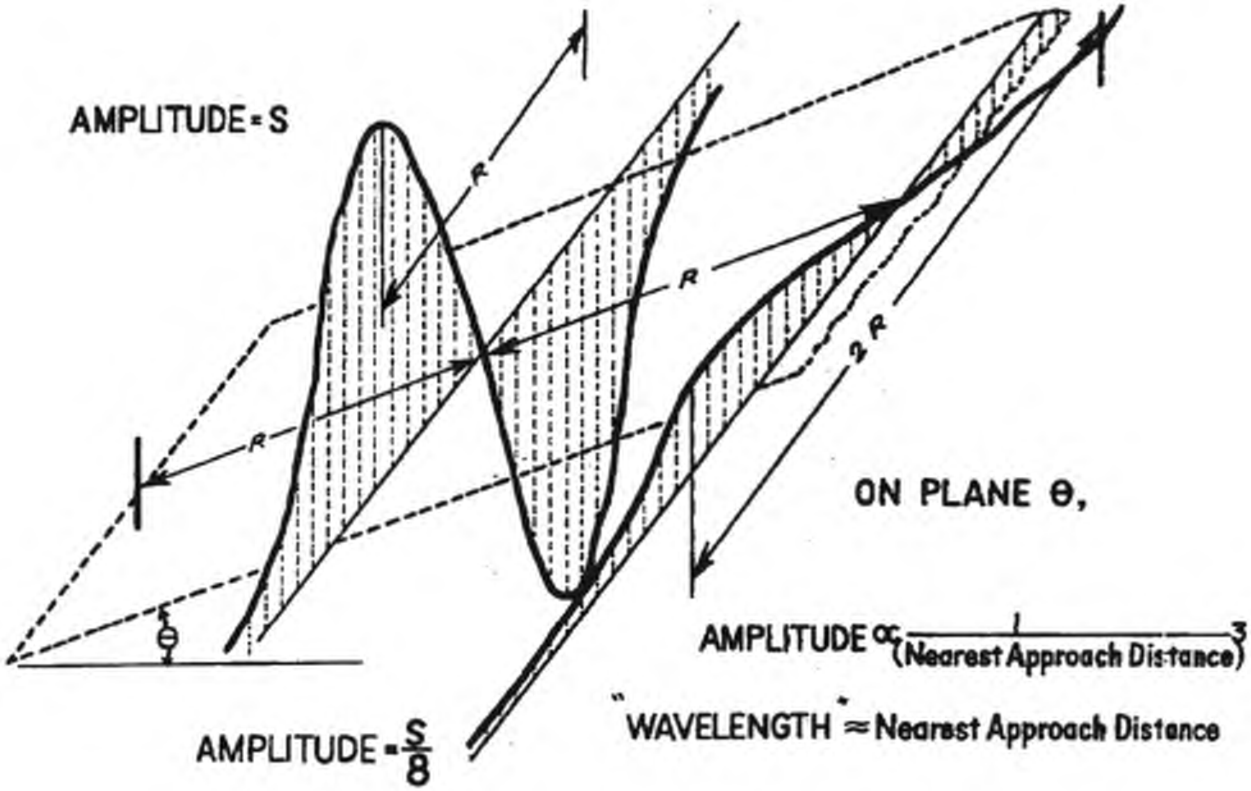


FIGURE 5 - VERTICAL DIPOLE

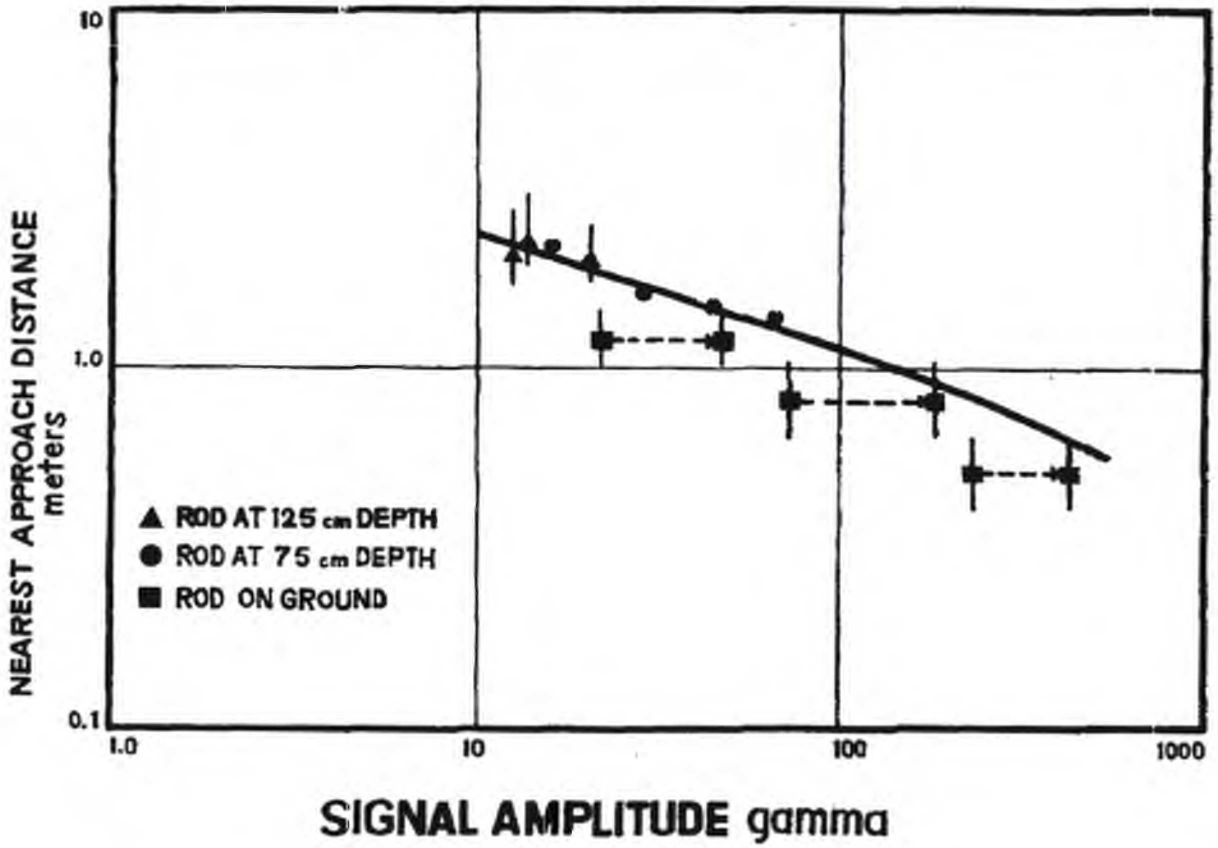


Figure 6 - STEEL ROD

A similar problem was noted with a model sten gun (Figure 7). Other items tested for response were 4 gasoline cans, a 50-gallon drum and 10 gasoline cans.

In all cases, the measurements were consistent with an inverse cubic relationship between signal amplitude and nearest approach distance. The signals of all these targets were typical of a horizontal dipole aligned north and south.

The next step was to determine whether target steel mass could be incorporated into the relationship. Figure 8 shows such an attempt over the range of steel target weights considered during tests. Plotted with nearest approach distance as the vertical logarithmic axis, and target steel weight as the horizontal logarithmic axis, lines of equal amplitude are linear over the ranges considered. Other data is also included.

The next step was examination of wavelengths. In some cases traverses were not long enough to detect the minima, and in others alignment of traverses to determine background variation and target response were not always the same. Thus errors of measurement are present. However, Figure 9 illustrates the relationship. Over typical detection ranges, it seems reasonable to assume a value of 2.75 for the ratio of wavelength to nearest approach distance.

Plotting the responses of 20 kilograms of scrap metal (mostly steel) and of a vertical iron rod, the amplitudes were much less than for equivalent masses of steel giving horizontal dipole responses. There was support for the suggestions from theory that the wavelength was equal to the nearest approach distance and that signal amplitude was inversely proportional to the cube of the nearest approach distance.

The assumption of different magnetic moments at various times of testing was supported by other tests. The iron bar was left in position for one week and then measured. The amplitude recorded was considerably greater than in other cases where no special previous treatment had been given the rod. Further, rotation of the rod through 180 degrees showed that the anomaly on reversal was much smaller than that existing prior to rotation. Magnetic moments thus do alter.

Immediately after installation of targets for the simulated search, a traverse was made with the recording version of the magnetometer. Targets included gasoline cans, oil drums, model rifles, a model sten gun and a model machine gun. The responses obtained were compatible with all previous data.

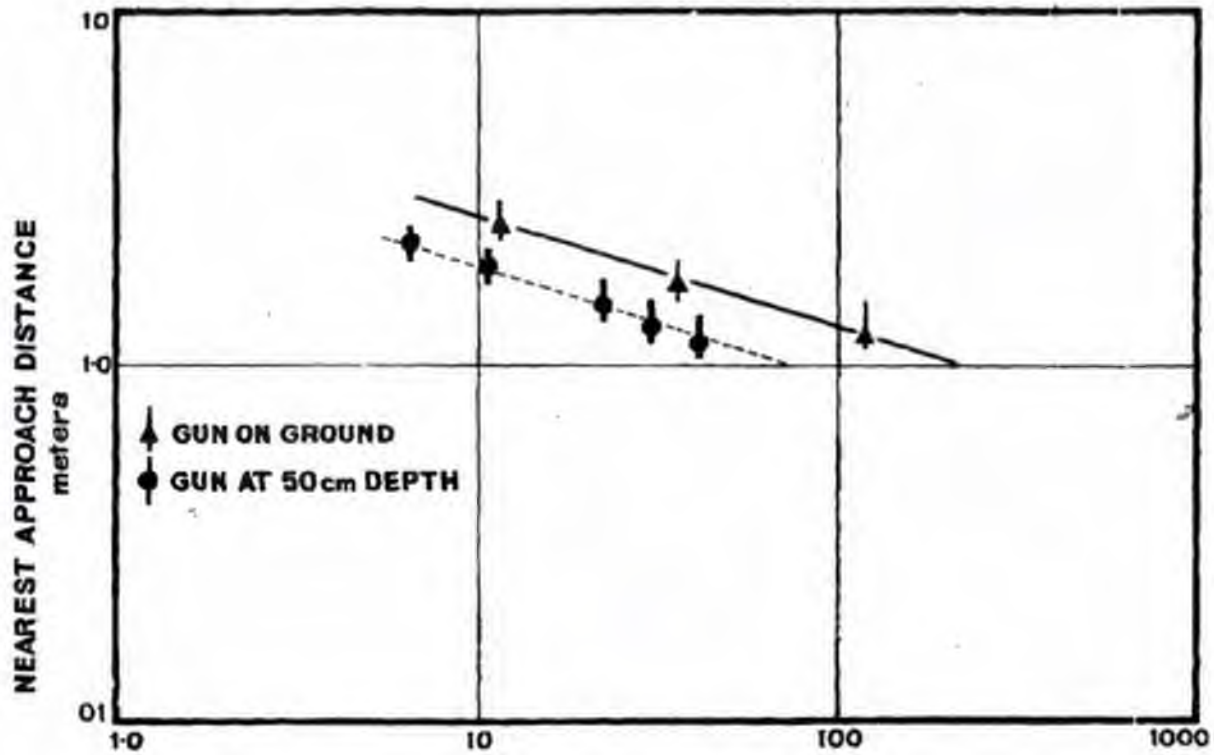
4.2 Tunnel Detection

Two series of tests were made to determine the feasibility of detecting tunnels by passive magnetic means.

The first attempt involved digging two tunnels in an east west direction into a cutting (Figure 10) at Prachinburi. Traverses were made in a north south direction over the tunnels. However, it rapidly became evident that the natural background variations were large, and that any variations in the vicinity were not necessarily due to the presence of the tunnels.

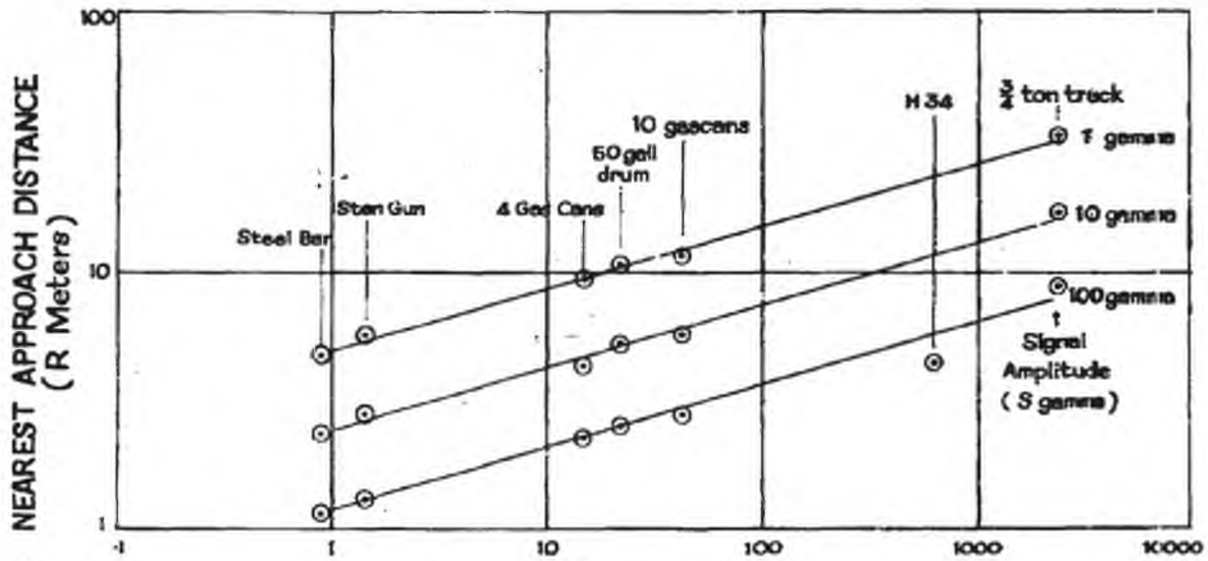
The second attempt involved the selection of two relatively quiet areas in the background measurement area at Prachinburi. These areas were again magnetically surveyed and differences noted. At some points, significant differences were found. However, the differences could have been easily attributed to the errors in measurement involved in making traverses in rapidly changing magnetic gradients. (Figure 11 and 12). It is possible, however, that the difference of about 15 gamma amplitude along the edge of the pit forming the entrance to the east west tunnel was due to the pit. The tunnel appeared to produce no measurable anomaly.

The soil at the Prachinburi site had one of the highest magnetic susceptibilities encountered during the tests. As such, a tunnel dug in this soil should



SIGNAL AMPLITUDE gamma

Figure 7 - **STEN GUN MODEL**



TARGET STEEL WEIGHT
(M Kilograms)

Empirical Equation is $SR^3 = 133\ M^{0.76}$

Figure 8 - Target Responses And Other Data

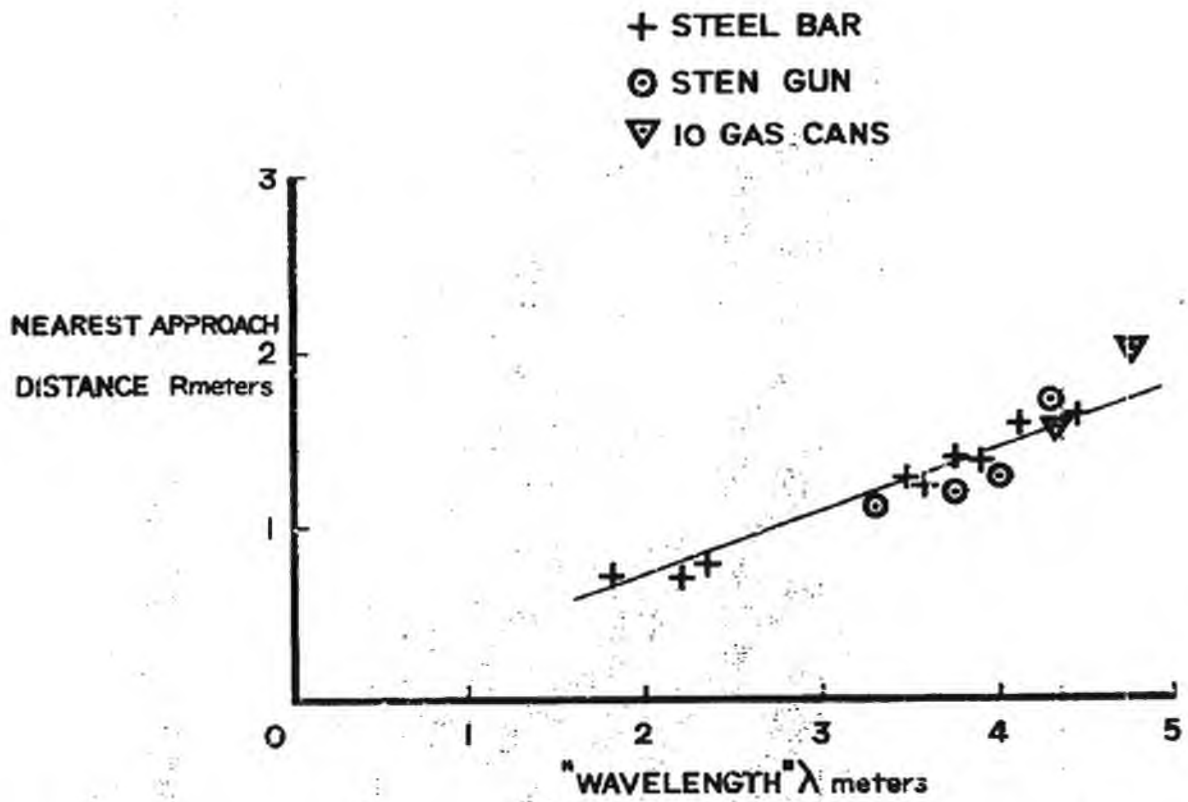


FIGURE 9 - "WAVELENGTH" TO RANGE RATIO

Figure 10 - First two tunnels constructed at Prachinburi (Tunnels are 1.2 meters high, 0.8 meters wide; overhead cover is one and two meters)

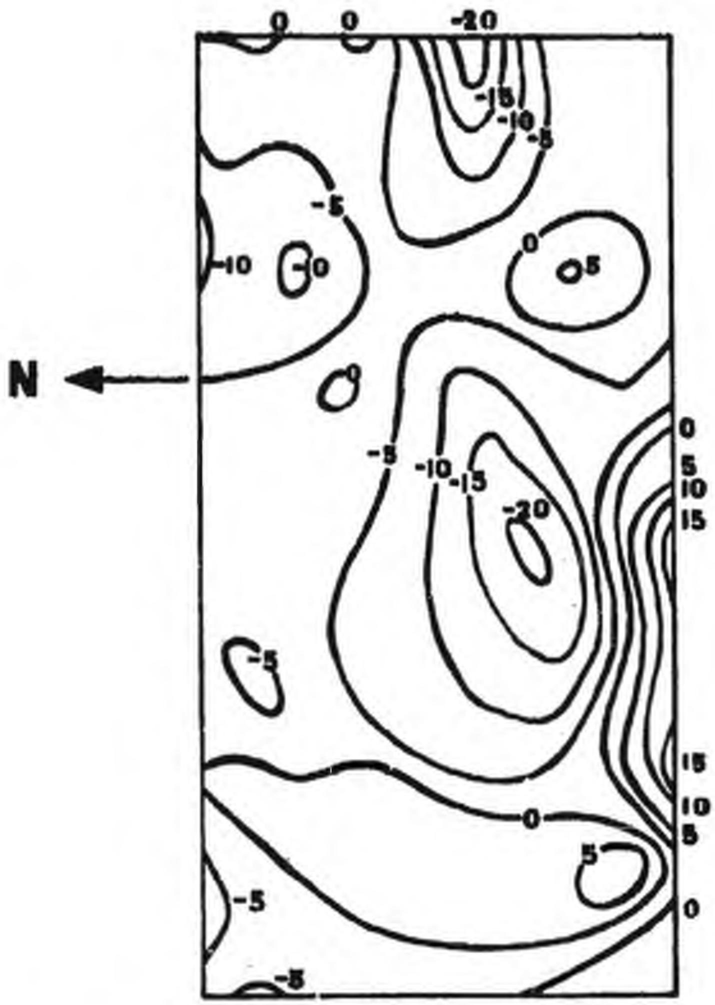


Figure11- Magnetic Field Contours Without Tunnel

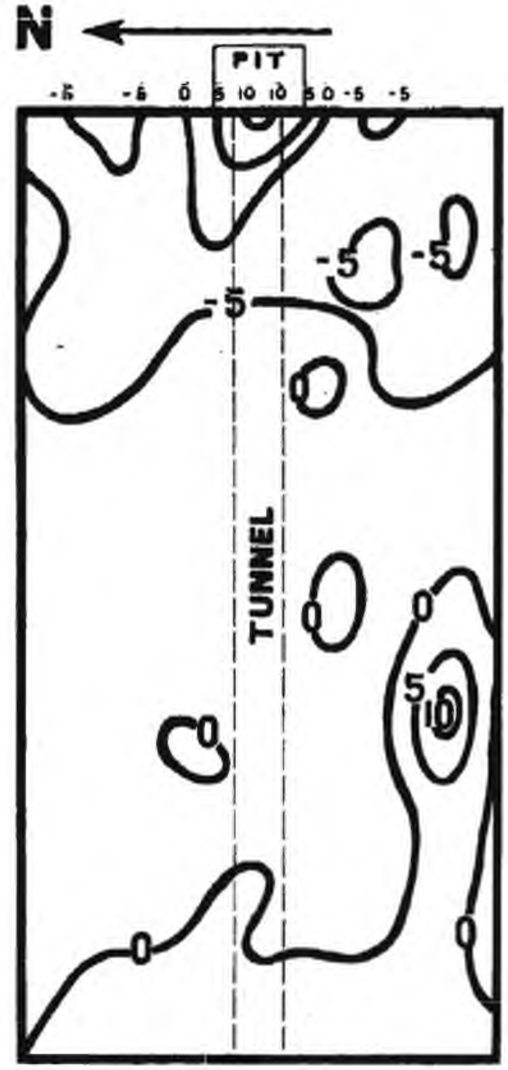


Figure12 - Effect Of Tunnel Scalar Magnetic Field Differences

produce a large magnetic signature compared with that produced by a tunnel in a soil of normal magnetic susceptibility. This effectively rules out the possibility of detecting empty tunnels by passive magnetic means, particularly when recent research is considered. Tests in Thailand and elsewhere indicate that the higher the soil susceptibility becomes, the greater is the probability of large background variations being present. Analysis suggested that any signal from the tunnels was less than 2 or 3 gamma in amplitude.

One hope remains--that is where tunnels are dug in a soil of high magnetic susceptibility but of low "noiseiness"-- that is where spatial variations are very small. Such a situation might occur in the soft laterite soils, but no tests have been conducted in this type of soil to date. The soil at the Prachinburi site was classified as a reddish-brown lateritic soil. The laterite present was not the soft variety but the hardened, nodular form--iron content was approximately 30 percent by weight.

4.3 Background Measurements

The effect of background variation on detection ability is not yet clearly understood. However, sufficient data has now been gathered on the nature of the background variation and target signals to enable this to be done in an acoustic laboratory. Such questions as:

"How does a man distinguish a possible target signal from background variation?" and

"Does he use amplitude of change, or time rate of change of signal?" and

"What can a man detect in a steady magnetic gradient?"

are questions which cannot yet be answered with certainty.

The simulated search (discussed later) indicated that at walking speeds of 3Km/hr, and experienced operator might be able to detect a change of 1.7 gammas per meter and should be able to detect a change of 6 gammas per meter. On this basis, the sites have been placed into three groups which might indicate what sites are favorable for weapons detection. (See Table 1). Where steady gradients were present over the site it was assumed that this would not greatly effect the problem of detection.

It can be seen that generally, latosols, lateritic and podzolic soils are more unfavorable than other soils. Of 23 sites tested, 13 are favorable, 7 partly favorable, and 3 quite unfavorable for the detection of buried weapons.

Some large concentrated magnetic anomalies which would certainly have resulted in digging, were found at various sites.

1. At MERS test site 35 at Sattahib, an anomaly of 180 gamma peak to peak amplitude was found. It was similar to that which might be created by a b steel dipole at 1-1/2 meters depth. The anomaly was recorded on a large low mound about 8 meters in diameter and one meter high. The mound may have been caused by a termites' nest having been ploughed down by a farmer.

2. At Prachinburi, a concentrated magnetic anomaly of about 650 gamma amplitude was found. The anomaly was similar to that created by a steel vertical dipole with center about 4.0 meters depth. A hole was dug at the anomaly center to a depth of 4 meters without encountering any ferrous materials. However, the laterite in the area appeared to be within a foot of the surface as opposed to a meter at other parts of the site. There was also a pocket of soil of a different color, but similar texture present (See Figure 14).

3. At Saraburi (MERS test site PD 255) a horizontal dipole response of

MAGNETIC BACKGROUND TEST SITES

GROSSLY CLASSIFIED

FAVOURABLE

BANGKOK UNIVERSITY GROUNDS	ALLUVIAL
KHON KAEN TS 12	ALLUVIAL
SONGKHLA TS 43	GREY BROWN PODZOLIC-NONCALCIC BROWN INTERGRADE
NAKHON SAWAN TS 17	LOW HUMIC GLEY-RENDZINA TRANSITION
AMPIRT FOREST SITE	NONCALCIC BROWN-RED BROWN EARTH INTERGRADE
HUA HIN BEACH	SILICOUS BEACH SAND
CHIENGMAI PD 241	LOW HUMIC GLEY
CHANTABURI TS 42	RED YELLOW PODZOLIC
SARABURI TS 25	LOW HUMIC GLEY
CHIENGMAI TS 5	ALLUVIAL
KHON KAEN TS 10	RED LATOSOL
NAKHON SAWAN PD 251	RED BROWN EARTH
DONG KENG	PROBABLY LOW HUMIC GLEY

PARTLY FAVOURABLE

PRANBURI TS 34	NON CALCIC BROWN
SATTAHIB TS 35	GREY PODZOLIC
CHIENGMAI TS 3	RED YELLOW PODZOLIC-REDBROWN LATERITIC TRANSITION
KHON KAEN PD 246	GREY PODZOLIC
SONGKHLA TS 46	ALLUVIAL
SONGKHLA PD 260	YELLOW LATOSOL
SARABURI PD 255	GRUMOSOL

UNFAVOURABLE

HUA HIN TS 30	RED LATOSOL
PRACHINBURI	RED BROWN LATERITIC
SONGKHLA TS 47	RED BROWN LATERITIC

TABLE 1

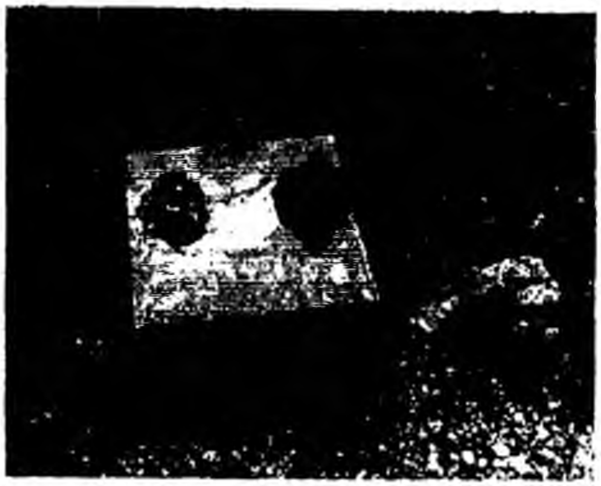


Figure 14 - Contrasting soil colours found in region of 650 gamma anomaly at Prachinburi (Left sample is grey, right sample redbrown)

175 gamma amplitude was noted.

4. At Hua Hin (MERS test site TS 30) many small amplitude but concentrated magnetic anomalies were noted. They were nearly always associated with small (1 foot diameter x 1 foot high) termite nests.

When the magnetometer sensor is held at ground level, the background variation is increased, but target signals will also be increased. Traverses at Prachinburi showed that the amplitude of variations were increased by a factor of 1.7 to 2.7 at ground level. In this case target detection would be easier with the sensor at ground level if the targets were buried at depths less than 1 to 3 meters.

4.4 Simulated Search Results

In early December 1965, an area of beach, 240 meters long and 16 meters wide, was staked out and magnetic background measurements made. On the basis of these measurements, the site was classified as being favorable for target detection. Seven targets were buried within the search area (targets and site aligned north south) and the target coordinates and depths recorded.

After the targets had been positioned, a run with the audio version of the magnetometer was made by a person who had used it several times before. He had participated in the siting of targets, so had a rough idea of where they were in the area. He felt that if he had not known where the targets were the results would not have been very different. He located all targets except the sten gun in about 20 minutes, and with no false alarms.

A search of the area was made a week later. The operators consisted of:

1. Nine Royal Thai Army personnel who were given a day's instruction on the magnetometer and

2. Three other personnel who had used the magnetometer but not the audio version used in the search.

All personnel could be classed as inexperienced with the proviso that the last three had a good knowledge of how it operated.

In all search efforts the operators were constrained to search along parallel lines marked 4 meters apart. On detection of an anomaly, the searchers were allowed to deviate from the line to fix the anomaly source. Searchers held the sensor staff at waist level or ground level as required. Results of this search are shown in Table 2.

Considering the results for this range of targets under favorable conditions, inexperienced operators can search at a rate of about 2000-3000 square meters/hour, for a detection rate of about 65% and a false alarm rate of 1 per 5,000 square meters.

The one attempt by an experienced operator under favorable conditions indicates a search rate of about 12,000 square meters/hour, for a detection rate of 85% and a negligible false alarm rate. The search pattern was not designed to fully utilize the ability of the experienced operator.

Figures 16 - 20 illustrate most of the targets used during the search.

The following estimates are based on the assumption that an experienced operator using the audio magnetometer can detect a change of 10 gammas/sec with a probability of unity, and 3 gammas/sec with zero probability. Experience has indicated that these figures might be fairly representative of what can be achieved by an experienced operator working under favorable conditions. Under normal

SIMULATED SEARCH - HUA HIN, DEC 65

INEXPERIENCED OPERATORS

TARGET AND WEIGHT	NEAREST APPROACH DISTANCE	ESTIMATED AMPLITUDE	N° OF ATTEMPTS TO DETECT TARGET	N° OF DETECTIONS	DETECTION RATE %
DRUM 22.7 Kg	2.0 meters	150 gammas	11	11	100
6 GAS CANS 24.5 Kg	1.7	230	10	9	90
5 RIFLES 11.4 Kg	2.4	53	10	10	100
MACHINE GUN 2.7 Kg	1.9	38	10	8	80
2 RIFLES 4.5 Kg	2.3	29	10	6	60
1 RIFLE 2.3 Kg	2.2	21	10	2	20
1 STEN GUN 1.4 Kg	2.2	16	10	NIL	NIL

NUMBER OF FALSE ALARMS = 9

TABLE 2

Figure 16 - Model Machine Gun

Figure 17 - Model Rifle

Figure 18 - Two model rifles

Figure 19 - Five model rifles
(Note arrangement designed to simulate stacking procedure used with real weapons)

Figure 20 - 50 gallon oil drum

conditions, it is also assumed that a man cannot hear a change of 3 gamma, no matter how fast it occurs. (Note that for rubidium 85, 1 gamma change is equivalent to a change of $4\frac{2}{3}$ cps).

The simulated search indicated that an inexperienced operator could not detect a change of less than 4 gamma per second and could clearly detect a 12 gamma per second change (operating frequency was about 300 cps). One reason for the relatively poor performance of the inexperienced operators was their very slow walking rate (something like 1 km/hr). If an experienced operator walked faster (say 3 km/hr) the same amplitude signals would become more obvious.

5. ESTIMATES OF POSSIBLE SEARCH RATES

Figure 21 illustrates anomalies at various slant ranges for a series of targets of 6 rifles, 3 rifles and 1 rifle lying in a north south direction. Detection ranges are indicated.

Assuming a burial depth of 30 cm and a sensor height of 70 cm, the detection ranges measured horizontally are as follows:

	Zero Probability	Unit Probability
6 rifles	3.7 meters	2.6 meters
3 rifles	3.4 meters	2.4 meters
1 rifle	2.6 meters	1.8 meters

Assuming a linear variation of probability of detection between these limits we can determine the detection probability for randomly distributed targets and various distances between parallel traverses.

For the following targets, the likely detection probability and search rates are:

	Detection Probability	Search rate m^2/hr
6 rifles	.85	22,000
3 rifles	.85	20,000
1 rifle	.85	16,000

These are essentially realistic figures for experienced operators working under favorable conditions.

Of the twenty-three sites investigated in Thailand, over 50% had favorable magnetic conditions. Where dense vegetation is present, these search rates may not be obtainable. Where searches are made in villages the false alarm rate may be greatly increased and search rate diminished.

6. OTHER TESTS IN THAILAND

A novel use for the magnetometer involved searching for a helicopter which had crashed and sunk in the Mekhong River near Vientiane. However, 8 knot currents, deep and turbulent water containing massive boulders, produced great difficulties. Natural anomalies of 600 gamma were common and previous tests had revealed that an anomaly of 45 gamma at 5 meters could be expected from the helicopter. The helicopter was not located but the sharp anomaly of 10 gamma produced by a long pipe fitted with grappling hooks led to the recovery of this item, which had been lost

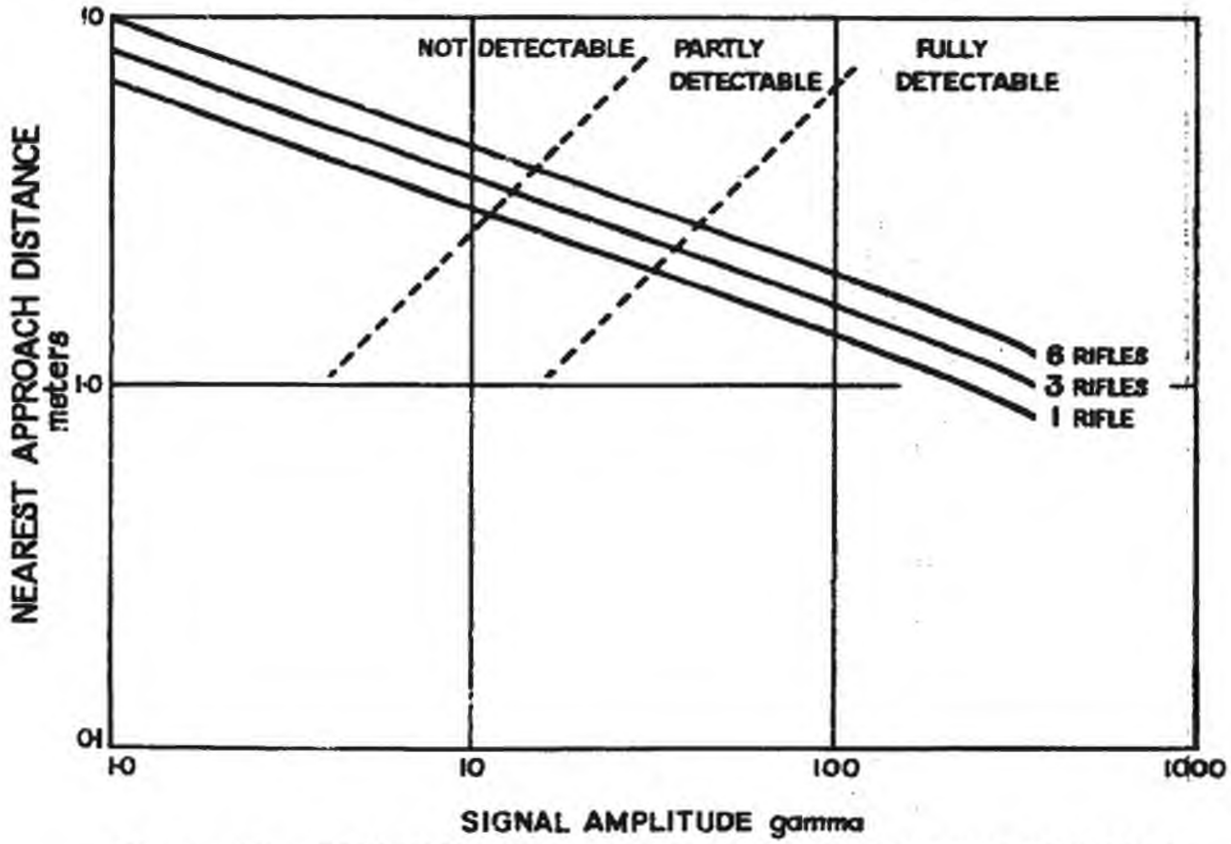


Figure 21- PREDICTED TARGET RESPONSES & DETECTABILITIES

by a group of Lao and American searchers.

In this search the magnetometer readout and recorder and other equipment was fitted in a fiberglass boat, powered by an outboard motor, and the search sensor carried in a rubber dingy which was towed behind.

Another test involved searching for laterite walls in a supposed ancient buried city near Dong Khong northeast of Korat. It was proved that laterite walls near the surface should be detectable. The site was certainly an ancient township but the mound which suggested a buried city appeared to be a natural feature. No evidence of laterite walls was obtained from the magnetometer tests. It was interesting to note that blocks of laterite, weighing about 100 pounds, gave anomalies varying between 1 and 100 gamma at ranges of about 50 cms.

Some people have suggested searching for trucks hidden under jungle canopies by use of an aerial magnetometer. To test this concept some measurements were made on the standard U.S. Army 3/4-T truck.

At ranges from the truck center of 4 meters, 14 meters, and 24 meters anomalies of 600 gamma plus, 30 gamma and 5 gamma respectively, were obtained. Using a magnetometer, the inverse cubic law holds and at a slant range of 40 meters, an anomaly of one gamma results. These figures are supported by other data. (See Figure 8). It is considered that the detection range of an airborne scalar total field magnetometer is insufficient for the purpose of truck detection when jungles 50 meters high are involved. Since most airborne magnetometers take the form of gradiometers, the situation is worse, since the gradiometer results in an inverse fourth power relationship.

7. CONCLUSIONS

For targets of the size of 6, 3 or 1 rifle search rates of 22,000, 20,000 and 16,000 square meters per hour appear possible with a detection rate of 85% under favorable conditions.

In favorable conditions, inexperienced operators have achieved search rates of 2000-3000 square meters per hour for these target types with detection rates of about 65% with a false alarm rate of 1 per 5000 square meters.

Magnetic backgrounds examined showed 57% were magnetically favorable, 30% partially favorable, and 13% were quite unfavorable. One can expect those figures to be reduced in villages or jungled and mountainous areas. Further testing of various configurations, and further knowledge on the subject of acoustic descrimination is required.

The rubidium vapor magnetometer in its audio form partly satisfies the U.S. Army requirement. Modifications to allow weight reduction and incorporation of a simple meter to get visual readings of gamma variations will make it a more useful instrument. The magnetometer will apparently not detect tunnels. Use of a bone conducting earphone instead of the highly magnetic earphones used in the tests would also be advantageous.

If comparison of the performance of the magnetometer with that of other devices is favorable, sufficient information is now available to proceed with the production of a prototype operational device.

BRIGADIER GENERAL JOHN K. BOLES, JR.

Brigadier General Boles is a 1939 graduate of West Point Military Academy. Commissioned in the Cavalry, he served with the 3d Armored Division in Europe during World War II. He remained with armored units following the war until 1949, when he became a student at the Command and General Staff College, where he was subsequently assigned as an instructor (1950-1954). He attended the Army War College, graduating in 1956, and then was assigned to Germany to command the 6th Armored Cavalry Regiment and, two years later, to serve as G-3, VII Corps.

General Boles' close association with the Army materiel effort began in 1959, when he joined the Office of the Chief of Research and Development, Department of the Army. Three years later he was assigned to the Joint Staff as Deputy and later as Chief of the Requirements and Development Division, J-5, until his departure for Southeast Asia in February 1964. He spent two and one-half years as Director of the Joint Research and Test Activity and participated actively in combat operations with the Army, Navy, Air Force, and South Vietnamese against the Viet Cong. He was assigned, effective 1 June 1966, Deputy Commanding General of the U. S. Army Test and Evaluation Command, a command responsible for the test and evaluation of all items of equipment and materiel for the use of the Army in the field.

PROBLEMS OF PERFORMING RESEARCH AND DEVELOPMENT IN THE COUNTERINSURGENCY ENVIRONMENT OF VIETNAM (U)

~~(Confidential)~~

Brigadier General John K. Boles, Jr.
Deputy Commanding General
US Army Test and Evaluation Command
Aberdeen Proving Ground, Maryland

Good afternoon, Gentlemen. I have been asked to address the problems of performing research and development in the Vietnam counterinsurgency environment. To address this specific subject, I can say very easily that there are very few problems in performing research and development in Vietnam, because very little research and development of hardware is done in Vietnam.

FIGURE 1. JRATA INSIGNIA

For almost 2 and 1/2 years I have been the Director of the Joint Research and Test Activity, or JRATA, in Saigon. We accomplished some studies, primarily through the Advanced Research Projects Agency - R&D Field Unit, and a little development, but our prime mission was to test and evaluate Army, Navy and Air Force hardware in the combat environment of Vietnam. It is important that the distinction be made between R&D and test and evaluation, which is our main mission. My main purpose in giving this presentation today is to inform you of the problems and environmental limitations that are imposed on testing and evaluation in Vietnam.

The CONUS agencies conduct the research and development and most of the testing, and finally propose a candidate item for evaluation. And this is the point where JRATA really comes into the picture.

JRATA is organized along both service and functional lines. In order to understand our test and evaluation procedures, I believe that it will first be necessary to understand the organization which is doing the testing. Here is the JRATA organization.

FIGURE 2. JRATA ORGANIZATION.

JRATA is composed of about 92 permanent party personnel for a total of about 150 permanent and TDY personnel in the Headquarters, and four test activities over which the Headquarters exercises operational control. The activities controlled are, from left to right, the Army Concept Team in Vietnam with 57 people permanent party, plus 35 TDY; the Air Force Test Unit of 9 permanent party personnel with 6 TDY; the Navy-Marine Test Unit with 9 permanent party personnel now - it has been changed from 4 - and 6 TDY; and, finally, the OSD ARPA unit with 13 military and about 6 civilian personnel plus additional TDY's. This brings us up to a total of about 150 and, in addition, we are co-located with and closely integrated with the 70-man Vietnamese Combat Development and Test Center.

The primary objectives of JRATA are:

FIGURE 1. JRATA INSIGNIA

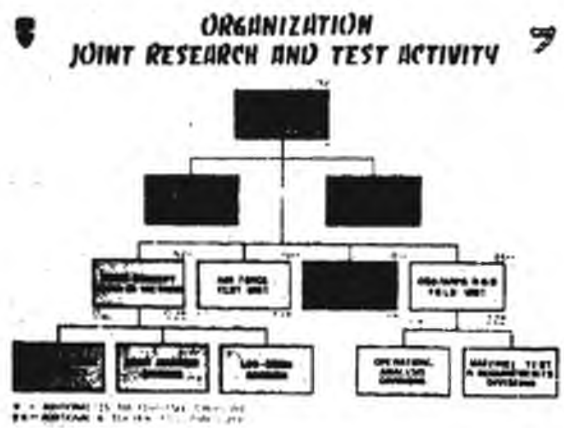


FIGURE 2. JRATA ORGANIZATION

1. To enhance the counterinsurgency capabilities of Republic of Vietnam Armed Forces (RVNAF) and US Forces.

2. Provide RDT&E and CD support to RVNAF.

3. Provide sound and fully objective evaluation of concepts, doctrine, tactics, techniques and materiel in the counterinsurgency environment of Vietnam.

Now, in conjunction with the last objective, the basic policy, as established by the JCS, CINCPAC and MACV, is that only those evaluations and other projects which require the combat or the counterinsurgency environment of Vietnam will be conducted there.

JRATA establishes our tasks under wartime uncontrolled conditions. This environment imposes constraint and limitations which have an effect to a greater or lesser degree on the validity of the report. However, we are not working in instrumented ranges, we are not working with a passive detail of "aggressors," we cannot wait for proper weather nor can we dictate that certain target arrays will be arranged just so and in a certain formation on the battlefield. We do observe and analyze combat which prevails. As a result of these conditions, it is frequently necessary to rely on professional opinion and judgment to interpret sketchy and sometimes, to be truthful, inconclusive data.

One specific case was a recent all-out attempt to determine the effectiveness of the Flechette warhead for the 2.75-inch air-to-ground rocket. This rocket, made by Northrop, contains 6,000 eight grain Flechettes - each about 1-1/2 inches long, about the thickness of a pencil lead. In the past we have been unsuccessful in determining the ground effects of the Lazy Dog, the BLU-3 Bomblet, which I show here,which is the 1.73 Air Force Bomblet

FIGURE 3. BLU-3 BOMBLET.

with about 253 little pellets in it; the XM75 40mm Grenade Launcher on the Sky Raider Aircraft and the 7.62mm Minigun (the Gatling Gun).

Consequently, I decided to make an all-out personal effort to obtain proper data on the Flechette warhead and set up a team of one O1F Air Force aircraft with the four rockets and one pick-up HUEY. For about 3 hours one day, in a very lucrative target area, we flew at between 50 and 200 feet. Although we did run into Viet Cong, we obtained no hits. The next day I worked two O1F aircraft and two helicopters. Each of the O1F aircraft was equipped with four of the 2.75-inch Flechette warheads. After flying for about 10 minutes in the same very fine hunting area of Hau Nhia Province, near Duc Hoa, a group of three Viet Cong were spotted and taken under fire by one of the aircraft about 7:30 a.m. My helicopter then landed and my Sergeant and I dismounted to attempt to locate and retrieve a body. A detailed search of the area revealed no bodies. We kicked open the little hootches and bomb shelters and we found the cooking fire still going. However, one prisoner was found in a water-filled trench with just his nose and mouth above water by the Sergeant. When I heard him calling to him I went over to him and backed up the Sergeant while he went in the trench and dragged the man out. The man attempted to get away from us and I grabbed him by one hand and assisted him to get back to the helicopter. We took him back to Duc Hoa and examined him and although he was wounded in the right leg slightly,

FIGURE 4.

the wound had not resulted from our Flechettes - he had been in some other action. We questioned him - he was quite impassive, of course - and, consequently, since the wound did not result from our rocket, I declared him an invalid specimen, in a joshing manner hazed the Air Force pilots about it, and directed we go back and create and retrieve a better one. Again, after flying about 10 minutes, a group of between 8 and 12 Viet Cong were spotted and taken under fire by the other O1F aircraft about 8:20 a.m. The forward air controller, who was in one of the O1's, reported seeing four Viet Cong bodies on the ground so I had the helicopter fly down low in order to locate specimens before we got on the ground with them. We were unable to locate any bodies; however, both the helicopters picked up bullet holes at an altitude of 10-15 feet.

FIGURE 3. BLU-3 BOMBLET

FIGURE 4.

Here's one hole in the rotor of the other helicopter

FIGURE 5. ROTOR.

and the crew chief put a piece of tape over it so it wouldn't whistle so loud - so it would not bother him. And here's the other helicopter - my helicopter -

FIGURE 6. HOLE IN DOOR.

which we got a hit through the right door of the pilot, about 2-1/2 feet from my left knee. The bullet went underneath the armor of the pilot's seat. I looked on the other side and noticed it had not come out so I told the pilot I would find it for him, so I dug around inside and I found it and gave it to him - dropped it in his hand. You would think I had dropped something very dirty in his hand because he wasn't at all keen on the thing. I told him to take it downtown and have a gold chain put on it and send it back to his wife for a locket. He didn't think it was very appropriate at all. Well, anyway, after picking up our hole here - I figured we still had Viet Cong nearby, so I directed the helicopter to land and the Sergeant and I bounced out in the hopes that we would find a wounded or dead Viet Cong who was hidden in the grass. Because the Viet Cong were shooting at us or had been shooting at us when we came in on the chopper, the door gunners continued to give us covering fire and, of course, the Sergeant and I fired sporadically with our weapons. I carried about 60 rounds of ammo that day for my AR-15 (M16) submachine gun, which, unfortunately, was not enough. We maintained this continuous suppressive fire because that kept the VC's heads down and we hoped we'd thereby be able to find one, cowering under a bush. We moved about 80 yards in front of the helicopter and found no one, and then I went about 100 yards behind the helicopter and under a bush I found a Thompson submachine gun, with 100 rounds of ammunition, including the 20-round clip in it, and a pack. I called into the bush to surrender and nobody there would surrender to me so I fired into the bush and, unfortunately, put a hole in the pack. I then picked up the submachine gun so no one else would, and put it and the ammunition on my back and continued the suppressive fire with my submachine gun, ran short of ammunition so I just slung my own weapon and continued using the Viet Cong submachine gun. To be honest, it was a whale of a lot more pleasant to shoot the Thompson submachine gun since it fired much slower than the AR-15 submachine gun, which fires about 900 rounds per minute. I personally believe the high rate of fire of the M16 (AR-15) submachine gun is excessive and over-kills the target at the range at which one normally uses full-automatic fire.

About that time I found a carbine belt under a bush and I aimed the Viet Cong submachine gun at the bush and my Sergeant came up and lifted the bush.

FIGURE 7. PRISONER AND WEAPONS.

Under it was a young VC, 15 years old, weighing about 95 pounds, and he had a US carbine in his hand which the Sergeant kicked out of his hands immediately and I took him prisoner. We took him back to the chopper with the weapons that I had picked up and then we intended to run down the freshly made trail in the wet grass - you see the dew was still on the grass and somebody had just run down this little trail. But the pilot said we were running short of fuel and he was very anxious to take off immediately to pick up more fuel at Duc Hoa. I told the pilot about the trail and I told him he was to fly down that trail at a low altitude. We flew about 10 feet off the ground for about 80 meters and I spotted a shotgun leaning up against a bush, directed the pilot to land there because I thought there might be a wounded VC nearby. He landed in the grass, which is two or three feet high, and because my Sergeant had not yet tied up the prisoner, I jumped out and ran around the grass trying to find a wounded VC, but couldn't. So I picked up the ammo belt and the shotgun - the shotgun, incidentally, was a Ithaca Featherweight 12-gauge, pump gun - loaded with three rounds of double-ought buckshot, and had five more rounds in two little leather boxes on a belt. The belt was so small that it wouldn't fit around half of your thighs - the belt was about 22 inches long. We returned to Duc Hoa and there we examined our prisoner, or "captive" as we call them. (Since we are not at war, we can't call these people "prisoners".) The examination indicated that he was untouched by the Flechettes. I told my aircraft people that they had let me down and that we would have to go back again. They said we were out of ammunition so I said we would get some and come back in a day or so. We opened up the VC pack and in it found a communist flag and a Viet Cong flag. In it also was a hand grenade which

FIGURE 5. ROTOR

FIGURE 6. HOLE IN DOOR.

my bullet had just missed - although it had, unfortunately, gone through the VC flag. The shotgun is in the picture, at our boy's feet, the next weapon is the carbine which he had had in his hands, and the third is the submachine gun which I borrowed from the VC.

Well, I felt that perhaps we could get some more evidence if a larger team were organized so I requested two F100's loaded with the 2.75-inch flechette rockets and one F100 with the BLU-3's. We also had two O1F's, this time equipped with three flechette rockets each and one smoke rocket each and a small Eagle Flight of four troop-carrying helicopters with 20 US soldiers and two armed helicopters with one command helicopter. The F100's attacked one group of Viet Cong but a 20 minute search on the ground located no casualties or anybody else either. The F100's then were diverted by the Control Center to a more important target, so we continued without them. We finally found three Viet Cong and attacked them with the Air Force O1F's that were with us. Then we dropped on down to land and one armed helicopter picked up several rounds of Viet Cong automatic fire through

FIGURE 8. BULLETS IN BUBBLE.

the bubble and radio. The shots messed up the left bubble there and one bullet went through the radio

FIGURE 9. BULLETS IN RADIO.

which caused him to lose communications and after that he had to "follow the leader" with the other gun ship.

FIGURE 10. STREAM.

We landed and after about 20 minutes of searching through some very tall grass - it was real rough country - it was flat but muddy and sloppy and you couldn't get into the tall grass

FIGURE 11. HELICOPTER.

because of the saw grass that would cut you if you just stuck your arm in it, and there were a few animal trails sort of like tunnels through the grass which several of us tried to get into but weren't very successful. Well, we discovered a Viet Cong helmet and radio and figured there were some VC nearby so I asked for both armed helicopters to fly down low in order to blow over the grass - to push the grass down - and then to mark anybody that they saw with smoke - any bodies, any wounded people or people that we could go in and capture. They located one man, threw a yellow smoke grenade at him and we went over and picked up this bird here -

FIGURE 12. BACK OF VC.
FIGURE 13. FRONT.

[redacted] speaks Vietnamese and was a Ranger with the Vietnamese Rangers, came over and interrogated this man and took his clothes off so he could see if he were wounded or not and to make sure he didn't have a knife on him.

FIGURE 14. VC IN SHORTS.

He then tied him up with his own trousers. I then interrogated him through my sergeant -

FIGURE 15. SERGEANT AND VC.

and the man gave us five different lies - one that he was 15 years old and actually was 19, one that he was married and had some children in the nearby village who would be killed if he answered our questions. One other tale was that he was fishing out there with his grandfather but he had no fishing equipment nor could we find any grandfather, and he couldn't explain the radio and the VC helmet that were near him. He had one wound in the top of his head and his back was cut up a little bit from thorns and then there was one suspicious wound over his left shoulder. We took him on back to Duc Hoa, questioned him, and had the medic check out the wound in the

FIGURE 7. PRISONER AND WEAPONS.

FIGURE 8. BULLETS IN BUBBLE.

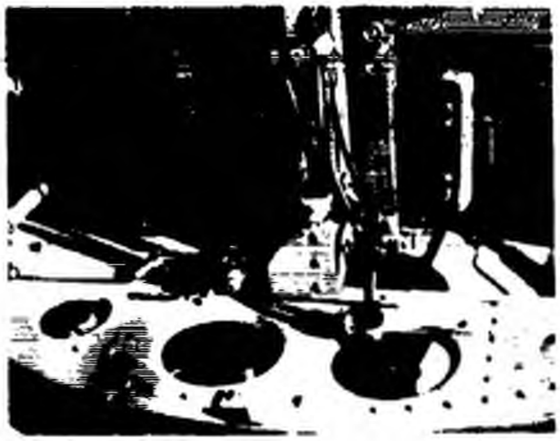


FIGURE 9. BULLETS IN RADIO.

FIGURE 10. STREAM

FIGURE 11. HELICOPTER.

FIGURE 12. BACK OF VC.

FIGURE 13. FRONT.

FIGURE 14. VC IN SHORTS.

top of his head - he shaved it with a razor blade - and we decided it was definitely one of our Flechette holes. It was the first Flechette wound that we have actually had verified as being from our weapon. I was fairly pleased - I thought it might also have touched the skull so I carried him on back to Saigon in my helicopter.

FIGURE 16. IN HELICOPTER.

(You can see, incidentally, where we patched up the previous bullet hole in the right door of the helicopter.) A funny thing about this VC - he was rather scared - he had never before been in a helicopter and he literally rested his bloody head on my thigh on the way back to Saigon.

FIGURE 17.

I put him in my sedan (probably the first time a prisoner had ever ridden in a general officer's sedan), and took him down to the hospital where the American medics said they couldn't treat Vietnamese - and that I had to take him to the Vietnamese hospital, and I said "this man isn't a Vietnamese, he is a Viet Cong." Well, that upset them even more, but they x-rayed him and there was no damage except to the skin so I sent him on back to Duc Hoa.

During this 3-day operation, we had three helicopters and one fixed-wing aircraft struck by enemy fire. We suffered no casualties, and the only casualty we caused, so far as we know, is this fellow here. This should definitely not be construed that we feel that the weapon is ineffective because we definitely believe it is effective. The point that I am making is only the difficulty of acquiring concrete facts during combat evaluations with a limited quantity of test items which does not permit sufficient training. Some of the rockets were fired too close to the target and did not explode or eject the flechettes prior to impacting the ground. They should be fired from a range of about 1,000 yards, and we fired them at 300 yards or less because the men are in the choppers and O1 type aircraft are used to closing with the enemy, and firing their weapons from less than 1,000 yards.

On the way back to Saigon from the first day's operation, we dropped by a Popular Forces fort nearby which had just successfully repulsed a Viet Cong attack. These slides show what we found.

FIGURE 18. LINE OF BODIES.

The people were just policing up the bodies - they had just dragged some out of the field - they had tied some of the legs together to make it easier to drag them through the mud and they are gray because of the mud that they were found in - it was of that color and was drying on their bodies. Some had lain out in the sun in the paddy for a while; others, of course, were found in water or on dry ground and are rather clean. An interesting array of weapons was picked up with them.

FIGURE 19. WEAPONS.

As you see all the small arms are American made weapons taken from other Popular Force units that these VC had overrun, those containers on the right are 75mm recoilless rifle ammunition containers made either in China or in the US - these are probably Chinese. On the lower right of the photo are the shell cases from both 75 and 50mm recoilless rifles that they fired at this fort. On the far left are the BA 40's, the 80mm Chinese anti-tank weapon - like the German Panzerfaust. It is a very fine weapon - they have a new one out now - called a BA-50 - it is 100mm and can penetrate clear through an M113. I've got a picture where it went through one side of an APC, through 8-1/2' of air and then out the other side of 1-1/2 inch armor on the APC. A pretty good weapon. Those things that look like tops for a sewing machine, at the bottom of the picture, are shaped charges that are used to blow holes in the walls of forts. As I got into the fort - it was a rather small fort, about 60 yards on each side - I was told that one woman in there had killed quite a few VC that had attacked the fort - they didn't know how many - they hadn't counted them yet. They had been taking care of their own people - they had had 6 killed in the fort - 6 men out of their 32. I went over and talked to her and congratulated her. She was wounded slightly in the left arm but had a bandaid on it and then I walked to the rear of the fort.

FIGURE 15. SERGEANT AND VC.

FIGURE 16. IN HELICOPTER

FIGURE 17.

FIGURE 18. LINE OF BODIES.

When the Popular Force soldiers were fighting on the front of the fort, the VC also came over the back corner of the fort and the woman ran back with three grenades and tossed them and accounted for this pile of eleven bodies.

FIGURE 20. PILE UP OF BODIES.
FIGURE 21. DETAIL OF PILE.

Here's a close-up picture of some of the people killed by one woman. The American M25 grenade is a pretty powerful little weapon.

FIGURE 22.
FIGURE 23. WOMAN NURSING.

There's a picture of the lady that did it, wounded in the left arm, nursing her baby, and life must go on. I went over and talked to her again, and shook her hand and gave her a 500 piaster note. It is probably the only award she will get. That makes people like Molly Pitcher and some of the American heroines look like school girls. These Vietnamese women have all the courage in the world, and the men, too. They are wonderful people. They have got a different culture than we have and it is unfortunate that some of our people criticize them.

It is hard to get precise answers from the debris of a battlefield, and, in fact, I'll go farther and say that it is impossible to get precise answers from the debris of a battleground. Of course, some things do lend themselves to precise answers that you and I need, such as range of radios from a given location and under certain specific conditions. Weapons and many other familiar items to be evaluated cannot be laid against a precise yardstick. Weapons effects are not the sole purpose of JRATA, nor are they the only parameters within which evaluations are conducted. In the case of effects, we must rely heavily upon professional judgment and the opinion of the evaluator. But on the other side of the ledger, we can and do perform evaluations to determine item dependability, user acceptance, support requirements, bases of issue, and so forth, all drawn from cold, hard facts.

Now let us take a look at a few of the more important items that have been evaluated by JRATA. The first is "PUFF, THE MAGIC DRAGON."

FIGURE 24. PUFF THE MAGIC DRAGON.

This is another example of the difficulty of obtaining definite evaluation data in combat. We had an awful lot of trouble trying to find out how effective the minigun was on the C-47. We got favorable radio reports from the folks on the ground during an action and we'd try to get back the next day to see what our weapons effects were and we'd get into trouble.

This is a C47 aircraft mounting 3 Miniguns - they are fixed guns mounted to shoot out the door and windows of the C47. They fire 6,000 rounds per minute each, that's 100 rounds per second for each of the 3 guns for a total of 300 rounds per second. We aim the guns by aiming through a little makeshift sight in the pilot's seat, we dip the wing down at about 30 degrees and fly at an altitude of about 3,000 feet, and we fire. I have been out with it a number of times. We needed more systems like this experimental system - and we weren't manufacturing them fast enough because it was a newly developed gun. So the Air Force, back in the States, mounted ten M2 1,000 rounds per minute Cal. 30 machine guns inside of a C47 and it worked out fine.

FIGURE 25. 10 GUNS.

It was a bit noisy when all ten machine guns started firing at once - all inside the same airplane - but they accomplished our purpose. These airplanes carry 50 flares and about 22,000 rounds of ammunition. They rendevous around a certain area and when some fort comes under attack and calls for help, we buzz over and help out. On one support mission, we supported two small forts which were surrounded by the enemy and, in so doing, in the space of about 1-1/2 hours, we expended 21,200 rounds of ammunition. During this time we were under almost constant small arms fire which had been diverted by the VC to shoot at us. We didn't get hit; at least not through the fighting compartment. This was pretty lucky because we were carrying 50 flares. We were under fire from the period of about 10:30 p.m. until around midnight. When we

FIGURE 19. WEAPONS.

FIGURE 20. PILE UP OF BODIES.

FIGURE 21. DETAIL OF PILE

FIGURE 22.

FIGURE 23. WOMAN NURSING.

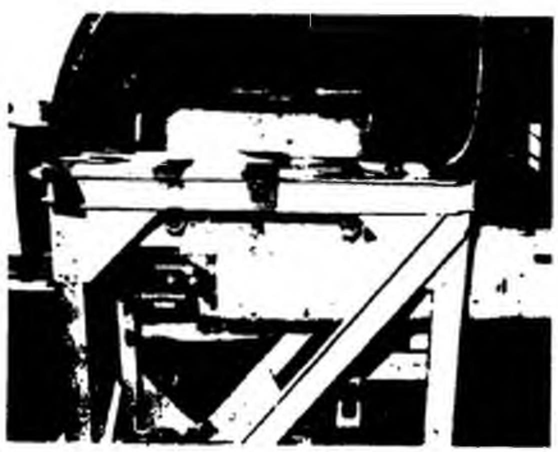


FIGURE 24. PUFF THE MAGIC DRAGON

returned from the mission after midnight, I directed that a helicopter be made available at 8 o'clock the next morning so we could go out and assess the effects of the operation.

FIGURE 26. FORT.

I flew off to the fort with my AF test unit commander and was later joined by two armed helicopters which first checked the two forts to make sure that they were still in friendly hands before I landed.

We then attempted to land and when our helicopter was about 7 feet above the ground, but the mortar which had been firing on the two forts the preceding night opened fire on us, and placed three rounds on one side of us and four on the other, so the pilot elected to postpone gathering data until some other day, and we took off for northern part of the Plain of Reeds, where we got in trouble again. I got word that a VC grenade factory had just been captured so we flew over to it. We landed just as two Vietnamese soldiers were wounded by booby traps.

Flying to battle is one thing - foot slogging is another. Particularly when the sloggee is paddling a sampan or is up to his waist in mud and water. There are many areas in Vietnam where this situation does exist, and one of the worst is the Plain of Reeds, which is almost completely inundated six months out of the year.

FIGURE 27. TWO SAMPANS.

The native friendly sampans possess no mobility advantage over the equally native VC sampans. This lake is a VC safe haven. They have got their hospitals and factories up in there and that is where I had gone to see the grenade factory. It's a lake about 80 miles in diameter and about 10 feet deep in the rainy season. And in the dry season it is just a plain of reeds on which you can travel in tanks. This is the company commander, a Vietnamese sergeant whom we fought with for two days. The preceding night, two Special Forces sergeants and I were with him - in one of these small triangular forts, and we were attacked around 11 o'clock that night. We stood behind the walls and fought it out just like the Wild West days. Most interesting! The next day we took off on this sampan operation.

FIGURE 28. LILY PADS.

The lily pads got so thick we couldn't use the paddles and we had to pull ourselves through it with our hands. Conventional power boats cannot be used effectively because of the weeds and aquatic grasses that foul up the propellers.

FIGURE 29. PLASTIC BOATS.

particularly if you cut from one water course over to another.

FIGURE 30. AIR BOAT ON WATER.

Finally a number of small air boats - twelve of them to be exact - six of one type and six of another type were introduced in Vietnam for evaluation by JRATA. They cost about $6,000 a piece - they are wonderful little 17 foot fiberglass swamp boats - powered by 180 hp Lycoming engines. The advantages were immediately apparent and there was a tremendous increase in mobility.

FIGURE 31. AIR BOAT ON GRASS.

Last year they were properly and aggressively employed and the results of the evaluation proved conclusively that we must have a hundred or better over there. In one attack, not long ago, before the dry season came, near An Phu it was just like an old time Cavalry charge. Three of these air boats tackled ten sampans - they first fired into them with the machine guns and then they overran them - actually physically crushed them while they were machine gunning and shooting with their rifles and then they wheeled around and came back to take care of the

FIGURE 25. 10 GUNS.

FIGURE 26. FORT.

FIGURE 27. TWO SAMPANS.

FIGURE 28. LILY PADS.

FIGURE 29. PLASTIC BOATS.

FIGURE 30. AIR BOAT ON WATER.

cripples. It was just like an old time Cavalry saber charge, and they killed about 20 of the enemy and crushed about ten of the boats.

Neither of the previous items entailed any R&D in Vietnam, but did entail in-theater modification such as machinegun mounts, flotation gear, and so forth.

FIGURE 32. HELICOPTER SEARCH LIGHTS.

Now there is one item of which I am very proud and this was invented, developed, R&D'd and T&E'd in the Republic of Vietnam by the ARPA-RDFU, then under Colonel Ben Hardaway. To be precise, it is a field improvisation, utilizing seven C123 landing lights and about $400 worth of other available military components on a locally made mount.

FIGURE 33. HELICOPTER SEARCH LIGHT.

It was designed by the ARPA-RDFU in Saigon, built under their contract - let to a local French firm for about $600 apiece, installed in a Army ACTIV (JRATA) helicopter and used there. It could be moved from one helicopter to another in just 30 minutes or less - it was evaluated by three helicopter companies and was proved in combat. I have flown with it a number of times and it is wonderful. It is like shooting ducks in a barrel except sometimes the ducks bite back. In the operations conducted under the code word "LIGHTNING BUG," the illumination system flies down a canal at about 1,500 feet and illuminates a sampan or a group of sampans. It is teamed up with a two gun-ship formation which flies behind it and out of the cone of light at 50 to 200 feet altitude. These gun-ships shoot up the sampans and junks with rockets and machine guns. It has proven very effective in denying the Viet Cong free use of the rivers and canals during the hours of darkness.

Now although this rather primitive light will not in itself be produced in quantity - only ten have been built recently - it has proved the concept for the use of searchlights to pave the way for more effective installations using the Xenon light. Present plans are to employ only these 12 systems as an interim system until the Xenon light becomes available. The first two lights resulted in the sinking of over 200 sampans and junks in a very short period of time.

Another area where some uncertainty exists is user acceptability. Materiel designed to fill a specific field requirement does not always meet with the desires of the user in Vietnam. Particularly was the case of the infrared weapon sight. We, in JRATA, knew that a crying need for night vision improvement existed, so a recommendation was made to MACV that operational quantities of the standard US Army small arms IR sight be brought to Vietnam for evaluation.

FIGURE 34. SNIPER SCOPE.

Only 50 were brought in and the sights were issued to ARVN units. When they were brought in, the ARVN personnel who were briefed on the devices were most enthusiastic and I was convinced that we should have brought in operational quantities rather than only a handful. However, as the data collection phase progressed, we discovered less and less enthusiasm and use of the lights. We shipped them over to other units expecting momentarily that someone would request vast quantities, but this did not occur. So we investigated the coolness and determined that the weight of the sight was all right for US-size troops, particularly in Europe or the United States, but the total of some 11 pounds was much too much for the average 108-pound Vietnamese soldier, when added to his normal combat load of anywhere from 25 to 35 pounds. About the same time this was determined, US combat units had been in the country for about two or three months, and we checked them out and we found out, much to our surprise, that they, too, had the devices stored in their supply tents gathering dust. The point here is that user acceptability is critical when considering an R&D piece of equipment. However, this is one of the many areas where JRATA can function effectively, even though we find out negative information. Equipment that is carried and used on FTX's in Europe and the US is not necessarily that which will be carried and used when the individual is subjected to hostile fire, tropical heat and the tangled jungle trails.

FIGURE 31. AIR BOAT ON GRASS.

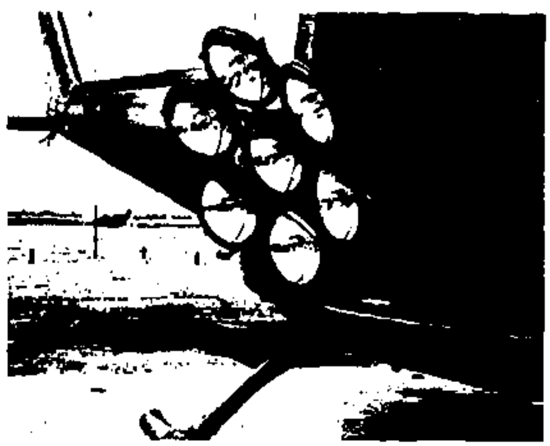


FIGURE 32. HELICOPTER SEARCH LIGHTS.

FIGURE 33. HELICOPTER SEARCH LIGHT.

FIGURE 34. SNIPER SCOPE.

Now one very good reason for the limited quantity and quality of in-country R&D is the very severely limited facilities available in the Republic of Vietnam. Associated with this is the general shortage of personnel professionally qualified and competent in R& D equipment and activities. I am now speaking of indigenous capabilities. The Combat Development and Test Center of Vietnam (CDTC-V) is the entire R&D capability in RVNAF, and its facilities are very limited. Its personnel are not, by US standards, qualified as R&D officers nor do they possess the training nor the experience necessary to accomplish the function. Every effort is being made to improve the CDTC-V capability, but it will take a long, slow process to establish anything comparable to US systems.

I might add here that we have other problems in Vietnam which are of deep concern to both commanders and CONUS agencies upon which we have laid the responsibility for solving. One is tunnel detection or destruction or denial.

FIGURE 35. TUNNEL.

The Viet Cong use tunnels extensively and effectively. A unit conducting a search and destroy operation is constantly in danger of VC popping out of concealed tunnels, sniping and then ducking back into comparative safety in his hideout. The 3d Brigade, 25th Division has lost some 50-odd men in their main bivouac area in this manner. Detection is virtually a matter of physically seeing the tunnel. IR, SLAR and other exotic electronic equipment is presently ineffective. Once the tunnel entrance is discovered, there remains the problem of effectively clearing it, mapping it, and destroying or neutralizing it. These tunnels go for probably 500 yards, or even 5,000 yards and have entrance shafts about every 50 yards, about 6 feet in diameter. The bottom of the shaft is 20 feet below the surface of the ground, the top of the tunnel is about 17 feet below the surface of the ground, the tunnels are about 20 inches wide, and 30 inches high. This one is dug so deep to avoid, I think, as all of them are, the roots of the trees. You can see one small root in there but this is dug under the jungle and, therefore, I think they dug it deep to miss the major tree roots. It forks down at the far end. Here is a picture of the sergeant who went down with me -

FIGURE 36. SERGEANT IN TUNNEL.

we went in on the original operation so we were the first people in this tunnel. That's not a light globe over his head - that's a mushroom. It was difficult to take pictures - it was pretty black down inside the tunnel. I took the picture as we were placing the charges and here is one charge that we placed right at the fork of the tunnel.

FIGURE 37. CHARGE IN TUNNEL.

Unbeknownst to us another team was placing a similar charge about 50-75 yards down the other shaft of the tunnel and they blew theirs less than one minute after we got out of the tunnel. Had we been in there when they blew it we would still be in there. While we were in the tunnel area - there was a great deal of sniper fire, and one of the members of the other tunnel team was killed by the snipers. First we heard he was wounded and I told them to carry him out in my chopper, but he was dead. I blew one more tunnel and then I went over to shoot at the sniper. I had gotten on this tunnel busting exercise by accident, to be honest. I was out with the XM148 40mm Grenade Launcher - I carried it with me in the back of my sedan while I inspected a new experimental bridge that the ARVN had put together - a combat assault bridge for M113 APC's they had put up. I intended later to go out to the Thu Duc range to fire the XM148 40mm Grenade Launcher but the range was in use so I went out the 173d Airborne Brigade to check on a project, but part of the unit was on an operation. They said that they had just found a tunnel system and so I hopped into a chopper and went out to where the tunnel complex was. That is how I got engaged in blowing a tunnel.

FIGURE 38. BOLES FIRING XM148.

This is the first time anybody had ever fired this weapon or a weapon of this type in Vietnam. Whether I killed the man I was shooting at I don't know, but, at least the first time it was ever fired in Vietnam, it was used in combat. Here is a better picture of it.

FIGURE 35. TUNNEL.

FIGURE 36. SERGEANT IN TUNNEL.

FIGURE 37. CHARGE IN TUNNEL.

FIGURE 38. BOLES FIRING XM148.

FIGURE 39. BOLES AND XM148.

It's a 40mm tube, single shot and fits on the underneath of the M16 or AR-15 rifle. It is a whale of a good weapon.

These are but some of the many problem areas in the conduct of war.

So much for the hardware. Now certainly there are other kinds of research going on in the Republic of Vietnam, not all of which are associated with military endeavor and hardware. However, disregarding the off-duty research, which has its own hazards, one major portion of the official research going on in-country is also in the social science area. This was well covered yesterday afternoon so I will not cover this portion in my presentation.

Basically, these are the problems confronting JRATA in Vietnam - inability to determine weapons effects; user acceptability (although this is not a problem limited to Vietnam alone); differences in sizes of soldiers, culture, language, and minority groups; quality of RVNAF personnel in the test and evaluation business; and limitations imposed by friendly hostilities as well as enemy hostilities. Nevertheless, we have been able to accomplish much in spite of the problems. During the existence of JRATA, some 75 tests and evaluations have been completed and there are another one hundred plus either undergoing evaluation or programmed.

In some cases, problems are solved by brute force - others by delicate diplomacy. In all cases where the job must be done, the problems faced must be overcome or outflanked. The job in Vietnam is vital and the people assigned there know it and are dedicated to the task. There are many problems, but as long as the personnel involved are professional and devoted to their duty and are patient and have a sense of humor, the job will be done. Rest assured that both the scientific and the military personnel in Vietnam are of that quality.

FIGURE 40. BABY.

Now one final item - R&D and production of female clothing, of course, has been one of our most important and expensive undertakings. The Thais have done quite a bit along these lines, too. I would like to show you one functional little apron that has been developed by the Thais - we call it a little chastity belt. It is made of silver, it is dainty, feminine, has great utility value, it is rust-proof, and, of course, does not restrict any movement of the wearer.

Thank you.

FIGURE 39. BOLES AND XM148.

FIGURE 40. BABY.

PAPERS NOT PRESENTED ORALLY

(b)(6)

[redacted]

JACK NOLL RINKER

Dr. Rinker received his BS, MS and PhD degrees in the biological and physical sciences from Purdue University. Since 1956 he has been on the staff of the group now known as U.S.A. CRREL (Cold Regions Research and Engineering Laboratories). He is active in the CRREL program of evaluating various airborne sensors (photo, thermal, and radar) as aids in environmental analysis. He is the author of several papers in the general field of remote sensing as well as papers in more restricted areas of biology.

INFRARED DETECTION OF HEAT SOURCES OBSCURED BY TROPICAL RAIN FOREST VEGETATION (U)

~~(Confidential)~~

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ABSTRACT
(Unclassified)

During November 1962 USA CRREL and the University of Michigan (under contract DA-27-021-ENG-9) conducted field work in Puerto Rico to determine the capability of detecting small heat sources obscured by a tropical rain forest.

This research was supported by the Advanced Research Projects Agency under ARPA Order 351-62 Amendment No. 1.

Two infrared scanners, one airborne radiometer, and a K-17 camera were used to obtain aerial imagery. The targets were charcoal fires in galvanized pails (14-in diam and 8.5-in high); the pails were placed on the ground at selected sites under a variety of canopy cover.

The use of an infrared thermal scanner to detect small ground fires obscured by a vegetative canopy has been demonstrated to be feasible. The filtered indium antimonide cell (4.5 to 5.5μ bandpass) proved to be the best choice in flying over dense canopy.

FOREWORD
(Unclassified)

This work has been reported elsewhere, with relatively limited distribution. The project, evidently the first of its kind to be carried out under ARPA sponsorship, has been succeeded by others of broader scope in the U.S. and by Project AMPIRT (ARPA Multiband Photographic and Infrared Test) in Thailand. The objective of Project AMPIRT is to establish the applicability of specialized airborne infrared and photographic techniques to detection of insurgent or guerrilla operations in the Southeast Asia environment. The field data acquisition phase was completed during 1965, and extensive ground radiometric, meteorological and target data are currently being analyzed for preparation of a final report scheduled for publication in November 1966. This work is being accomplished jointly by the University of Michigan, Institute of Science and Technology, (infrared), and by Cornell Aeronautical Laboratory (photography). The work at Michigan is covered by Air Force contracts AF 33(657)-13139 and AF 30(602)-3540.

INFRARED DETECTION OF HEAT SOURCES OBSCURED BY TROPICAL RAIN FOREST VEGETATION (U)

1
INTRODUCTION
~~(Confidential)~~

The varying tropical environment of the island of Puerto Rico was studied in November 1962 by flying airborne sensor systems (infrared thermal scanners and conventional cameras) over selected areas in concurrence with a ground-based instrumentation and data-collection program. This project, sponsored by the U. S. Army Cold Regions Research and Engineering Laboratory (CRREL) and the Advanced Research Projects Agency,* was conducted by personnel from CRREL (responsible for site selection, ground instrumentation, data collection and analysis) and from the Infrared Physics Laboratory of the Institute of Science and Technology, University of Michigan† (responsible for flying the EC47J (R4D) aircraft of Project MICHIGAN** and for operation of the airborne infrared and photographic systems supplied by Project MICHIGAN and USA CRREL). Data reduction and imagery analysis was a joint effort of these two laboratories.

The objective of the ARPA-sponsored portion of the program was to determine the detectability of heat sources of the type associated with guerrilla activity in Vietnam. Previous experience indicated that, while many targets such as personnel, shelters, weapons caches, vehicles , etc., would have an extremely low probability of detection in a tropical rain forest, intense heat sources such as cooking and warming fires might be more readily detected. Implementation of the heat source detection program was based as closely as possible on descriptions of guerrilla activities and environmental factors relayed by ARPA personnel stationed in the area of conflict. Part of a letter from [redacted] [redacted] Unit of ARPA, to [redacted]

*ARPA support under APC No. 563 and Amendment.

†The University of Michigan participated under USA CRREL Contract DA-27-021-ENG-9.

**Project MICHIGAN is conducted under Department of the Army Contract DA-36-039-SC-78801, administered by the U. S. Army Electronics Command.

[redacted] ARPA, dated 18 September 1962, is quoted below:

"Under agreement reached on August 11, 1962, [redacted] was to investigate and report upon heat energy sources associated with guerrilla activity. This information is required as soon as possible for use in OPERATION TROPICAN, an effort receiving ARPA support under APC No. 563 and Amendment to AO 351-62.

Discussions with appropriate personnel in Vietnam have resulted in the following conclusions:

a. <u>Heat source:</u> A heat source that can be associated with most guerrilla groups is the cooking stove. This stove is a portable ceramic or baked clay device common to the East and frequently called by the Japanese name "Hibachi." Charcoal is the universal fuel. The clay stove is a hollow vertical cylinder 10 to 14 inches high and open at the top. A grate on which the charcoal is placed is located above an air-port in the side of the cylinder. The food is cooked in a round-bottom iron kettle or flat-bottom pan which is placed directly over the open top of the stove. This type stove is large enough to cook the food for a squadron (8-12) of men. This heat source will be employed in all regions from the delta country to the mountains. A second heat source is the small campfire. This fire is found only in the mountain regions and is employed during the early evening hours for warmth. The fuel is wood, as opposed to charcoal, and the fire is laid on the ground. The fire is carefully tended so as to produce the minimum of smoke and remain small (firebed of 12 to 18 inches in diameter) in order to permit rapid extinction. The use of other fuels is extremely unlikely because of logistic problems.

b. <u>Shelter:</u> Under the majority of conditions the charcoal stove will be used outside of huts or lean-to's. Under stable, secure military conditions the cooking may be done in a hut or lean-to, particularly in the mountainous region. Campfires will be built outside of a hut if a hut exists.

c. <u>Surrounding environment:</u> Guerrilla activity is not limited to tropical rain forests. Consequently the cooking stoves will be used in foliage ranging from 4- to 5-foot high scrub trees and brush to dense forests. Any foliage capable of furnishing protection from visual observation can constitute surrounding environment.

d. <u>Time of day of greatest fire activity:</u> In the opinion of personnel queried, the time of greatest cooking activity is a 2 to 3 hour period centered around sunset. Campfires generally exist for about 4 hours starting at sunset.

e. <u>Additional heat sources:</u> No additional significant heat sources are believed to exist. Charcoal is stolen or confiscated by guerrilla troops in the delta region. Troops in "safe" areas may process charcoal, but this is believed to be unlikely. No armament foundries are believed to exist other than individual use of a charcoal stove as a forge."

Conditions described in the letter were simulated as closely as possible by CRREL personnel responsible for instrumentation in the test areas. All effort was concentrated on determining the detection probability of small fires under conditions simulating those encountered in Vietnam. Charcoal was employed in all cases, as there was no natural fuel available in the rain forest. Two test sites were instrumented in the Luquillo division of the Carribean National Forest, corresponding roughly to those described.

2

AIRBORNE INSTRUMENTATION AND DATA RECORDING (U) ~~(Confidential)~~

2.1. (Unclassified) Sensors and Aircraft

Two infrared scanners, one airborne radiometer, and a K-17 aerial camera were provided for the Puerto Rican field studies and installed in a Navy EC47J (R4D) aircraft on bailment to the University of Michigan. The scanners used were the Project MICHIGAN M-1 infrared scanner[*] and a modified AN/AAD-2[**] drone scanner. The airborne radiometer, a single channel instrument, could be used with either cooled or uncooled detectors and with various filter combinations in order to acquire quantitative infrared-radiation data. The K-17 camera was equipped with an image motion-compensation computer. A ground-glass view finder and drift meter were also available.

The C-47 flew to Puerto Rico fully equipped, and was based at Roosevelt Roads Naval Air Station. Communication between the aircraft and ground teams was maintained on FM radio frequencies, using the PRC-10 handheld transceiver on the ground. Radio transmission from the forest floor to other points on the ground was usually good, while communication with the airplane was variable and frequently poor.

All flights over the target area were made under VFR (visual flight rules) conditions, but low clouds were nearly always present and frequently too low to permit safe flying in the area. Acquisition of data from altitudes above 2500 ft was prevented by clouds.

2.2. ~~(Confidential)~~ M-1 Infrared Scanner

The M-1 scanner is a completely rebuilt instrument utilizing an AN/AAR-9 XA-2

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*The M-1 scanner is a completely rebuilt AN/AAR-9 (XA-2) scanner.

**The AN/AAD-2 scanner and the K-17 aerial camera with gyro-stabilized mount are on loan to the Infrared Laboratory from USA CRREL.

four-sided scanner mirror, parabolic collecting mirror, and gyrostabilization system. The optical system is a Newtonian type to permit vertical mounting of liquid-cooled infrared detectors.

Design of the detector mounting system provides for use of indium antimonide (InSb), long wavelength copper-doped germanium (Ge:Cu), and mercury-doped germanium (Ge:Hg) detectors. These three detector combinations permit scanning throughout the wavelength region from the visible to 25μ. Only the indium antimonide and the copper-doped germanium detectors were used for this study.

The scanning mirror is driven by a variable speed-dc motor whose speed is adjusted to the proper V/H (velocity/height) ratio of the aircraft. The over-all scanning angle is approximately 72°, and maximum system resolution is one milliradian using a 1/4 x 1/4 mm detector size.

2.3. ~~(Confidential)~~ AN/AAD-2 Infrared Scanner

The AN/AAD-2 scanner, which was purchased from the manufacturer by CRREL in 1961, has been modified by the University of Michigan to accept the large dewars associated with helium-cooled long-wavelength detectors. Several other changes were made to improve electrical bandwidth and final image quality. Preamplifier and glow-tube driver circuits were redesigned, and provision was made for magnetic tape recording. The 3-inch-diameter optical system of this lightweight instrument has a shorter focal length than that of the M-1 scanner, and the instantaneous field of view when using a 1/4 x 1/4mm detector is 1.5 milliradians. Three data recording methods are available. A 70-mm film strip within the scanner is exposed by a flying light spot from a gas-filled glow tube which is modulated by amplified signals from the detector. This recording system is relatively difficult to control with precision; its primary virtue is that no synchronizing system is required, since the glow-tube optics are mounted directly on the shaft of the primary scanning mirror and rotate with it, assuring optimum line synchronization. Signals from the scanner amplifier are also directed to the magnetic tape recorder and, when desired, to the cathode-ray tube direct recording unit.

2.4. (Unclassified) Magnetic-Tape Processing

The electronics are designed to handle processing of signals from both the M-1 and AN/AAD-2 scanners. The tape deck is an Ampex CP-100 seven-channel unit with playback amplifiers providing optimum tape monitoring while recording. Two oscilloscopes are used to display video signals. A Tektronix Model RM 15 displays signal amplitude on the y-axis, with a linear scan triggered by the scanner synchronizing signals on the x-axis and a Model RM 35 (with a long-persistence phosphor) displays the thermal maps as generated by the scanner. The cathode-ray tube in the photographic recording unit (Dumont 5FP11a or 5CKP11 hi-resolution) has magnetic focussing and deflection and displays a single-line repetitive sweep which is triggered by the scanner-synchronizing signal and is intensity-modulated by the video signals from the infrared detector. In the SM-100 recording camera, successive scans are recorded side by side on a continuously moving 70-mm film strip.

Other specialized equipment includes a slope-compensating amplifier for correcting curvature in the scan resulting from low-frequency amplitude variations; a video amplifier with adjustments for gain and d-c level; and phase-shifting and mixing circuits for combining signals from FM and direct-recording channels. Frequency response in the FM mode, at 60-ips tape speed, extends from d-c to about 20 kc. AM response extends from 100 cps to 300 kc, and both recording methods must be used to obtain the required bandwidth.

The magnetic-tape data-processing system has several important advantages. Setting the CRT intensity and lens aperture and setting the film speed for optimum negative density and minimum distortion in the final picture present the greatest difficulties in achieving direct in-flight film recordings. These settings must be adjusted in accordance with ground speed and altitude changes. Magnetic tape, on the other hand, can be replayed any number of times to achieve optimum conditions for producing a good negative. The sort of electronic "improvement" of the final picture that can be achieved by aperture compensation techniques and high-frequency emphasis would be difficult to accomplish in flight, since the necessary adjustments are subject to considerable variation.

3
OPTIMUM SCANNER PARAMETERS
~~(Confidential)~~

3.1. (Unclassified) Spectral Choice

The optimum spectral region for detection may be determined by a consideration of black-body curves approximating the energy distribution of the targets and the backgrounds. While the energy from a typical fire (800°C) is greatest at short wavelengths below 3μ, solar reflection from the vegetation is serious, even early in the morning, in this spectral region. Figure 1 shows the energy distribution for (blackbody) targets at 800°C and 100°C (dashed curves) and for the background at an assumed temperature of 30°C. Solid lines indicate the amount of energy transmitted through the canopy, assuming 90% obscuration. Signal-to-background ratio for the open fire is much better in the shaded area between 4.5 and 5.5μ than in the region of atmospheric transmission between 8.6 and 13μ, and the ratio is somewhat better even for the 90% obscured target at 100°C. An indium antimonide (InSb) detector filtered for acceptance of wavelengths between 4.5 and 5.5μ appears to be an optimum choice; solar reflection is negligible, background energy is sufficient for mapping, and the target signal to background ratio is favorable for detection. (Experimental results presented in a later section of the paper confirm this reasoning.) Factors of less importance, such as emissivity values and atmospheric transmission, need not be considered. The emissivity is fairly close to unity for both the fires and the vegetation and only those regions where atmospheric transmission is large for the fairly short, near-vertical paths of interest have been considered.

3.2. ~~(Confidential)~~ Resolution

For single-element scanners of the type used in this work, signal to noise ratio (or target signal to background signal ratio) is best when the ground resolution (size of ground intercept element subtended by the solid angle representing the instantaneous field of view of the detector-optical combination) is equal to or smaller than the target of interest. In other words, the target should at some instant fill the instantaneous field of view for the most positive detection.

Since the instantaneous field of view of the M-1 scanner is 2 milliradians using a 1/2 x 1/2 mm detector and 1 milliradian for the 1/4 x 1/4 mm size, the ground intercept at 1000 ft altitude is 2 ft square or 1 ft square, depending upon the detector in use. The latter figure is nearly optimum in that the maximum ratio of signal to background is obtained for heat sources of the size provided for these tests. Although even better angular resolution might be desirable for higher altitudes, 1 milliradian is about the best that can be expected for existing scanners. Long-focal-length optics and very high scanning-mirror rotation rates are required for further improvements.

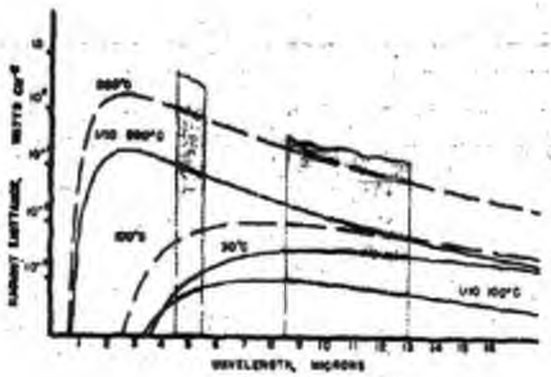

Figure 1. (Unclassified) Energy distribution for targets at 300 and 100° C and for the background at 30° C.

3.3. (Unclassified) Temperature Sensitivity

The ability to detect very small temperature differences is not of critical importance to the problem of detecting small intense-heat sources in the environment considered here. Degradation due to reduced detector sensitivity is first noticed in the quality of terrain imagery. The targets appear as hot spots, and often as overload signals, in all of the InSb target imagery obtained in Puerto Rico, although considerable variation in temperature sensitivity of the scanner system resulted from drifting of the detector bias voltage. For operation at high altitudes, where the decreased ground resolution might tend to smooth out the background variations and where the target would fill only a very small part of the field of view, temperature sensitivity would be a more important factor.

4
TARGET CHARACTERISTICS
(Unclassified)

4.1. (Unclassified) Location

The target sites, located within the boundaries of the Carribbean National Forest, were selected by the USA CRREL advance party during the month of October. This area was selected because of its dense rainforest-cover type, accessibility, and proximity to living accommodations. Two forms of vegetation were chosen as cover for the thermal targets: flight line 1 (a high, dense canopy) located in the La Mina River Valley extending approximately 1/2 mile NE from La Mina Falls, and flight line 2 (a low-lying, dense canopy) located and adjacent to a road connecting Pico del Oeste and Pico del Este.

4.2. (Unclassified) Vegetation - flight line 1

The site selection for the experiments had to be relatively undisturbed rain forest with maximum canopy density that was reasonably accessible by foot trail. As a result of these qualifications, the targets were positioned on or near an abandoned foot trail along the La Mina River. Figure 2 is an air photo of an area similar to line 1. The valley wall is steep, the aspect is northeast, and the elevation is 1950-2150 ft. Intermittent tributary streams dissect the valley wall. A well-developed, subtropical wet forest or montane rain forest, locally known as the tabonuco (Dacryodes excelsa) type, predominates in the valley bottoms and lower slopes at this elevation. Palm brakes of nearly pure mountain palm (Euterpe globosa)

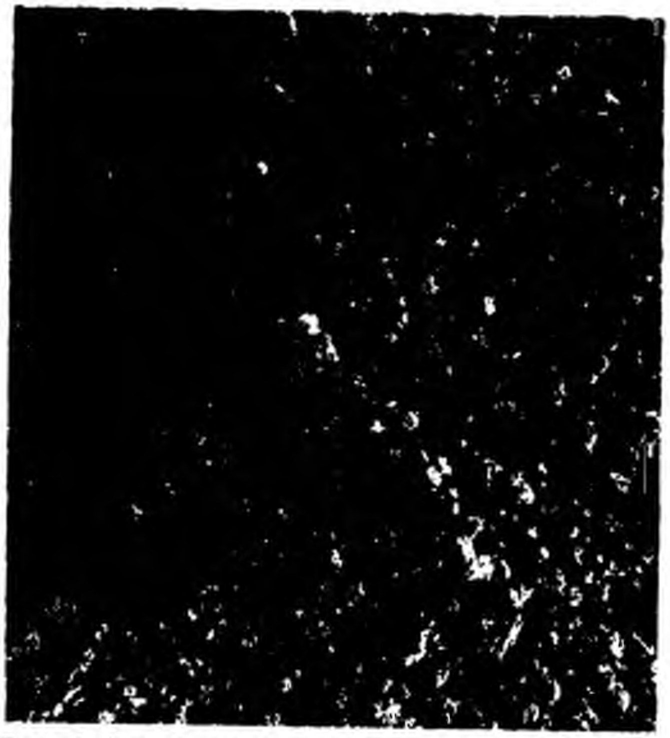

Figure 2. (Unclassified) Airphoto of area similar to Line 1. This is the same stream bed (La Mina) as the study area, but about one half mile downstream. Vegetation types and densities are essentially the same in both areas.

occur on steep, unstable slopes above this elevation and interfinger into the study area along the first- and second-order tributary drainages. Emergent crowns overtop the forest canopy; these trees grow primarily on ridges of shallow bedrock to heights of 150 ft. A lower canopy stratum averages 100 ft in height and this in turn is underlain by a third poorly defined canopy layer of palm, young trees, and minor species from 20 to 60 ft high. Arboreal epiphytes, particularly Philodendrom, Marcgravia, and bromeliad species, contribute considerable biomass to the lower two crown levels.

4.3. <u>(Unclassified) Vegetation - flight line 2</u>

A second study area was selected to represent shorter vegetation type and to obtain more precise flight control. This ridge site is in the dwarf thicket or mossy forest type. The shrubby tree species with very similar microphyllous leaves seldom exceed 20 ft in height. Epiphytic mosses, orchids, and bromeliads are abundant but smaller than at line 1. The seven target locations vary from dense shrubbery with only small sky openings to an open grassy sward without woody plants. The grassy openings are apparently the result of a perched water table caused by an impermeable iron-pan layer in the lateritic soil. Figure 3 is an aerial photo of this region.

4.4. <u>(Unclassified) Targets - charcoal fires and measurements</u>

To approximate the conditions and the cooking stoves described earlier, charcoal fires were placed on the ground at selected sites along flight lines 1 and 2. To prepare the fires, 8 to 10 lbs of charcoal was placed in each of the galvanized pails (14-inches in diameter and 8.5 inches high); the charcoal was then doused with kerosene and lit. The fires were usually started 1/2 to 1 hour before each flying mission. Previous experiments had shown that fires of this type could burn for as long as 24 hours and that for the first 4 or 5 hours the radiation output decreased very slowly. The highest temperature for these fires was about 800° C.

Radiation measurements of the fires were made with a GE radiation meter type DK-60 and with a Stoll-Hardy radiometer (Williamson Development Co.,West Concord, Mass.). Both instruments were modified with an aperture for use over hot targets. A second Stoll-Hardy radiometer was used to obtain radiation measurements of the various natural surfaces. Contact temperatures were read with an Alnor contact pyrometer. An Assman psychrometer was used to obtain dry bulb and wet bulb readings when desired. A helium-filled balloon (protected

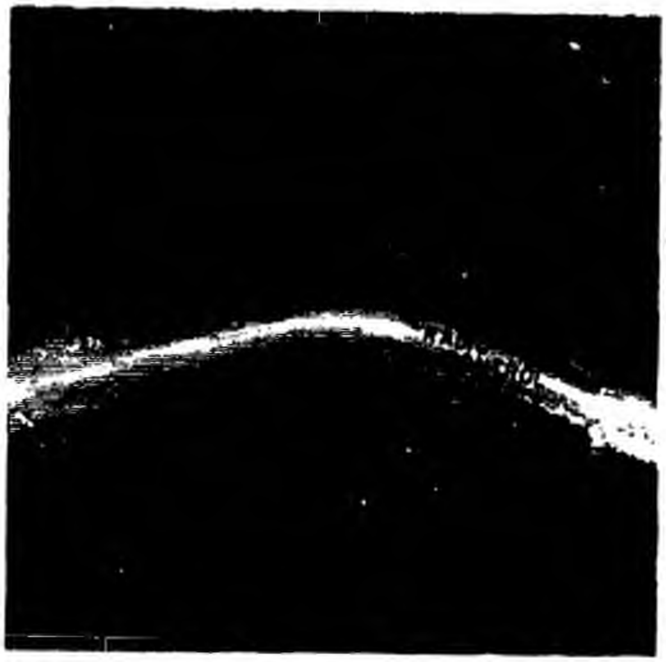

Figure 3. (Unclassified) Airphoto of Flight Line 2. The approximate locations of the charcoal fires are indicated on the overlay.

with a parachute cover) served to suspend and raise a thermistor (Victory Corp., type 32A84) through the vegetation so that the thermal gradient could be established from ground level to above canopy height. The balloon was stopped every 2 meters and the resistance of the thermistor was read with a modified Rubicon portable Wheatstone bridge. (One of the photographs in Figure 8 shows the thermal gradient gear in use.) Figure 4 shows one such gradient plot and Figure 5 is a radiometric trace produced by the airborne radiometer which indicates the magnitude of thermal variations as recorded with a 5 milliradian instantaneous field of view in the 4.5 to 5.5μ wavelength interval. The average flight altitude was about 800 ft so that the instrument integrates or averages an area of about 16 ft^2. The rapid fluctuations ranging in magnitude from 1 to 3° C are in good agreement with measurements of the vertical temperature gradient obtained from ground level to the top of the canopy. The ridge road, where flight line 2 was located, appears at the left of the trace. The road and terrain immediately adjacent are warmer than the vegetation cover. The terrain descends rapidly from this ridge to the bottom of the valley containing flight line 1, dropping some 900 ft over a distance of 1 mile. There is a corresponding gradual rise in temperature down this slope of about 6 or 7° C. Little confidence can be placed in absolute magnitudes of temperature indications, as the emissivity of the vegetation in this wavelength region is not accurately known.

5

RESULTS
~~(Confidential)~~

Tables I, II and III sum up the number of times each fire was detected. As discussed elsewhere in this presentation, the 8-14μ bandpass is not the best region of the spectrum to use for this particular detection problem. Our results certainly support this statement. Of all the fires on line 1 that were available for detection, the copper-doped germanium cell (8-14μ) detected 14.8% and the indium antimonide cell (5.5μ long-wavelength cutoff) detected 41.5% of them. However, the copper-doped cell (8-14μ) did not detect any fires that were obscured by vegetation. The indium antimonide cell detected about 30% of the hidden fires. Examination of the imagery shows that the 8-14μ bandpass is better suited for recording radiation variations within the canopy itself.

There were a few cases where the identity of a target site, visible in the imagery, could

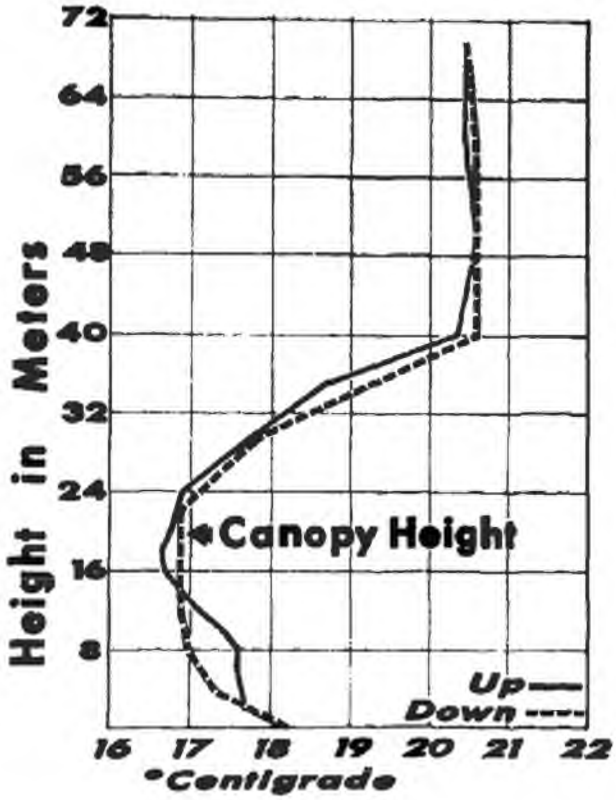

Figure 4. (Unclassified) Thermal gradient in forest (near Cabin No. 1, 12 Nov at 2100 to 2130 hours). This four degree temperature range was the maximum measured for any vertical gradient.

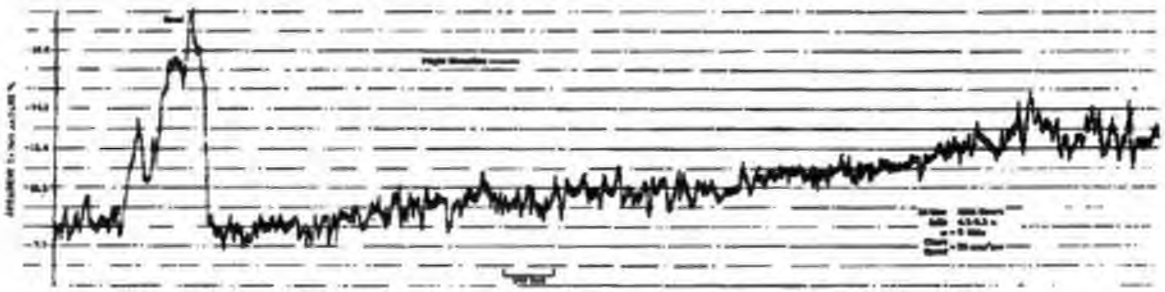

Figure 5. (Unclassified) A radiometric trace over canopy and ground that shows a temperature change similar to the thermal gradient.

Table I. ~~(Confidential)~~ Summary of Results of the M-1 Scanner (Indium Antimonide) Over Line 1.

Overall detection = 41.5%
Detection of obscured fires only = 30.6%

	Tape no.	Bandpass	November date-time	Alt. (ft)	A	1	2	3	4	5	6	7	8	9	10	11	12	B	No. of fires available for detection	No. of fires detected
					Fire sites*															
1	521-7-1	VIS-5.5 μ	17-0614	1500	0	0	0	0	0	0	0	0	0	X		0	X		4	-
2	521-7-2	VIS-5.5 μ	17-0618	800	0	0	0	0	0	0	X	0				0	X		6	2
3	521-7-3	VIS-5.5 μ	17-0624	1500	0	0	0	0	0	0	0	0	0			0	X	0	3	1
4	521-7-4	VIS-5.5 μ	17-0630	800	0	0	0	0	0	0	X	0				0	X		6	2
5	521-7-5	VIS-5.5 μ	17-0635	1500	X							0		X		0	X		12	3
6	521-7-6	VIS-5.5 μ	17-0642	1000	?							0		X		0	X	X	12	3
7	522-8-8	VIS-5.5 μ	17-0653	900	0	0	0	0	0	0	0	0		X		0	X		5	2
8	522-8-9	VIS-5.5 μ	17-0658	1700	X							0				0	X	X	12	3
9	522-8-10	VIS-5.5 μ	17-0705	900	X			X		?	X	0		?		0	X	X	12	5
10	526-12-20	4.5 μ-5.5 μ	17-0910	1000				X				0		X		0	X	X	12	4
11	530-16-2	VIS-5.5 μ	19-0611	1000	X		X	X			X	X	?	X			X	X	14	8
12	531-17-6	VIS-5.5 μ	19-0632	1000	X				X		X		0	0	0	0	X	X	10	5
13	531-17-8	VIS-5.5 μ	19-0642	1000	0		X	X	X	X	X		X	X		X	X	X	13	10
14	531-17-9	VIS-5.5 μ	19-0647	1500	X	X	X	0	0	0	0	0	0	0	0	0	0	0	3	3
15	534-20-21	4.5 μ-5.5 μ	19-0936	1000	X			X			X	X		?		X	X	X	14	7
16	534-20-22	4.5 μ-5.5 μ	19-0940	1500	X	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
17	536-22-4	4.5 μ-5.5 μ	21-0728	800				X			X		X	X				X	14	5
18	536-22-5	4.5 μ-5.5 μ	21-0732	800	0	0	0	0	X	?				X			X	X	10	4
19	537-23-6	4.5 μ-5.5 μ	21-0737	800	X	X	?			X		X					?	X	14	5
20	537-23-8	4.5 μ-5.5 μ	21-0746	800	X	X	X			X		X					?	X	14	6
21	537-23-9	4.5 μ-5.5 μ	21-0751	2500	X	X	X			X	X	X					?	X	14	7
22	537-23-10	4.5 μ-5.5 μ	21-0754	800	X							X						X	14	3
				Total	12	4	5	6	3	4	9	6	2	9	0	2	15	14	219	91
	No. of fires available for detection				15	15	15	14	15	15	17	10	17	19	19	9	20	19		
	% Detection, each site				80	27	33	43	20	27	53	60	1	47	0	22	75	74		

Remarks: 17 November — Sites 7 and 11 were not lit. The fires were left from 2045 hr of 16 November

19 November — All fire sites were burning, but nos. 3 and 10 were beds of hot coals left from 0545 hr of 18 November

21 November — Fire no. 12 was covered with a palm frond shed on all passes.

*X = Fire detected
? = Questionable detection — faint signal
0 = Site not in field of view or not lit

Table II. ~~(Confidential)~~ Summary of Results of the D-2 Scanner (Copper Doped Germanium) Over Line 1.

Overall detection = 14.8%
Detection of obscured sites only = 0.7%

	Tape no.	Bandpass	November date-time	Alt. (ft)	A	1	2	3	4	5	6	7	8	9	10	11	12	B	No. of fires available for detection	No. of fires detected
						Fire sites*														
1	521-7-3	8-14 μ	17-0614	1500	0							0				0			11	0
2	521-7-2	8-14 μ	17-0618	800	X							0				0			12	1
3	521-7-5	8-14 μ	17-0635	1500								0				0	X		12	1
4	521-7-6	8-14 μ	17-0642	800	X							0				0	X	X	12	3
5	522-8-8	8-14 μ	17-0651	900	?							0				0	X		12	1
6	522-8-9	8-14 μ	17-0658	1700	X							0				0	X	?	12	2
7	522-8-10	8-14 μ	17-0705	900	X							0				0	X	X	12	3
8	530-16-2	8-14 μ	19-0611	1000	X												X		14	2
9	531-17-3	8-14 μ	19-0620	?	X							0	0	0	0	0	0	0	7	1
10	531-17-6	8-14 μ	19-0632	1000	X											0	0	0	11	1
11	531-17-7	8-14 μ	19-0635	1500												0	0	0	11	0
12	531-17-8	8-14 μ	19-0642	1000	X												X	X	14	3
13	531-17-9	8-14 μ	19-0647	1500	X					X									14	2
14	531-20-21	8-14 μ	19-0936	1000	X												X	X	14	3
15	534-20-22	8-14 μ	19-0940	1500	X														14	1
				Total	11	0	0	0	0	1	0	0	0	0	0	0	8	4	182	24
			No. of fires available for detection		14	15	15	15	15	15	15	7	14	14	14	5	12	12		

*X = Fire detected
? = Questionable detection — faint signal
0 = Site not in field of view or not lit

Remarks: 17 November — Sites 7 and 11 were not lit. The fires were left from 2345 hr of 16 November.
19 November — All fire sites were burning, but nos. 3 and 10 were beds of hot coals left from 0545 hr of 18 November.

Table III. ~~(Confidential)~~ Summary of Results of the M-1 Scanner (Indium Antimonide) Over Line 2.

Overall detection = 92.6%
Detection of obscured sites = 90%

	Tape no.	Bandpass	November date-time	Alt (ft)	Fire sites* 1	2	3	4	5	6	7	No. of fires available for detection	No. of fires detected
1	534-20-1	VIS-5.5 μ	20-0636	500	X	X	X	X	X	X	X	7	7
2	534-20-3	VIS-5.5 μ	20-0644	600	X	X	X	X	X	X	X	7	7
3	534-20-4	VIS-5.5 μ	20-0649	800			?	?	X	X	X	7	5
4	534-20-5	VIS-5.5 μ	20-0652	800	X	X	X	X	X	X	X	7	7
5	534-20-6	4.5μ-5.5μ	20-0657	700	X	X	X	X	X	X	X	7	7
6	534-20-7	4.5μ-5.5μ	20-0700	500	X	X	X	X	X	X	X	7	7
7	535-21-8	4.5μ-5.5μ	20-0706	300	X	X	X	X	X	X	X	7	7
8	535-21-9	4.5μ-5.5μ	20-0710	300	X	X	X	X	X	X	X	7	7
9	535-21-10	4.5μ-5.5μ	20-0715	400	X	X	X	X	X	X	X	7	7
10	535-21-11	4.5μ-5.5μ	20-0718	400	X	X	X	X	X	X	X	7	7
11	535-21-12	4.5μ-5.5μ	20-0722	400	X	X	X	X	X	X	X	7	7
12	535-21-13	4.5μ-5.5μ	20-0725	900	X	X	X	X	X	X	X	7	6
13	535-21-5	4.5μ-5.5μ	20-1420	800	X		X	X	X	X	?	6	5
14	535-21-8	4.5μ-5.5μ	20-1435	600	X		X	X	X	X	0	6	5
			Total		13	11	13	13	14	14	11	96	89

*X = Fire detected
? = Questionable detection — faint signal
0 = Site not in field of view or not lit

Remarks: On most passes, ground personnel were detected. For all passes, no. 7 was a ground fire (i.e., not in a pail). On passes 7, 8, and 9, fire no. 7 was covered with branches. On pass 10, fire no. 4 was covered with palm fronds and no. 7 had a 2-in. layer of dirt over the branches. On pass 14, fire no. 7 was very weak, but still apparent.

not be positively established. This did not influence the final figure for percent detection, but only the frequency of detection distributed among the sites.

5.1. ~~(Confidential)~~ Flight Line 1

Flight line 1 was located in an area of the rain forest that had the densest canopy to be found; for the purpose of detecting small ground fires through a vegetative cover, we considered this area to represent the worst possible case.

Figure 6 is a schematic layout of line 1. The picture by each target-site number is a view of the canopy directly over the charcoal-fire pail. Sites A and B were selected as control points in canopy openings that undoubtedly would show in the imagery if the detector's field of view passed over them. These signals would at least prove that the aircraft had passed over the correct area and would also help to identify any other targets detected. Figures 7 and 8 are photographs of the general region associated with line 1 and Figures 9, 10 and 11 are photographs of some of the target sites. Figures 12 and 13 are examples of the thermal imagery of line 1.

The mission on 17 November (see Table I and Figures 12 and 13) is interesting in that the fires were, by then, several hours old and were radiating less energy than new fires. Twelve fires were lit by 2045 hours on the 16th, but weather prevented the aircraft from flying over them until 0614 hours on the 17th. If the results from the 17th are examined separately it is seen that 32% of the available fires were detected under the adverse conditions of dense canopy and relatively cool fires.

If the data from the 19th and 21st are combined, the results show that 48% of these fires were detected (see Fig. 13). With the exception of two cases, fires were new and relatively hot. The two exceptions are fires 3 and 10 for the mission on 19 November. These were residual coals from fires lit at 0545 on the 18th for a mission that was cancelled due to weather. Number 3 was detected on the 19th some 25 hours after it was lit. For all passes of the aircraft on the 21st, fire 12 was covered with a palm frond roof. This very effectively reduced the radiation to a level of questionable detection.

Several fires were detected that are treated as misses in the tables. These cases are indicated by question marks and represent signals so weak that they would normally not be noticed in the imagery.

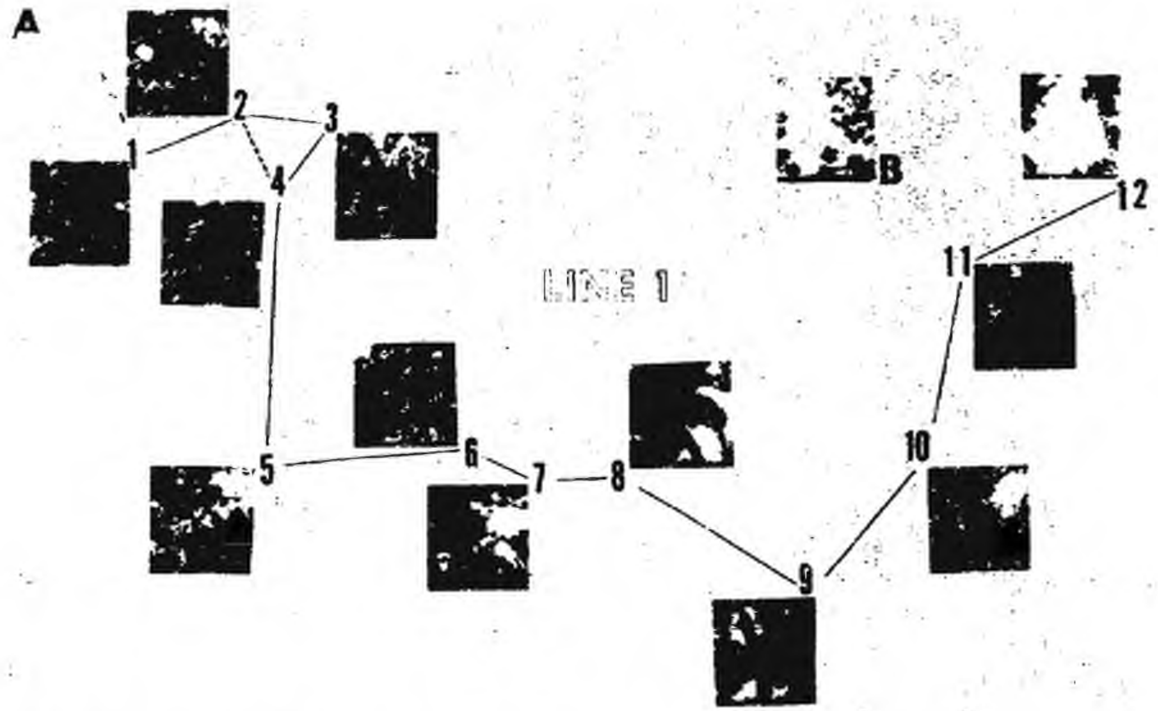

Figure 6. (Unclassified) Schematic layout of Line 1. Each target site is represented by zenith ground photography of the canopy.

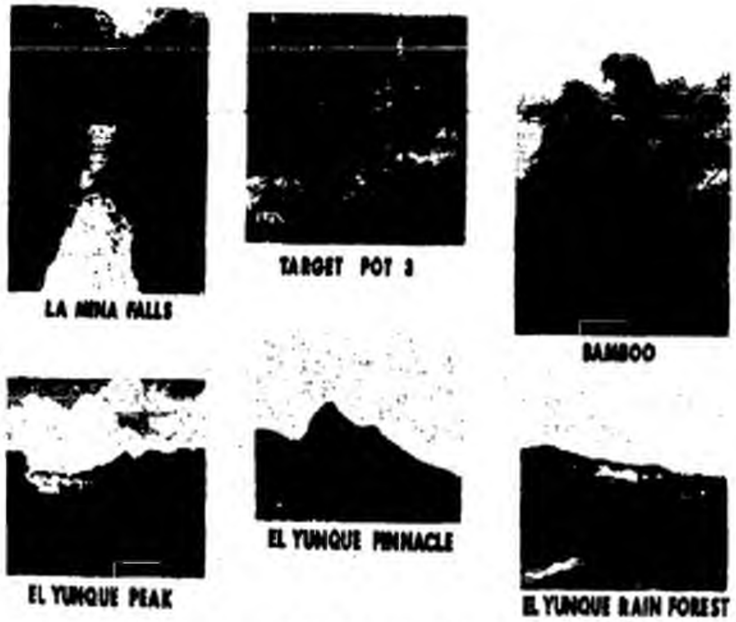

Figure 7. (Unclassified) Typical areas in the El Yunque montane rain forest.

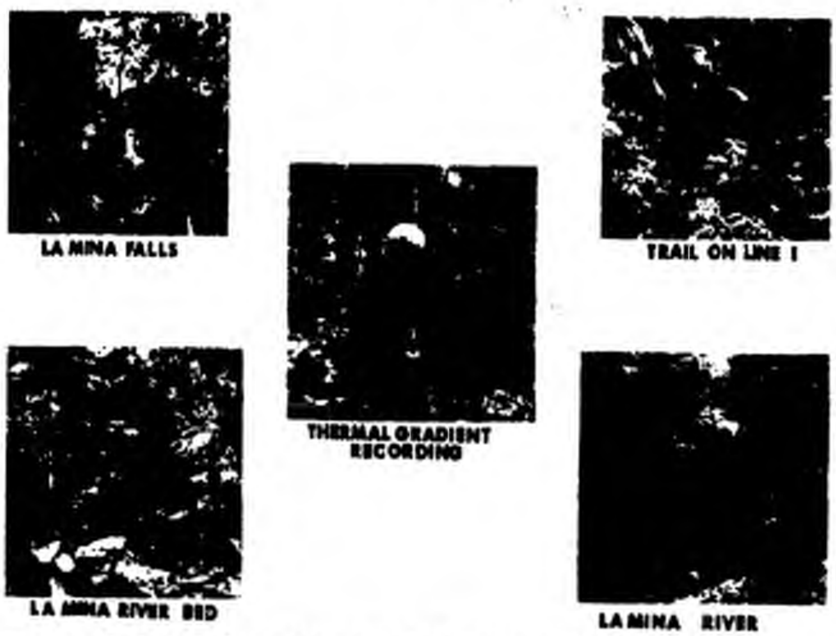

Figure 8. (Unclassified) Representative areas associated with Flight Line 1.

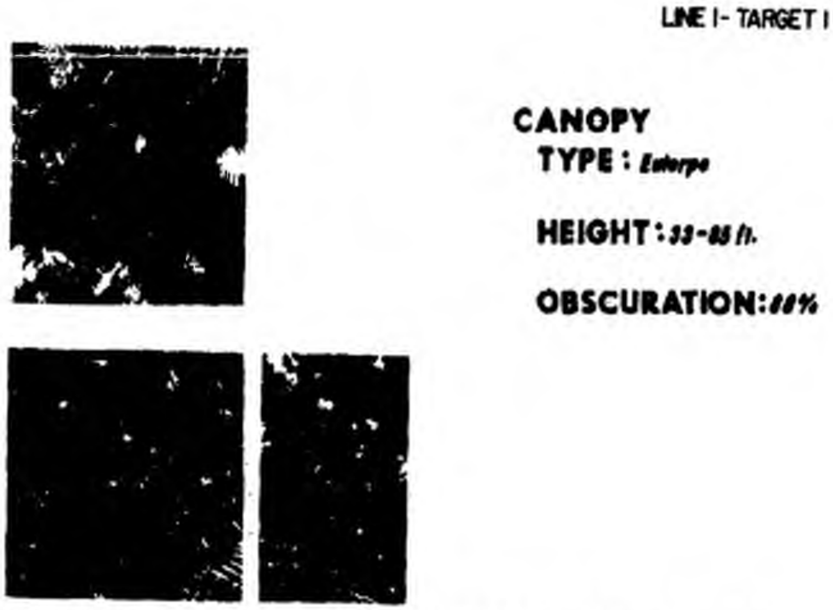

Figure 9. (Unclassified) Zenith view of canopy and target firepot 1, Line 1.

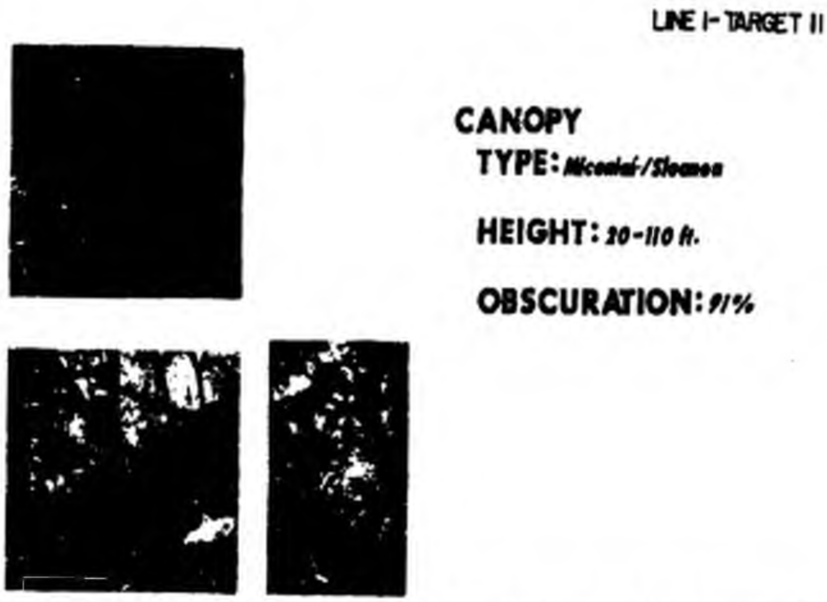

Figure 10. (Unclassified) Zenith view of the forest canopy and target fireport 11, Line 1.

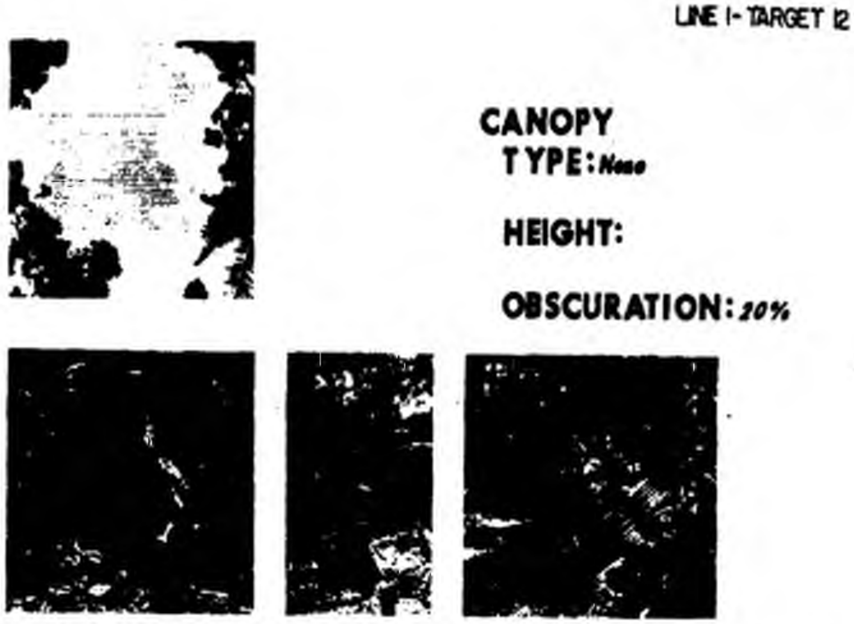

Figure 11. (Unclassified) Zenith view of the canopy and palm shelter over target firepot 12, Line 1.

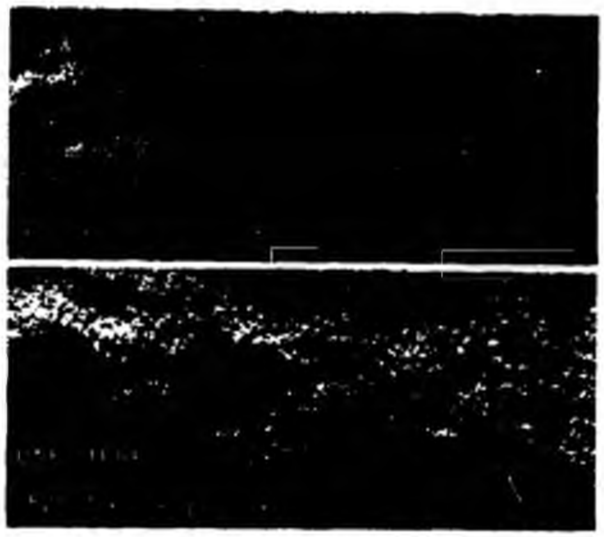

Figure 12. ~~(Confidential)~~ The influence of reflected sunlight on the thermal image. Both strips are of Line 1 on 17 Nov 1962.

Strip 521-7-5, 0635 hrs at 1500 ft. Three fires out of twelve were detected (Sites A, 9 and 12).

Strip 521-7-6, 0642 hrs at 1000 ft. Three fires out of twelve were detected (Sites 9, 12, and B1). Site No. 1 can also be found in the imagery, but it is well hidden in the contrasting background. The InSb detector is sensitive to visible frequencies as well as infrared frequencies and when used without a filter (as above), presents an image composed of thermal radiation plus any reflected radiation. The images above were made at sunrise and show the influence of sunlight reflected from the canopy. These fires were left over from 16 Nov and were about 11 hours old at the time of this imagery.

Figure 13. ~~(Confidential)~~ A comparison of two different bandpasses over Line 1 on 19 Nov 1962.

Strip 543-20-21 InSb (filtered 4.5-5.5μ), 0936 hrs at 1000 ft. Seven fires out of fourteen were detected (Sites A, 3, 6, 7, 11, 12, and B). Sites 6 and 7 are almost in line below Site 3 and Site B is just above 11. Site 3 was about 29 hours old by the time of this pass. Site 9 can be identified on the film but its signal is too weak to be readily apparent.

Strip 534-20-21 Ge:Cu (8-14μ), 0936 hrs at 1000 ft. Three fires were detected out of fourteen (Sites A, 12 and B). This represents some of the best imagery of the canopy.

Thus, it is felt that the figure of 30% is a realistic value for the overall capability of the indium antimonide cell in detecting individually obscured fires. If it is in error, it is on the conservative side.

5.2. ~~(Confidential)~~ Flight Line 2

Seven charcoal fires were prepared under varying amounts of cover and 13 scanner runs were flown over the area shortly after dawn, followed by additional runs in the afternoon. During the morning runs, closely controlled conditions were maintained through radio contact with the four-man ground team. Following each pass by the aircraft, a description of target indication as observed on the cathode-ray C-scan presentation in the aircraft was reported to the ground and changes were made in the target complex prior to the next pass by obscuring certain fires with varying amounts of cut vegetation and other materials.

On line 2, 92.8% of the fires were detected with the indium antimonide cell. Table III shows the summary of the data and Figure 14 is a schematic diagram of line 2. Figure 15 shows one of the fire sites. Figure 16 is an example of thermal imagery of line 2. With the exception of three targets (sites 1, 2 and 5) all of the fires were more or less free of vegetative cover. One target, number 7, was a charcoal fire laid on the ground. During some of the passes of the aircraft, efforts were made to conceal certain of the fires. For all practical purposes, these were unsuccessful. Target 7 was detected when covered with small branches, a layer of dirt, and a layer of grass (Table III).

It is significant in connection with this test that, although there was sufficient daylight during the last few passes of the morning mission for determination of detail on the ridge, nothing could be seen visually in the target area even though the aircraft crew knew exactly where to look and were passing over the ridge at altitudes as low as 400 ft. Personnel were observed only when they were clear of the growth concealing the fire targets and standing in the open. (Visual reconnaissance conducted from a helicopter at low altitude over the Project AMPIRT forest site Thailand, in 1965, yielded similar results.)

No sign of activity was ever observed visually on line 1, except when the ground party lofted a balloon above the canopy or fired a flare up through the trees.

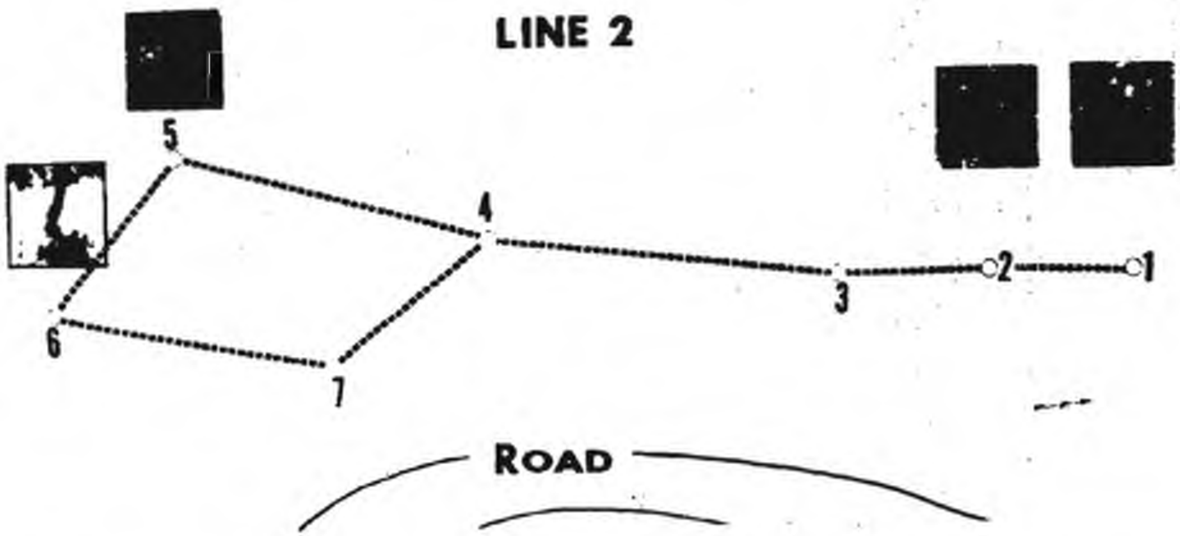

Figure 14. (Unclassified) Schematic layout of targets on Line 2 utilizing zenith photography to show cover. There was essentially no vertical canopy over targets 3, 4, and 7.

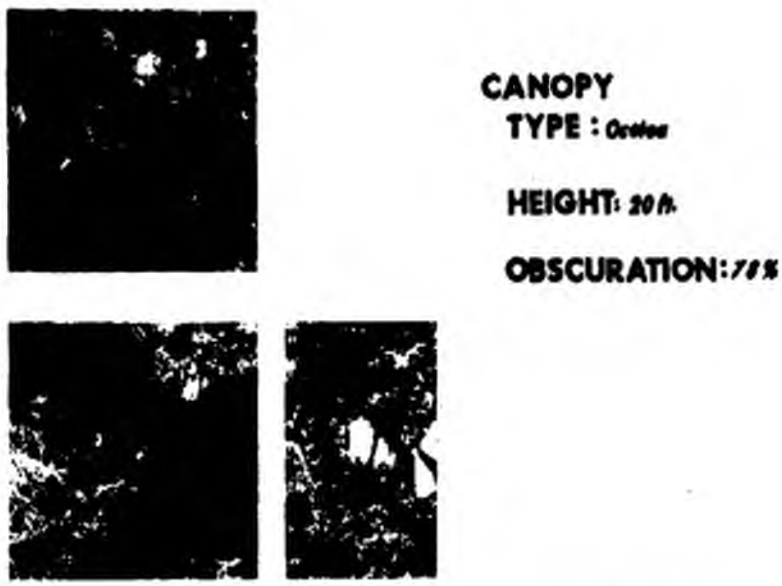

Figure 15. (Unclassified) Zenith view of the forest canopy and firepot 1, Line 2.

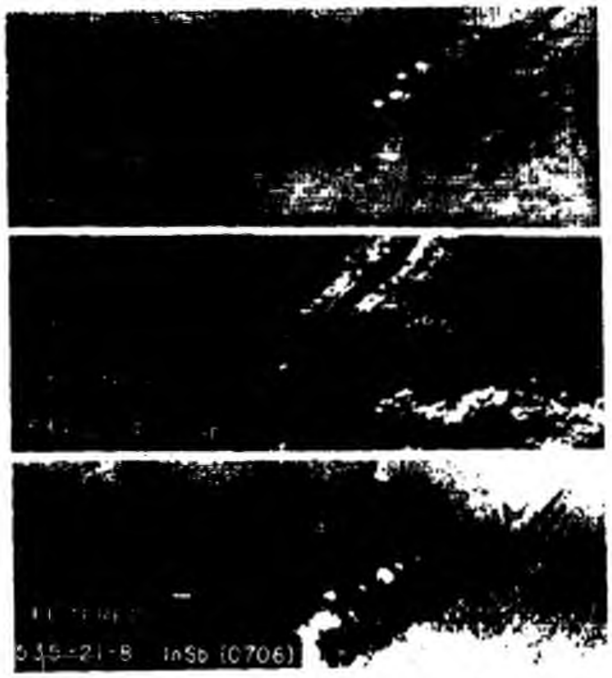

Figure 16. ~~(Confidential)~~ A comparison of different bandpasses over Line 2 on 20 Nov 1962.

Strip 534-20-1 InSb (visible - 5.5μ), 0636 hrs at 500 ft. All seven fires were detected. The upper, small arrow points to a group of 3 or 4 people near the radio control site, and the lower small arrow indicates the location of other personnel. There is some reflected sunlight in the image.

Strip 534-20-4 InSb (visible - 5.5μ), 0649 hrs at 800 ft. There is enough reflected sunlight to seriously interfere with detection capability.

Strip 535-21-8 (filtered, 4.5-5.5μ), 0706 hrs at 300 ft. All seven fires were detected, although Site 7 was covered with a layer of branches. The small arrow indicates personnel. Note the improvement in detection by filtering out the reflected sunlight.

DISCUSSION
~~(Confidential)~~

It is very significant that some fires were detected on every flight of the M-1 scanner over the targets. In applying the results of these experiments the detection of any activity may be more important than the detection of a large percentage of individual fires.

In order for the charcoal fires to be detected with the systems used on this project, an unobstructed line of sight must exist between the fire and the detecting cell. This is true because the infrared energy will not penetrate the vegetation of the canopy. If "holes" are not available --the fires will not be detected. For some fires there will not be a zenith line of sight, but there may be one off to either side. For other fires the reverse will be true. Thus, on successive passes of the aircraft (all slightly different) some fires will appear and disappear. The problem of detection is not concerned as much with the total amount of openness in a canopy over a fire as it is with the distribution of this openness. In some cases chances of detection are better through a dense canopy with several holes than through a less dense canopy with its greater hole area combined into a single opening.

For equal densities of cover, chances of detection are better through a low-lying cover, such as on line 2, than through a high canopy, such as on line 1. This is analogous to viewing newsprint through a tissue with the tissue midway between the print and the eyes, in contrast to viewing the newsprint when it is in contact with the tissue.

It is reasonable to think of the average percentage detection figure as the probability for detection of a single fire concealed beneath vegetation representing an average obscuration (i.e., 100 attempts to detect a single fire through average vegetation should yield essentially the same results as 10 passes over 10 fires). This is probably a valid assumption, since detection depends upon chance alignment of the scanner aperture with a fire through line-of-sight openings in the vegetation. Using the detection figure for line 1, 30.6%, as the probability for detection of one fire from an arbitrary angle on one pass ($p_1 = 0.306$), we may predict the increase in detection probability for multiple passes at other angles from the relation $p_n = 1-(1-p_1)^n$, where $\underline{n}$ is the number of passes, or number of looks toward the fire from different points overhead. Results are as follows: For n = 1, 2, 3, 4, and 5, $p_n = 0.306$, 0.518, 0.666, 0.768, and 0.839. If the aircraft could cover each unit of area on the ground five times, or if the instrument could be arranged to scan every point on the ground from different aspect angles during a single flyover, the detection probability might be increased to a value greater than 0.8. Several possibilities exist for implementing this favorable replication in the scanning pattern. A framing scanner which makes a series of overlapping scans is possible (some years ago the obsolete AN/AAS-4 scanner had this capability), or a design combining several detectors with wide-field optics might be devised. The advantage of seeking a target from several different angles within the wide cone subtended by radiation from the target is almost unique to this particular detection problem and relatively little serious thought has been given to it previously.

The thermal imagery shows that the signal-to-background ratio is quite large--large enough for detection to be feasible from higher altitudes. It was intended to make successive runs over the targets at higher altitudes until the signals were lost. Weather prevented such flights and the highest passes were at 2500 ft above the targets.

The figure of 41.5% over-all detectability or 30.6% obscured detectability with the indium antimonide cell over line 1 applies only to these tests. In a real situation, this figure may be too high, for in many ways this project was biased towards success. For example, all missions were coordinated between the aircraft and ground personnel at the target site. The air crew knew where to look for the fires and they were often directed in by radio, flashing lights, or flares. Even under these conditions, many passes were off the selected line and beyond the field of view of some or all of the fires. The imagery itself was checked and rechecked. The people evaluating the imagery knew where to look for signals from the fires, and could place prepared overlays on the imagery to check off the various sites.

A more realistic test would be provided by selecting an area (1 or 2 square miles) in the rain forest where a small group could wander for several days, lighting fires at sunup and sundown. The aircraft would then be forced to search for fires. This would provide a figure of merit more applicable to the situation of interest in military operations.

A variety of methods were used in an effort to conceal some of the fires--as indicated, these were not all successful. For one mission, five charcoal fires were lit in a large open parking lot and pans of water were placed over two of the fire-pails. These pans were larger in diameter than the pails and effectively hid them from vertical views. Both the indium antimonide and the copper-doped germanium cells detected all pails on all passes. Although, when looking directly down, the detector would sense radiation from a 100°C source, it could, when looking from any other angle, receive radiation from the hot sides of the pail. Pans of water would effectively reduce the detectability of these fires if measures were also taken to block the radiation from the pail itself. This could easily be done by placing the pail in a hole in the ground.

Some consideration was given to the possibility of detecting warm smoke or warm air rising at treetop level or above. In a warm tropical environment, detection of warm air would only be possible in selected, very narrow spectral regions where the width of the molecular absorption band might be sensitively temperature dependent. Available energy is severely limited in any such narrow region, and the thermal variation or "noise" presented by the background (see the radiometer trace, Fig. 5) would seem to preclude the possibility of success with this approach. Smoke is rarely detectable by infrared systems, even if warmer than the ambient air, unless it is dense enough to be detected visually.

7

CONCLUSIONS

~~(Confidential)~~

1. The use of an infrared thermal scanner to detect small ground fires obscured by a vegetative canopy has been demonstrated to be feasible.

2. The filtered indium antimonide cell (4.5 - 5.5μ bandpass) proved to be the best choice in flying over dense canopy as this cell detected 41.5% of all fires and 30% of the fires located under the canopy.

3. Under conditions of a high, dense canopy the success of detection depends as much on the distribution of the openings in the canopy as it does on the total amount that is open.

4. The signal intensity from many of the fires was so great that detection could be successful at much higher altitudes. The flights for this project were usually flown at around 1000 ft with 2500 ft being the highest pass. Weather prevented flights at higher altitudes.

5. In open grassy areas the indium antimonide cell detected personnel at 500 ft.

6. One of the problems that will be encountered in field operations is the exact location of "hot" signals and the speed with which they can be relocated for strike purposes.

RECOMMENDATION
(Unclassified)

It would be interesting and worthwhile to determine the capability of the systems used in this study to detect fires under conditions of search. For this purpose a target area in the rain forest of Puerto Rico, 1 mile by 2 miles in size (preferably along line 1), could be selected. A research ground party could traverse this area, lighting fires at dusk and dawn in different locations each night. Following a series of controlled location flights the sensor aircraft would have as its objective "search and detect." These operations should be accompanied by a truck-mounted radar which could track and position the aircraft throughout its passes in the target area. This would be necessary for determining the position of the plane with respect to the targets for proper analysis of the study. All of the above would necessitate detailed canopy observations at each fire-lighting period.

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ERROR ANALYSIS AND DATA REQUIREMENTS
FOR MODELS OF PRE-REVOLUTIONARY CONDITIONS (U)

(Unclassified)

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ABSTRACT

(Unclassified)

Models of pre-revolutionary conditions can be useful to inter-relate data from the actual world situation so that critical problems contributing to instability can be identified early enough for timely action. The reliability of model results depends on data collection efforts to provide values for variables that are within acceptable error limits, and model sensitivity to data accuracy should be compared with the feasibility of timely data collection required to keep accuracy within these limits.

Models of pre-revolutionary conditions can be useful to inter-relate data from the actual world situation so that critical problems contributing to instability can be identified early enough for timely action. The reliability of model results depends on data collection efforts to provide values for variables that are within acceptable error limits, and model sensitivity to data accuracy should be compared with the feasibility of timely data collection required to keep accuracy within these limits. The following example may be helpful in illustrating this point.

The preliminary model of Internal War Potential (IWP) designed by Avila* contains an expression for aspirations, $A = b_1 T + b_2 \frac{\Delta M}{\Delta t} + b_3 (\bar{L} - L_i)$ where T = literacy, M = mass media coverage, and $(\bar{L} - L_i)$ = achievement difference of a sub-group from the average. For this example, the following assumptions are made:

Literacy (T) -- Out of a population of 8 million, 40% are literate (3.2 million). A 50% increase in literacy is expected over 10 years, which would add about 160,000 new literates each year. Literacy data are available yearly with a one year delay. Extrapolation may be used to estimate current literacy:

3,200,000	one year old data
160,000	extrapolation
3,360,000	estimated current literacy

Assume an error of ± 20% in the extrapolation = ± 32,000 people.

[redacted] "Preliminary Model of Internal War Potential", Working Paper. The American University, Washington, D.C. April, 1965.

Mass Media Coverage (M) -- One indicator of this factor is daily newspaper circulation per 1000 people. Assume that circulation figures are available weekly and contain relatively little error. However, population errors are significant. Assume that population data are updated yearly with a one year delay and that an annual growth rate of 2.3% can be expected:

8,000,000	population data one year old
184,000	extrapolation (2.3%)
8,184,000	current estimate

Assume an error of + 20% in the extrapolation = ±36,800 people. The increase in circulation is 80 copies per 1000 people, or 654.72×10^6 copies per $8.184 \times 10^6 \pm 36{,}800$ people. The error is about ±0.6 copies per 1000 people.

Achievement Differences ($\bar{L} - L_1$) -- To simplify the level of achievement term for the purpose of this example, assume that achievement differences can be measured by differences in personal income. The average annual income ($\bar{L}$) is recognized to be \$300. However, annual income to the sub-group (L_1) is assumed to be undetectable for a 3 month period and to vary from \$400 to \$1000 per year, producing an error in L_1 of \$600 per year.

$$\text{Assuming no errors,}\quad A = b_1 T + b_2 \frac{\Delta M}{\Delta t} + b_3 (\bar{L} - L_1) =$$
$$b_1(3{,}360{,}000 \text{ people}) + b_2 \text{ (80 copies/1000 people)}$$
$$+ b_3 (300 - 400 \ \frac{\$}{\text{year}})$$

If this final value for aspiration were scaled to equal 50 (on a 0 - 100 scale), and if each of the 3 factors were assumed to contribute equally to aspirations, then:

$$b_1 T = \frac{50}{3}$$
$$b_1 = \frac{50}{3} \left(\frac{1}{3{,}360{,}000 \text{ people}}\right) = \frac{4.97 \times 10^{-6}}{\text{people}}$$
$$b_2 M = \frac{50}{3}$$
$$b_2 = \frac{50}{3} \left(\frac{1000 \text{ people}}{80 \text{ copies}}\right) = 208 \ \frac{\text{people}}{\text{copy}}$$
$$b_3 (\bar{L} - L_1) = \frac{50}{3}$$
$$b_3 = \frac{50}{3} \left(- \frac{\text{year}}{\$100}\right) = -.167 \ \frac{\text{year}}{\$}$$

$$\text{The error (Assuming random errors)} = \pm\sqrt{(\epsilon_1 b_1)^2 + (\epsilon_2 b_2)^2 + (\epsilon_3 b_3)^2} =$$

$$\pm\sqrt{\left[(32{,}000 \text{ people}) \left(\frac{4.97 \times 10^{-6}}{\text{people}}\right)\right]^2 + \left[\left(0.6 \frac{\text{copies}}{1000 \text{ people}}\right) \left(208 \frac{\text{people}}{\text{copy}}\right)\right]^2 + \left[\left(\frac{\$600}{\text{year}}\right) \left(- \frac{.167 \text{ yr.}}{\$}\right)\right]^2} =$$

$$\pm\sqrt{.0253 + .0156 + 10{,}040} = \pm 100$$

Since $A = b_1 T + b_2 \frac{\Delta M}{\Delta t} + b_3 (\bar{L} - L_1) \equiv 50$,

the error is $\pm \frac{100}{50} \times 100 = \pm 200\%$!

To hold the error down to ± 10%, $\epsilon_3 = \frac{\$30}{\text{yr.}}$

In this hypothetical situation, the most critical factor is the change in income of a sub-group. An undetected change in yearly income of greater than \$30 (in the \$400 per year sub-group) would increase the error in the aspiration value beyond $\pm 10\%$. If such a calculation is to be made in a model for operational use, data collection efforts in support of aspiration determination should clearly be concentrated on accurate and timely determination of $(\bar{L} - L_i)$, with relatively little effort devoted to T and M.

In the case shown, it does not seem feasible to collect data that would detect a \$30 difference in yearly income of any significant sub-group. Even if this were feasible, such differences might very well be random perturbations in the "noise level", and data collection efforts to detect it would be of little value. Here the model designer must be called on to see if another indicator above the noise level with feasible data collection requirements might be used to fulfill the intended function, or to see if the function is so critical to the modeled process that it could not be eliminated. If it is not feasible to collect data for an essential function, the model cannot be used to provide operationally useful information.

Similar calculations can be made for the other terms in this model and others under consideration for matching model requirements and data collection efforts.*

Because of the difficulty imposed by data collection problems, it might prove useful to have available a rather simple model that could accommodate whatever data were available, and that would impose no unique data collection requirements. It could also serve as a check on other models that might be in use, since data preparation should require little additional effort. The following chart and corresponding example indicate the overall operations involved.

*When the model requires multiplication of terms, products with random errors are of the form: $\prod x_i \left\{ 1 \pm \left[\sum \left(\frac{\epsilon_i}{x_i} \right)^2 \right]^{1/2} \right\}$

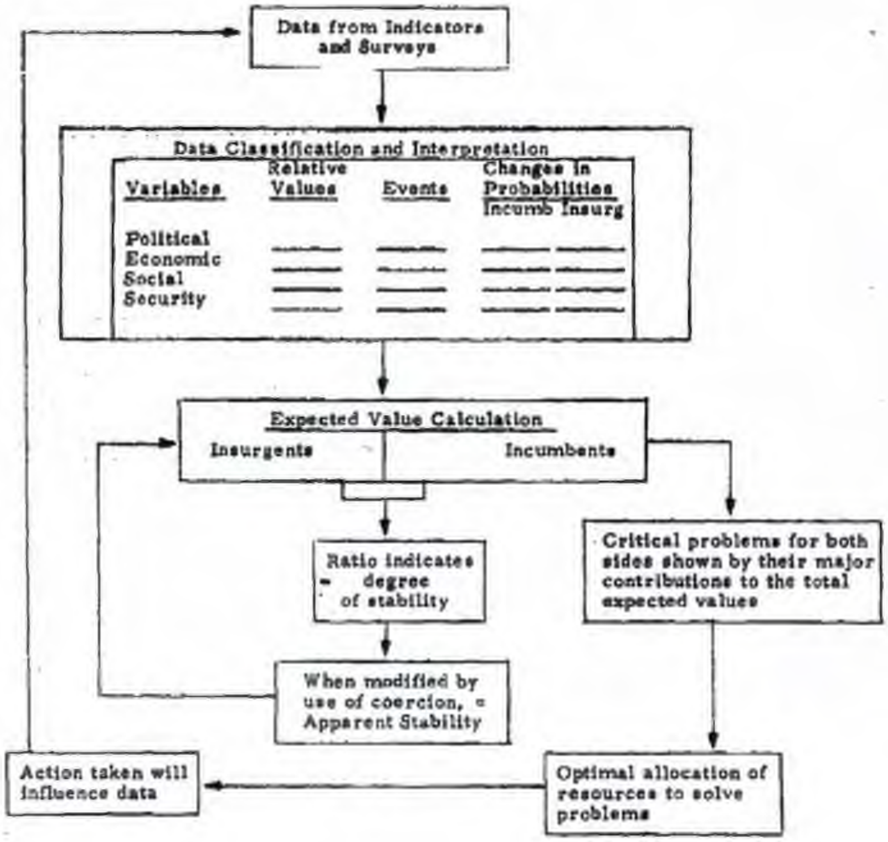

FIGURE I. MODEL FLOW CHART

For example, the independent variables in Avila's IWP model were used with assumed events and values, and they are shown in the table on the following page. The first line of the table considers the factor, Literacy. Assume that the incumbents have been forced to curtail a previously instituted system of village schools and mobile literacy teams due to a lack of resources. The population might very well interpret this event as an indication that the incumbents would not be able to provide the potential economic and social benefits available to those who can read and write, and the promises of the insurgents to provide these benefits would become more credible. This situation is interpreted as the change in probabilities shown.

The assignment of both probabilities and relative values of benefits is a subjective operation and must be performed by area experts with knowledge of the significance of individual indicator changes. However, the range of possible values that could be assigned to represent the change of population attitude due to the event is rather small, and those assigned to represent relative value is small because of the requirement for a set of internally consistent values. The impact of absolute errors is further reduced by the fact that only relative values are important in the final results. Area experts are required to make decisions about indicators significance one at a time only. The subsequent operations serve to combine these decisions in a meaningful way and allow the accommodation of many more factors than a single expert could relate at any one time.

The expected value calculation is made for each opponent for both before and after the events, and "Stability" ratios of Incumbent Value/Insurgent Value are formed, as shown on page 7, 8.

Variable	Relative Values*	Assumed Events	Probability that either side can provide the Benefit			
			Before Event		After Event	
	(1 - 10)		Incumb.	Insurg.	Incumb.	Insurg.
1. Literacy	7	Drop in previously steady improvement rate (0. 8) x (7) = (5. 6)	0. 8 (5. 6)	0. 1 (0. 7)	0. 6 (4. 2)	0. 4 (2. 8)
2. Mass Media Exposure	6	Powerful rebel radio station operates daily. Government station jammed.	0. 7 (4. 2)	0. 3 (1. 8)	0. 4 (2. 4)	0. 7 (4. 2)
3. Level of Achievement	7	a) Newly organized national airline fails because of unreliable operations	0. 9 (7. 2)	0. 2 (1. 4)	0. 4 ([illegible]. 8)	0. 4 (2. 8)
		b) Drop in consumption of building materials	0. 6 (4. 2)	0. 1 (0. 7)	0. 5 (3. 5)	0. 2 (1. 4)
4. Real per capita income	9	No change. Previous growth rate--0	0. 7 (6. 3)	0. 2 (1. 8)	0. 5 (4. 5)	0. 3 (2. 7)
5. Percentage rural population	4	No reduction after period of steady decline	0. 7 (2. 8)	0. 2 (0. 8)	0. 5 (2. 0)	0. 3 (1. 2)
6. Percentage unemployed in labor force	6	Reduced	0. 5 (3. 0)	0. 3 (1. 8)	0. 7 (4. 2)	0. 1 (0. 6)
7. Prestige attached to a given level of achievement	6	Increased prestige for police work resulting from apprehension of criminals and heroic deeds	0. 5 (3. 0)	0. 5 (3. 0)	0. 7 (4. 2)	0. 3 (1. 8)

TABLE I

DATA CLASSIFICATION AND INTERPRETATION

* The Churchman-Ackoff approximate measure of value procedure would be useful in assigning an internally consistent set of relative values. (b)(6) [redacted] Scientific Method: Optimizing Applied Research Decisions, Wiley, 1962, p. 87.

Variable	Relative Values * (1 -- 10)	Assumed Events	Probability that either side can provide the Benefit			
			Incumb.	Insurg.	Incumb.	Insurg.
			Incumb.	Insurg.	Incumb.	Insurg.
8. Percapita investment in social projects	5	Decreased from slowly rising trend	0.6 (3.0)	0.4 (2.0)	0.4 (2.0)	0.6 (3.0)
9. Governmental Extremism	6	Ratio of extremist Government leaders to rest increases	0.7 (4.2)	0.1 (0.6)	0.4 (2.4)	0.4 (2.4)
10. Involvement of country in international affairs	7	U.N. membership achieved	0.4 (2.8)	0.2 (1.4)	0.6 (4.2)	0.1 (0.7)
11. Multiplicity of non-governmental patterns of authority	4	Trend toward uniformity--Bipolarization more likely	0.5 (2.0)	0.5 (2.0)	0.4 (1.6)	0.6 (2.4)
12. Number of elite groups	4	More identified-reduced cohesion	0.6 (2.4)	0.2 (0.8)	0.4 (1.6)	0.2 (0.8)
13. Number of common threats to elite group	5	Reduced	0.6 (3.0)	0.2 (1.0)	0.4 (2.0)	0.2 (1.0)
14. Overlapping interests of elite groups	5	Industrial leaders become government officials	0.4 (2.0)	0.3 (1.5)	0.7 (3.5)	0.2 (1.0)
15. Number of salary increases to Army officers	5	Reduced	0.8 (4.0)	0.3 (1.5)	0.5 (2.5)	0.4 (2.0)

TABLE I (cont.)

DATA CLASSIFICATION AND INTERPRETATION

Expected Value Calculation

$\sum_{i=1}^{15}$ (Probability of providing benefit i) (Value of benefit i)

Results:	Before Events		After Events	
	Incumb	Insurg.	Incumb	Insurg
	59.7	22.8	47.6	30.8
Stability Ratio: $\frac{\text{Incumbent Value}}{\text{Insurgent Value}}$	2.6		1.55	

Critical Problems Identification

If the range of the ratio for serious instability were set to be from 1.5 to 0.5, the events described would have led to the brink of this range. The variables that contributed to the reduction of Incumbent value in the order of decreasing importance were:

Variable	Reduction
3a	4.4
2	1.8
4	1.8
9	1.8
15	1.5
1	1.4
8	1.0
13	1.0
5	0.8
3b	0.7
11	0.4
12	0.4

Variables that contributed to the increase of Insurgent value in the order of decreasing importance were:

Variable	Increase
1	2.8
2	2.4
9	1.8
3a	1.4
8	1.0
4	0.9
3b	0.7
15	0.5
5	0.4
11	0.4

If the Incumbent assigns equal weight to decreasing his own loss of value and reducing Insurgent gains, then his priority for action list would be ordered as follows:

Variable	Change Potential	
3a	5.8	(4.4 + 1.4)
1	4.2	
2	4.2	
9	3.6	
4	2.7	
8	2.0	
15	2.0	
3b	1.4	
5	1.2	
13	1.0	
11	0.8	
12	0.4	

If the Insurgent considered that he could accelerate the decreasing ratio trend by continued concentration on the issues that led to his more favorable position, his priority for action list would be the same as above. If he preferred to concentrate on the issues that detracted from his value and added to Incumbent value (with equal weight), his priority list would be:

Variable	Change Potential	
6	2.4	(1.2 + 1.2)
7	2.4	
10	2.1	
14	2.0	

This same list would hold if the Incumbent wished to further strengthen his advantages.

Action taken by either side would produce new events. As they occurred they could immediately be added, the less salient events eliminated, and new ratios and priority lists produced. Even though priority lists of problems would assist action decisions, they would not indicate what actions are best. However, data in the form of problems with relative numerical values for potential payoffs for problem solution are suitable for processing by mathematical resource allocation techniques. What remains is the collection of data during the decision-making process on (1) the quantities of various resources such as money and manpower that could be expected to reduce each problem size; (2) the total quantities of these resources that were available for problem solutions; and (3) indications of preferences for minimizing value losses, maximizing value gains or attacking the opposite conditions for the opponent. Indications of optimal allocations of resources would then be available more effectively to assist final allocation decisions.

In summary, candidate models for operational testing and use should be analyzed term-by-term for compatibility of model data requirements, and the feasibility of collecting appropriately accurate and timely data. It would be useful to have more than one model in operation to provide independent means of processing data, so that correlations would be available to support decisions for action. The model described would be particularly appropriate for this purpose, since it has no unique data collection requirements. The main advantage to be gained is the ability for action decision-makers properly to consider a much larger number of factors than could be taken into account without the use of such techniques, and thereby to use their resources more effectively.

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RESONANT-REGION, PHASE COMPARISON RADAR FOR DETECTION OF OBJECTS IN CLUTTER(U)

~~(Confidential)~~

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ABSTRACT

~~(Confidential)~~

Based on known characteristics of resonant object scattering and reflections from terrain as functions of frequency, a HF radar suitable for airborne detection and location of trucks, guns and aircraft with dimensions of approximately 20 ft. is being designed and tested at AFCRL. This paper describes design considerations for a radar with 1° or better azimuth and elevation location accuracies without electronic or mechanical scanning or delayed data storage and processing. Results on an S-band phase-comparison radar are presented emphasizing importance of the coherence characteristics of clutter and resonant objects. Some preliminary scattering data obtained by modeling objects in foliage is available. Particular attention is given to antenna design and special phase comparison receivers in connection with a 30 MHz radar.

1. INTRODUCTION

This paper reports initial experiments and studies being conducted at AFCRL to develop an airborne radar system capable of locating ground vehicles, aircraft, and weapon installations against a background of natural vegetation when these objects have structural dimensions from 15-30 ft. Such objects are nearly resonant at an operating frequency of approximately 32 MHz and present a large radar backscattering cross-section even when concealed in foliage or by camouflage techniques. Work to date on a radar capable of providing the range and range-angle resolution needed for Recce strike operations is reported along with relevant experimental and theoretical results on the phase comparison and diffraction principles underlying the radar method.

2. BASIC SCATTERING RELATIONS WHICH MAKE HF AND VHF RADARS ATTRACTIVE FOR DETECTING AND DISTINGUISHING LARGE RESONANT OBJECTS ON THE EARTH'S SURFACE

Metal objects of almost any shape about $\lambda/2$ long scatter essentially like dipoles.[1] It is well known that, σ the radar cross-section for a resonant dipole depends on wavelength approximately proportional to λ^2 or

$$\sigma = k\lambda^2 \quad \text{(dipole or resonant object)}$$

where $k \cong 0.1$ and σ varys relatively slowly with orientation of thick objects and changes in radar polarization. At lower radar frequencies, λ becomes large and the cross-section of a 20 ft. automobile at 30 MHz might be several square meters.

At the same time, objects with a maximum dimension, D, which is small compared to the 10 meter wavelength, such as leaves, branches, rocks, etc., scatter very little because they are in the Rayleigh scattering region characterized by scattering dependence on wavelength

$$\sigma \propto \frac{D^6}{\lambda^4}$$

However, the earth's surface covered with vegetation tends to appear relatively smooth and specular at these frequencies (and lower) and reflects most of the electromagnetic waves in directions other than back toward the airborne radar. The simple equation governing the roughness of the surface is

$$\xi = \frac{D}{\lambda} \sin \theta$$

where ξ is the Rayleigh roughness parameter and θ is the angle of observation from the horizon. A smooth surface, of infinite extent would be wholly specular and would not reflect electromagnetic energy back to the radar except at normal incidence.[2,3,4]

Under ideal conditions then (see Figure 1), very large objects might completely dominate the back scattering from the rough surface of the earth if detected by radars with low frequencies when such objects are $\lambda/2$ long and at low angles of incidence. No doubt the radar display for a 1-2 MHz vertically polarized radar might register only tall buildings, broadcast antenna towers, mountains, etc., if the sensitivity vs. time response were properly controlled.

A first order complication to this simple picture results, however, when we consider the so-called Fresnel coefficients[5,6] which describe the reflection from a lossy plane surface for different plane waves polarized in or transverse to the plane of incidence. For low elevation angles the field strength for horizontal polarization is very small near the surface of the earth. This means that ground vehicles or installations will be weakly illuminated by low flying radars and, therefore both the low objects and clutter from low vegetation will scatter very little. For vertical polarization, a similar effect takes place reducing to a lesser extent the field strengths near the earth's surface and in particular causing a sharp dip in illumination at the polarizing, or Brewster, angle. Thus the smooth lossy earth's surface is anisotropic in its reflection properties. In addition, trees and most natural growth have strong vertical support members increasing the dipole-like backscattering for vertically polarized radars with wavelengths about equal to the vegetation height.

The choice of radar polarization for detection of targets of military interest is not obvious. Horizontal polarization will reduce the masking echoes from trees with vertical dimensions about the same as missile launchers or trucks. However, vehicles near the earth will be more strongly illuminated by vertical than horizontal polarization. It is difficult to determine whether object cross-section will be strong enough relative to background to give a useful amplitude contrast on a radar display. Experience with a properly designed radar to investigate polarization responses, frequency characteristics of echoes, coherence characteristics of echoes, and elevation angle functional dependence will be obtained with both air and ground installations at AFCRL. It is felt that the differential frequency response of clutter vs. resonant metal objects can be exploited by a phase comparison radar operating at about 10 meter wavelengths leading to a simple airborne radar for Recce strike missions.

3. WHY PHASE-COMPARISON RADAR?

There are two principal reasons why phase-comparison radar is well-suited to the needs of a Recce strike airborne radar in the HF band. First, it is difficult to get high-gain narrow-beamwidth antennas on aircraft at 30 MHz. Angular accuracy and resolution for display or guiding a missile from the aircraft for example, must be obtained by means other than producing a diffraction pattern with a physically large phased array or focussing antenna. Second, the contrasting coherence qualities of point and distributed targets are useful in clutter discrimination. The phase-comparison radar performs an auto and cross correlation on the phase of all target returns in connection with the technique used for angle determination within the wide antenna beams.

3.1 Working Principles of the Radar

Although the details of phase-comparison radar design are covered in the references,[7, 10] the basic parameters for a practical HF system are given here. Figure 2 shows a possible dual-yagi 5-element antenna with two phase centers. Each 5-element yagi will produce approximately 70° E-plane beamwidths to 3 dB points or 110° beamwidths to 10 dB levels. Assume a 1 μ sec pulse (center frequency of 32 MHz) is transmitted on antenna Number 1 only. A returning plane wave reflected by a distant point target is also represented on Figure 2.

The plane wave will arrive at antennas Numbers 1 and 2 with equal strength, because their patterns are identical, but retarded at antenna Number 1 relative to antenna Number 2 by

$$kd = k\lambda \sin\theta = \phi \text{ electrical radians}$$

$$k = \frac{2\pi}{\lambda} \text{ or } \phi = 2\pi \sin\theta$$

at $\pm$ 30° E plane angle, at ~ 3 dB level of the antenna patterns ϕ will equal π radians or 180 electrical degrees.

If electrical phase can be measured on received echoes to an accuracy of 3 electrical degrees an E plane bearing angle of $\frac{30^\circ \cdot 3^\circ}{180^\circ} = \frac{1}{2}$ angular degree can be measured.

Direct measurement of the angle of arrival of plane waves by an antenna system through phase measurements is not new. An application to focussed antennas to obtain instantaneous display of angular coordinates in a wide search beam for a wide dynamic range of signal strengths was reported in references 7 and 8. Angular accuracy and resolution do not depend on the usual Rayleigh diffraction limit $\theta_{radians} \approx \frac{\lambda}{D}$, where D is the dimension of the antenna in the plane where θ is measured. Angular accuracy on a phase comparison radar is controlled by signal-to-noise (or clutter) which limits phase measuring accuracy and the phase-in-space diagrams of each antenna pattern. When only one isolated target or a dominant single target due to a resonant object at low frequencies is present, then its angular position can be determined accurately. Aircraft over a smooth sea or land might provide such ideal conditions. Another yagi antenna one wavelength above the transmitting antenna could provide both azimuth and elevation coordinates on a single flying object. Angular resolution of multiple targets in a given range bin depends on the interference or coherence characteristics of targets at different angles of arrival. Incoherent returns, or targets with sufficiently large doppler shifts in frequency, can be resolved in the phase correlation process used to measure angle of arrival. By definition, incoherent scattering due to rapid random motion of sea or foliage will produce reflected pulses with cross-correlation equal to zero. To see how reflected pulses with different doppler frequencies will interfere, consider the following example:

A simple model for phase comparison radar for determining target azimuth is that of a correlation receiver. Consider Figure 3, An aircraft having two omnidirectional antennas separated by a distance d is observing the radar return from a target having an azimuth angle θ_1. For simplicity, the clutter return is represented as coming from a point scatterer at azimuth θ_2. The clutter return is assumed to have arbitrary (but coherent and constant) amplitude and phase with respect to the target return. Further, the target and clutter have a common range R. In Figure 3 the plane waves scattered by the two targets are shown arriving at the antennas. The total signal at each antenna terminal is the sum of the signals due to each plane wave. The signal from one antenna terminal is delayed and multiplied by the signal from the other terminal. The result is integrated to give the system output.

Let us consider the system output in detail. Let S_{ij} be the signal at antenna terminal j due to plane wave i. Consider first the signals due to plane wave 1 or, equivalently, the target return. At antenna 2, $S_{12} = A \cos(\omega_1 t + \psi)$.

where A and ψ are the relative amplitude and phase of the signal from the target compared to the clutter signal. Also at antenna 1,

$$S_{11} = A \text{ Cos } (\omega_1 t + \psi - kd \text{ Sin } \theta_1)$$

where $k = \omega_1/c$ and $kd \sin \theta_1$ represents the phase shift due to the delay of plane wave 1 in arriving at antenna 1.

The signals due to plane wave 2 or, equivalently, the clutter return, will have a different frequency, $\omega_1 + \Delta\omega$, due to the Doppler frequency shift which in turn is due to the different normal components of the aircraft velocity for the two scatterers. Thus at antenna 2

$$S_{22} = \text{Cos } \left[(\omega_1 + \Delta\omega)\, t - \Delta kR\right]$$

where ΔkR accounts for the phase shift due to the additional number of wavelengths in a distance R in the higher frequency wave. At antenna 1

$$S_{21} = \text{Cos } \left[(\omega_1 + \Delta\omega)\, t - (k + \Delta k)\, d \sin \theta_2 - \Delta kR\right]$$

where $kd \sin \theta_2$ is the phase shift due to the delay of plane wave 2 in arriving at antenna 1 and $\Delta\, kd \sin\theta_2$ is the additional delay due to the fact that plane wave 2 is at a higher frequency.

The total signal at antenna 1 is

$$S_1^T(t) = S_{11}(t) + S_{21}(t)$$

and at antenna 2

$$S_2^T(t) = S_{12}(t) + S_{22}(t).$$

The correlation process corresponds mathematically to

$$\phi(\tau) = \frac{1}{T_1} \int_0^{T_1} S_1^T(t - \tau)\, S_2^T(t)\, dt$$

where T_i is the system integration time and $\phi(\tau)$, the correlation, is the system output.

Using the above signals

$$\phi(\tau) = \phi^{(\tau)}_{S_{11}, S_{12}} + \phi^{(\tau)}_{S_{21}, S_{22}} + \phi^{(\tau)}_{S_{11}, S_{22}} + \phi^{(\tau)}_{S_{21}, S_{12}}$$

where

$\phi^{(\tau)}_{S_{11}, S_{12}}$ = target signal autocorrelation taken between antenna terminals

$$= \frac{A^2}{2} \cos(\omega_1 \tau - kd \sin \theta_1)$$

$\phi^{(\tau)}_{S_{21}, S_{22}}$ = clutter signal autocorrelation taken between antenna terminals

$$= \frac{1}{2} \cos \left[(\omega_1 + \Delta\omega)\tau - (k + \Delta k) d \sin \theta_2\right]$$

$$\approx \frac{1}{2} \cos(\omega_1 \tau - kd \sin \theta_2)$$

$\phi^{(\tau)}_{S_{11}, S_{22}}$ = target-clutter cross correlation taken between antenna terminals

$$= \frac{A}{2\Delta\omega T_i} \Big[\sin\left[kd \sin\theta_1 - (\omega_1 + \Delta\omega)\tau - \Delta kR + \Delta\omega T_i - \psi\right] - \sin\left[kd \sin\theta_1 - (\omega_1 + \Delta\omega)\tau - \Delta kR - \psi\right]\Big]$$

$$\approx \frac{A}{2\Delta\omega T_i} \Big[\sin\left[kd \sin\theta_1 - \omega_1 \tau + \Delta\omega T_i - \psi\right] - \sin(kd \sin\theta_1 - \omega_1\tau - \psi)\Big]$$

and $\phi^{(\tau)}_{S_{21}, S_{12}}$ = target-clutter cross correlation taken between antenna terminals

$$= -\frac{A}{2\Delta\omega T_i} \Big[\sin\left[(k + \Delta k) d \sin\theta_2 - \omega_1\tau + \Delta kR - \Delta\omega T_i + \psi\right] - \sin\left[(k + \Delta k) d \sin\theta_2 - \omega_1\tau + \Delta kR + \psi\right]\Big]$$

$$\approx -\frac{A}{2\Delta\omega T_i} \Big[\sin(kd \sin\theta_2 - \omega_1\tau - \Delta\omega T_i + \psi) - \sin(kd \sin\theta_2 - \omega_1\tau + \psi)\Big]$$

It has been assumed here that the integration time T, is large compared to the period of the sum frequency output of the multiplier.

Consider an aircraft flying at 100 meters/second or 194 knots and a target at an azimuth angle, θ_1, of 21° at a range R of 30 kilometers or about 20 miles. Take the separation between the target and the clutter point to be -1°. Thus $\theta_2 = 20^{\circ}$. The separation between the antenna is 1λ or 10 meters. The radar operates at a frequency of 30 MHz and a pulse width of 1 μ sec. Using these parameters the following results are obtained:

$\omega_1 = 1.89 \times 10^8$ as compared with $\Delta\omega = .775$

$kd = 2\pi$ as compared with $\Delta kd = 2.58 \times 10^{-8}$

The other angle which can be ignored $\Delta kR = .775 \times 10^{-4}$

The τ necessary to maximize the first terms of $\Phi(\tau), \Phi(\tau)_{S_{11}, S_{12}}$ would then be

$\tau = 1.293 \times 10^{-8}$ sec

or 12.43 nanosec.

This corresponds to a phase shift at 30 MHz of $\omega_1\tau = 134^{\circ}$. This phase shift is introduced between antenna 1 and the multiplier and will be exactly equal to the phase shift which the plane wave from the target undergoes between the time it impinges upon antenna 1 and the time it impinges upon antenna 2. A measurement of this phase shift thus determines the angle of arrival. A representative radar problem was simulated on an IBM 7040 digital computer. Figure 4b is a plot of the total correlation output vs the delay time τ. The problem parameters are shown on the graph. The τ which maximizes the correlator output will determine target angle according to the expression

$$\theta_{Target} = \sin^{-1} \frac{\tau c}{d}$$

The lower the relative amplitude between the target and the clutter, the more this peak will be spread out and in error since the target-clutter cross-correlation terms will have more of an effect on the total correlation function.

For the case of Figure 4b, the relative amplitude of the target to clutter fields is 3:1 and the separation is 1° of azimuth. The τ which maximizes Φ, is 10.7 nanoseconds which gives a target angle of 19.8°. The target angle entered into the simulation was 20°. Thus it can be seen that with a reasonable target to clutter ratio good resolution is possible with an integration time of 1 μ sec.

If the target to clutter ratio is degraded the target-clutter cross correlation terms must be reduced for good resolution. This is best done by integrating the correlation output for a longer time. Figure 4a is a plot of the crosscorrelation terms and output integration times for the same parameters as the simulation in Figure 3. It can be seen that for integration times on the order of seconds these crosscorrelating terms are reduced because they have a frequency equal to the differential doppler shift between the target and the clutter. It is apparent that the best system would be a side looking one since the relative doppler shifts would be the highest.

The following conclusions may be made concerning the result for $\Phi(\tau)$. When the target signal is large compared to the clutter signal ($A >> 1$) the target autocorrelation term predominates. Further, this term is a maximum for a phase shift τ given by

$$\tau = \frac{d}{c} \sin \theta_2$$

and hence the azimuth angle of the target may be determined. The next largest terms in $\Phi(\tau)$ are the signal-target cross-correlation terms, they being of order A. These terms oscillate at a frequency of $\Delta\omega$, the relative Doppler frequency, whereas the autocorrelation terms are D. C. Notice that for large integration times, T_1, these cross correlation terms can be made small. This is true only as long as $\Delta\omega \neq 0$, that is, there is some angular separation between target and clutter. Target and clutter at the same angular position cannot be distinguished unless the target return is much larger than the clutter return.

An additional interesting aspect occurs when we consider both signals as being due to targets of comparable scattering Amplitude A. The D. C. terms of the correlation function are, neglecting $\Delta\omega\tau$ and Δkd as being small, as follows:

$$\Phi(\tau) = \frac{A^2}{2} (\text{Cos} (\omega_1 \tau - kd \sin\theta_1) + \text{Cos} \quad (\omega_1 + \Delta\omega)\tau - (k \quad \Delta k)d \sin\theta_2 \quad)$$

$$= A^2 \text{ Cos} \quad \frac{kd}{2} (\sin\theta_2 - \sin\theta_1) \quad \text{Cos} \quad \omega_1 \tau - kd \frac{(\sin\theta_1 + \sin\theta_2)}{2}$$

This last result shows that without processing the cross-correlation terms, two scatterers of approximately the same magnitude appear as a single scatterer of amplitude

$$A \sqrt[q]{\left[2 \text{ Cos} \quad \frac{kd}{2} (\sin \theta_1 - \sin \theta_2)\right]}$$

located at an angle

$$\theta = \text{Sin}^{-1} \frac{\text{Sin}\theta_1 \quad \text{Sin}\theta_2}{2}$$

somewhere between θ_1 and θ_2

It would appear, therefore, that this method of radar detection and angular location will work best when the scattering from the resonant metal objects exceed the clutter scattering in a pulse packet or at least in that angular sector of the pulse pocket where reflection is largely coherent and differing little in doppler frequency shift. The autocorrelation performed on reflections from the same targets but received on the two antennas will always map target positions faithfully. However when there is substantial phase correlation on multiple targets in a pulse volume over the time intervals used in integrating the display, blurring or destruction of the angular location data may result. In our design, we are incorporating automatic gain control and time sensitivity control methods to sort out the strong targets of interest before limiting (clipping) and phase comparison is done. In addition, Doppler filters are planned for resolving the 180° ambiguities resulting from bidirectional antennas (dipoles) looking both fore and aft.

Using these design principles, an aircraft carrying 3 dipole or slot antennae might survey 200 azimuth degrees (30 elevation degrees) at 30 MHz and with sufficient power and receiver sensitivity to cover 100-mile radius for aircraft, trucks and munitions of resonant dimensions.

Some results have been reported[7] for a phase comparison radar operating at S-band. Enough experience is available to draw some inferences about the effects of the coherence of multiple targets on target location in the broad elevation beam of this radar. Figures 5a, b and c show how precipitation echoes fill the elevation sector where rain is falling as expected from temporally incoherent (non-interfering) targets. Figure 5a shows a rainstorm approaching the Isle of Shoals (the large dips indicating the Isle of Shoals at zero elevation). Shortly after Figure 5b was taken it shows how the storm has spread and increased in intensity. Note that the weather in the area just to the right of the last isle in the figure is still moderate in intensity. Figure 5c shows all three islands engulfed in rain. Now, the Isles of Shoals are completely inundated by the storm but the three islands are clearly indicated.

The phase comparison antenna (see Figure 6) and receivers being used here allow about 20° of elevation angle to be displayed at any time during 360° azimuth search with ± 2 electrical degree phase accuracy over 80 dB amplitude variation in signals.[8]

The HF resonant region radar will use the same phase comparison receivers as the S-band system but small antenna arrays suitable for airborne installations will be used for initial tests on the ground. Transmitters will be those used in the TRAP-IV 30 MHz and

100 MHz airborne radars for detecting ionized wakes from reentry vehicles. The Ipswich site selected overlooks both the Atlantic ocean and wooded lands in Massachusetts. These ground tests scheduled for summer and fall 1966 are expected to yield information (1) on the azimuth angular accuracy for 40 - 60° beamwidths at approximately 32 MHz using phase comparison techniques, (2) the ability to detect and discriminate automobiles, resonant wires, boats, aircraft, and other near-resonant objects against a background of ground and sea clutter, and (3) the coherence or interference situation between solid objects and moving foliage and sea clutter at both horizontal and vertical polarization. Model aircraft antenna studies will be made preliminary to flying the phase comparison radar. The flying system will have fluctuating phase and amplitude return echoes as a function of azimuth direction and also will permit a wider range of elevation look angles. Because the phase comparison radar is expected to provide the best angular resolution on phase varying targets at elevation angles from 5° - 70° from the horizon the airborne system is expected to have the better performance.

4. SCATTERING CHARACTERISTICS OF METAL OBJECTS AND TERRAIN INFLUENCING RADAR PERFORMANCE

The performance of HF or VHF phase radar for airborne reconnaissance depends critically on the actual radar cross-section of objects on or near the earth's surface in relation to the backscattering from the earth's surface and the natural objects on it. In addition to the primary scattering functions already mentioned, several other known aspects of the problem can not be neglected and will affect the resonant region radar's characteristics. Certain model measurements and calculations have been conducted at AFCRL and a literature search for additional data is being made. The visibility of a dipole-like object in vegetation is of especial interest as a function of radar frequency, polarization, and angle of observation, coherence, motion, and other properties. By visibility we mean relative amplitude of the resonant object's reflection to background echoes (or other measurable distinguishable features of the target such as distinctive polarization or frequency response).

4.1 Radiation Properties of a Dipole Over Lossy Earth

An estimate of the effects of an imperfect earth on the long wavelength scattering from surface vehicles can be made using established results in electromagnetic scattering theory along with a few reasonable assumptions. Consider Figure 8a where a transmitting dipole at an altitude h is illuminating a vehicle and the imperfect earth. The origin of coordinates is taken directly beneath the vehicle at the surface of the earth. The transmitting dipole is assumed to have an arbitrary orientation in space and azimuth and elevation angles given by φ and ψ respectively.

In the frequency region where wavelength is comparable or larger than scatterer physical size, most scatterers will reradiate essentially as if they are dipoles. The equivalent dipole moment is proportional to the incident electric field, the constant of proportionality being the object polarizability. It will be assumed for the purpose of this analysis that the vehicle has only one dimension with a significant polarizability and further, this dimension is parallel to the ground and oriented along the x axis. Thus the vehicle is replaced for the electromagnetics problem by an x-oriented dipole at altitude d and dipole moment αE_x^i [E_x^i is the total incident field due to the transmitting dipole at (o, o, d)].

The scattering problem may now be solved once one knows the total field at any point in space radiated by a dipole. This result is known having been originally derived by Sommerfeld[9] for the vertical dipole and Hörschelmann[10] for the horizontal dipole. We use here the summary given by Norton.[11]

Consider Figure 8b. In the sinusoidal steady state for large scatterer-transmitter separations the scattered field returned to the transmitting dipole consists of the specularly reflected field from the earth directly beneath the transmitter superposed with the scattered field due to the equivalent dipole. The dipole scattered field consists of two terms—one directly radiated, and the other specularly reflected from the earth. Thus the total scattered field is known once the effective dipole moment αE_x^i of the equivalent dipole is known. The field E_x^i is the total field due to the transmitting dipole at the position of the vehicle (θ, 0, d) in the absence of the vehicle but in the presence of the imperfect earth. This may be calculated using Norton's results. The polarizability α was chosen to be that of a slender dipole and was calculated from an integral equation solution for the current distribution on a receiving dipole due to Chen and Liepa.[12]

The results of this analysis are quite complicated and will not be given here. However the results are being investigated numerically and a typical result is shown in Figure 8c. Indicated here is the target signature at 100 MHz of a half wavelength dipole located $\lambda/4$ above the earth. The transmitter is assumed flown at a constant altitude of 100λ in the plane of the target. A constant transmitter power is assumed. The earth corresponds to flat, marshy, densely wooded land with $\epsilon_r = 12$ and $\sigma = 7.5 \times 10^{-3}$ mho/meters.

The ordinate denotes the power scattered by the target arbitrarily normalized to the (constant) power specularly reflected by the earth. The curves show a maximum scattering at elevation angles of between 50° and 90° and tail off for small values of ψ and large values of ψ due to the $1/R^4$ attenuation of the power scattered by the target. Minor resonance effects occur probably due to the interference of the scattering from the target and its image in the earth. The deep nulls at $\psi = \chi + 90°$ are due to the fact that the target is off the end of the transmitting dipole and hence is not illuminated.

In a practical pulse radar system no specularly reflected ground return will be received since the radar receiving system will be turned off when this return arrives at the receiver.

Thus the results of Figure 8c are useful for comparing with the clutter return from a pulse range bin in the vicinity of the target. A sharp reduction in the 16 MHz clutter return has been reported by Steele[3] at elevation angles less than about 13°. It would would appear that from the point of view of maximizing the power return from the target with respect to clutter power the optimum value of ψ for observing the target would be something less than the 50° - 90° predicted by Figure 8c. This effect is presently being considered. Additional results, similar to Figure 8c for various frequency ranges and land conditions are presently available at AFCRL. More quantitative use of the targets cross-section as a function of frequency might be made by designing a variable frequency radar or a multifrequency radar system. Figure 7 illustrates the variations in radar cross-section a radar operating at a given single frequency might measure for discrete objects with different maximum dimensions (in the plane of radar polarization). Using simultaneous emissions on two frequencies certain objects might be bracketed in size by making use of the rather steep Rayleigh, $1/\lambda^4$, cut-off curves. Amplitude comparison of target returns on a low frequency radar could possibly be used to blank out targets appearing on the higher frequency radar. Construction of such a system will certainly be more complicated than a single frequency system and too little is known about terrain response as a function of frequency to be very optimistic about the value of a dual frequency radar in a clutter environment.

Experiments were conducted, using modeling techniques at 3 GHz on resonant objects surrounded by foliage. A forest, Figure 9a was constructed of fresh spruce tree clippings whose heights varied in size from $\lambda/2$ to 4λ with diameters from $\lambda/64$ to $\lambda/16$, and which were contained in an area with dimensions of 3λ by $2\text{-}1/4\lambda$. Resonant objects varying in length from $\lambda/2$ to λ and with diameters of $\lambda/16$ to $\lambda/8$ were placed at different positions within the foliage during the tests. Measurements were made of the backscatter from the foliage alone and then with the resonant objects placed in position using the AFCRL cw radar cross-section measuring facility.

The size of the foliage area used in the measurements was kept small, since it would be more representative of what a radar operating in a pulsed mode would see. Although the foliage cannot be accurately modeled it is felt that the measurements are representative of what can be done to detect objects in clutter. In the tests both horizontal and vertical polarization were used, i.e., for horizontal polarization the electric field was parallel to the earth; and for vertical polarization the electric field was normal to the earth. (See Figures 9b and 9c)

Pattern 1 is the recorded return for the foliage alone and also for the dipole in a horizontal position rotating behind the foliage. It should be noted that for horizontal polarization the returns increase by 3 to 6 dB when the long dimension of the object is normal to the radar.

When the scattering object was placed so that its resonant dimension was in a vertical position and vertical polarization was used, see pattern 2, the return was approximately 2 - 3 dB above the foliage return alone. It should also be noted that the return from the foliage alone is greater by approximately 5 dB for vertical polarization than for horizontal polarization. This can probably be attributed to the polarization being parallel to the length of the clippings in the vertical polarization case.

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APPENDIX A

VEILING EFFECT OF A LAYER OF VEGETATION OVER A LOSSY EARTH

Some measure of the terrain scattering characteristics can be obtained by theoretical consideration of a plane wave incident normally on an absorbing layer with constitutive parameters ϵ_2 and σ_3 representing the jungle sandwiched between two semi-infinite regions representing the lossy ground below and free space above the jungle where the plane wave originates. The relative strength of the incident plane wave compared to the reflected wave is indicative of the veiling effect of the jungle on objects near the earth's surface.

If we derive the ratio $\frac{b_1^o}{b_1}$ of the reflection coefficient of the absorbing layer over a lossy ground compared to the reflection from the same layer over a perfect conducting ground plane, some hint about the visibility of metal reflector in the lossy media can be inferred. If the parameters at our disposal - primarily radar wavelength, λ - are varied in order to maximize $\frac{b_1^o}{b_1}$ we might expect that the target reflections would be enhanced relative to clutter and terrain return. We are essentially looking for the conditions which best match the impedance of free space to the lossy earth by means of the foliage layer.

We can write this ratio assuming normal plane wave incidence as:

$$\frac{b_1^o}{b_1} = \frac{K_2\left[(1-K_2^2)\,i\sin(2w) + 2K_2\right] + K_3\left[(1-K_2^2)\cos(2w) - (1+K_2^2)\right]}{K_2\left[(1-K_2^2)\,i\sin(2w) - 2K_2\right] + K_3\left[(1-K_2^2)\cos(2w) - (1+K_2^2)\right]}$$

$$K_2 = \sqrt{\epsilon_2 + i\frac{2\sigma_2}{f}}\,, \qquad K_3\sqrt{\epsilon_3 + i\frac{2\sigma_3}{f}}$$

(ϵ_3 and σ_3 are earth constants)

$$w = 2\pi\frac{D}{\lambda} \quad K_2 = 2\pi\frac{D}{\lambda}\sqrt{\epsilon_2 + i\frac{2\sigma_2}{f}}$$

(D = height of jungle)
(f = radar frequency)

Even if this formula is relatively simple compared with those of the unaltered model, it does not yield the desired result (the optimum frequency under given circumstances) immediately since all constituents are complex. One conclusion can be drawn, however. Since the sign of $2K_2$ in the first terms is the only difference between numerator and denominator, K_2, plays the decisive role in this problem. $|K|_2$ varies between 1 and ∞. To make the difference drastic, K_2 should be big, but if it becomes too large, going toward ∞

$\frac{b_1^*}{b_1}$ goes again to 1, therefore veiling the metallic objects, since K_2^2 in the first bracket outweighs the term with K_2 alone. This confirms the expectation that an optimum frequency exists. Since, according to best available measurements, ϵ for jungle lies between 1.1 and 2.5, $|K|$ can be enlarged only by lowering the frequency, which suggests radars with larger wavelength. To go too far in this direction will worsen the situation again. Unfortunately the optimum wavelength can not easily be obtained from the formula. To raise K_2 somewhat above ϵ or

$$\epsilon << \frac{\sigma}{w}, \text{ or } w << \frac{\sigma}{\epsilon}, \; \epsilon_3 = 2.5, \; \sigma_3 = 7.5 \times 10^{-3} \text{ mohs/meter}$$

A calculation of $\frac{\sigma}{w}$ using the sparse data reported at the April 1960 URSI Meeting and assuming a frequency of 3×10^9 shows a $\frac{\sigma}{w}$ of 10^{-2}, whereas ϵ is around 1.8. It is therefore a justifiable estimate to ask for a 100 times lower frequency of 3×10^7 or for a wavelength of $\sim$ 10 m.

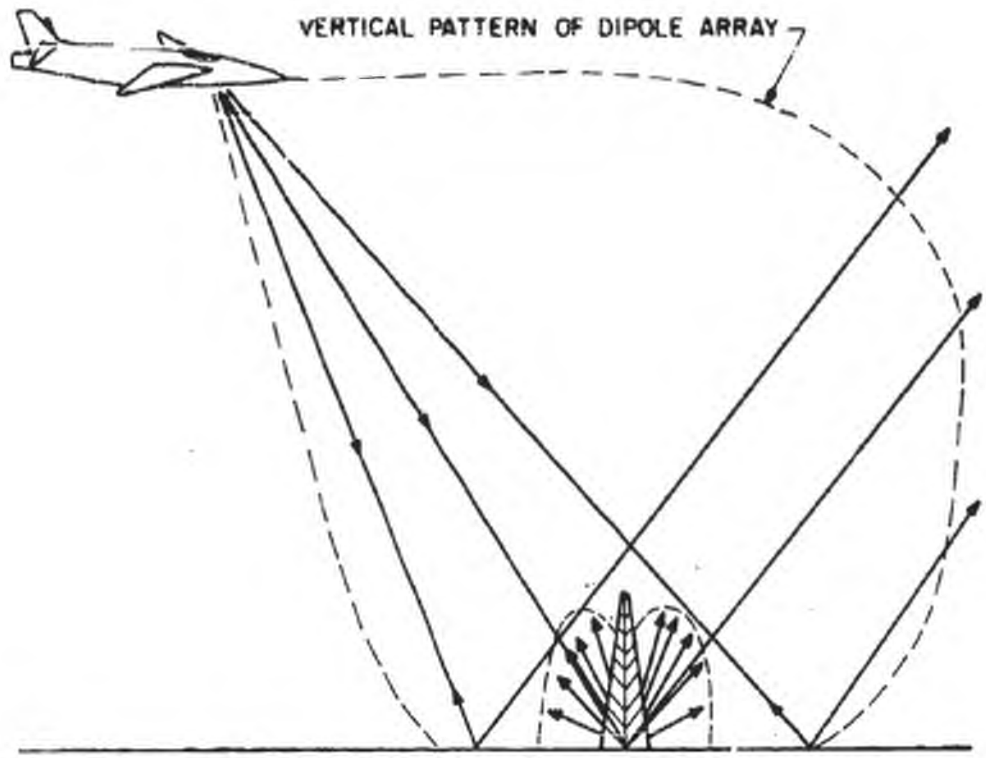

FIG. I SPECULAR SURFACE SCATTERING PHENOMENA COMPARED TO DISCRETE METAL OBJECT SCATTERER (IN RESONANT REGION)

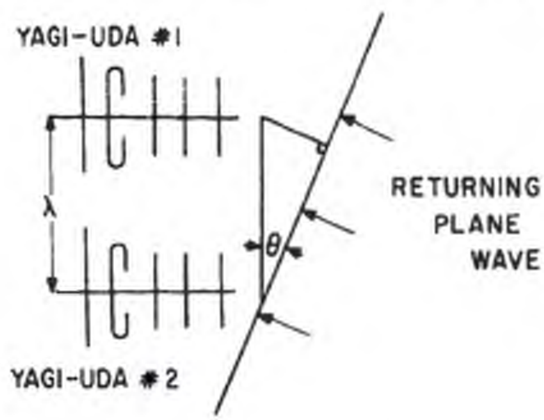

FIG.2 POSSIBLE ANTENNA CONFIGURATION FOR PHASE COMPARISON

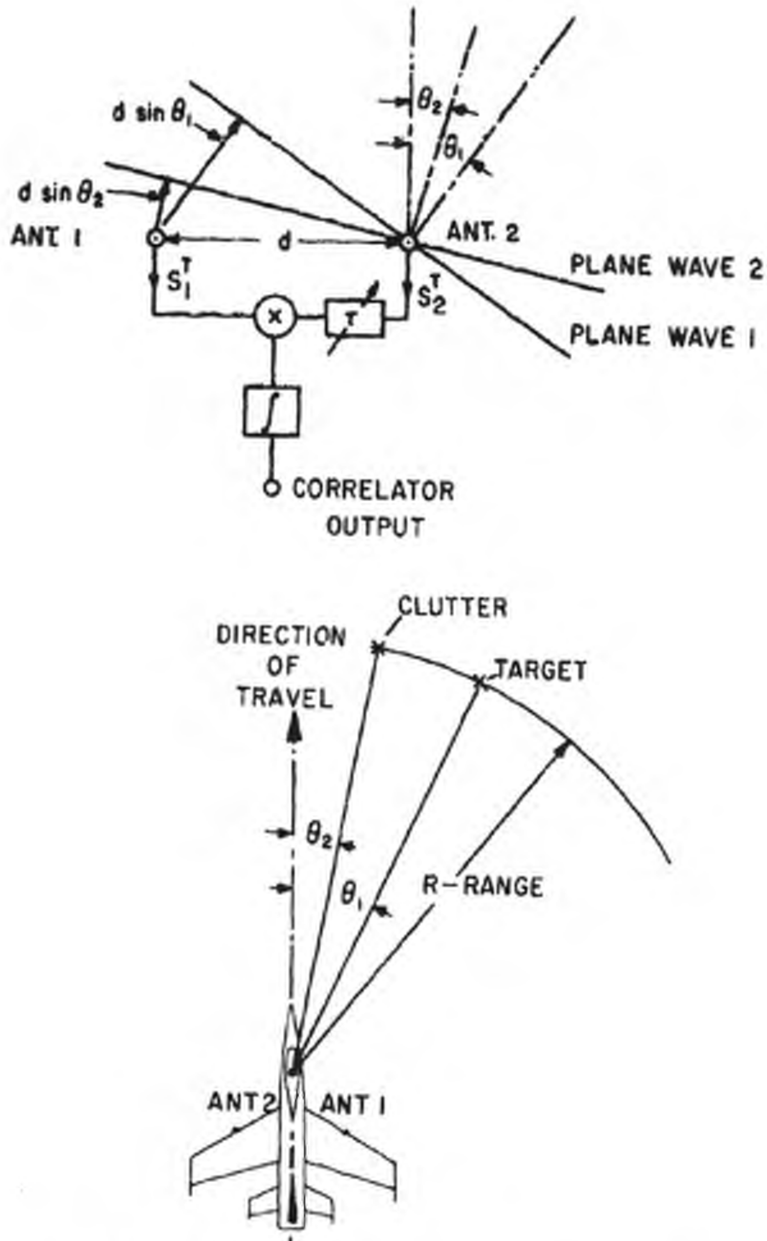

FIG. 3 GEOMETRY OF MOVING AIRBORNE RADAR TO INVESTIGATE DOPPLER FREQUENCY EFFECT ON PHASE CORRELATION OF TARGET ECHOS ON ANGULAR ACCURACY

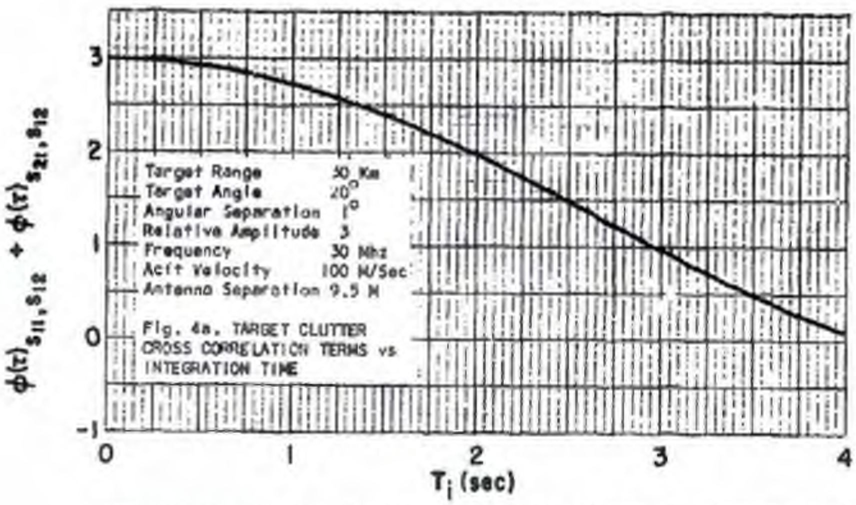

Fig. 4a. TARGET CLUTTER CROSS CORRELATION TERMS vs INTEGRATION TIME

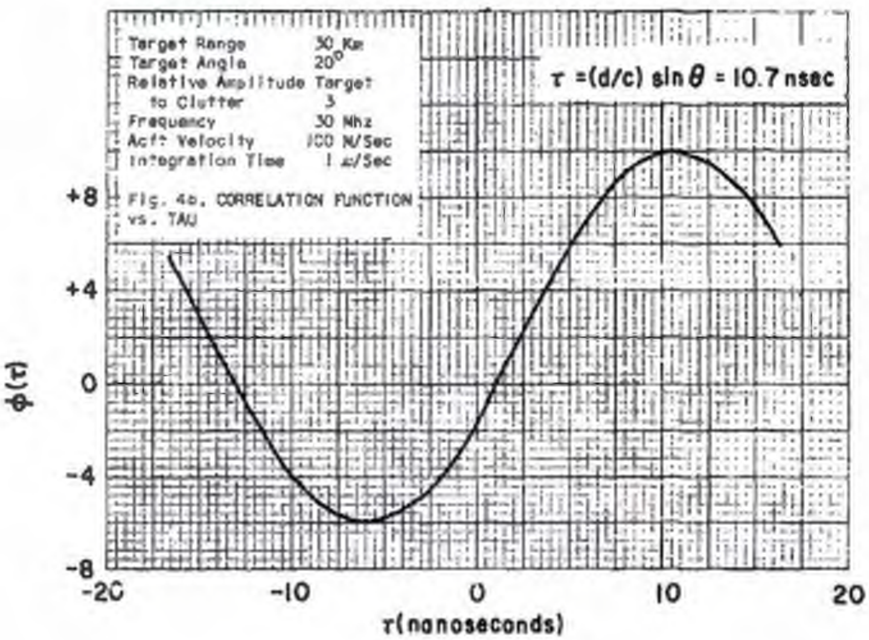

Fig. 4b. CORRELATION FUNCTION vs. TAU

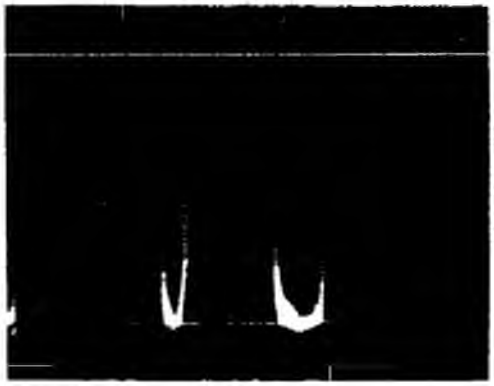

FIG 5a

FIG 5b

FIG 5c

FIGURE 5 ELEVATION PROFILE OF FIXED TARGETS IN RAIN CLUTTER

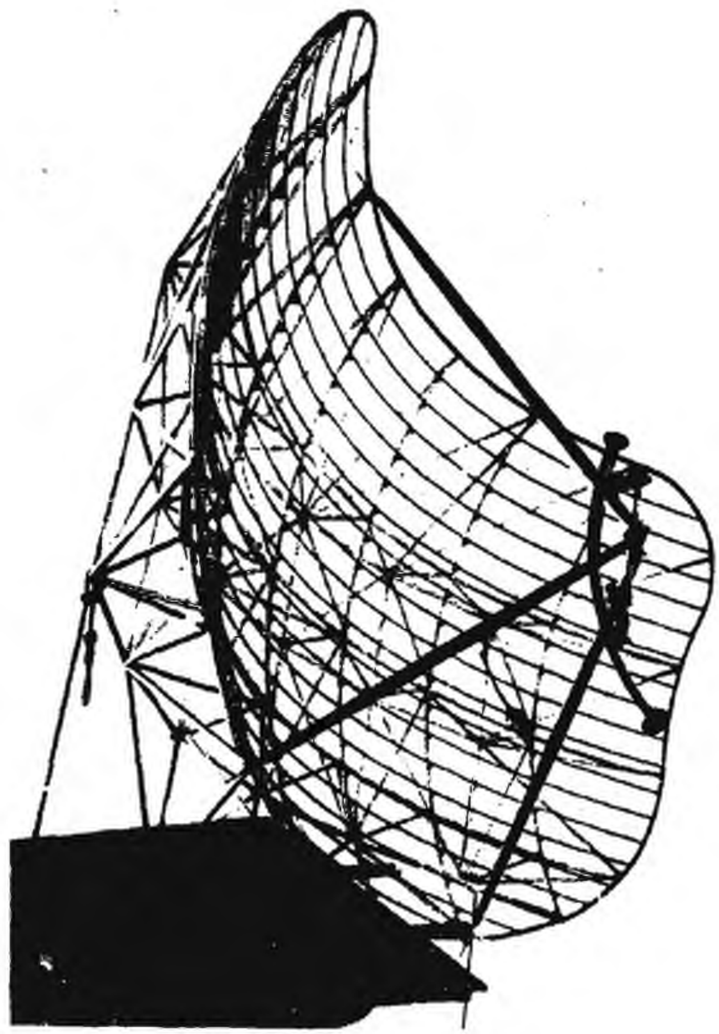

FIGURE 6 S-BAND PHASE COMPARISON RADAR ANTENNA

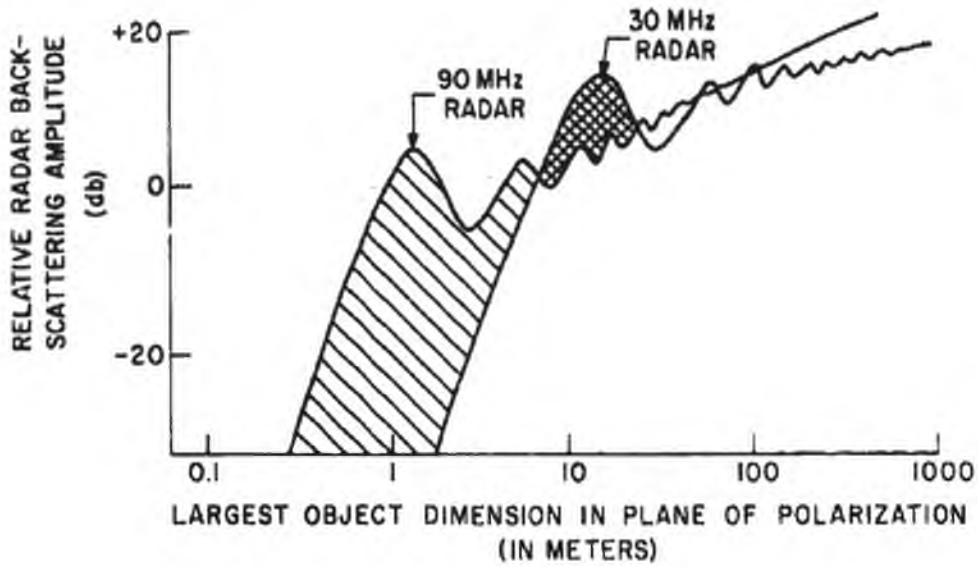

FIG. 7 RADAR BACKSCATTERING AT GIVEN FREQUENCIES AS A FUNCTION OF OBJECT DIMENSIONS

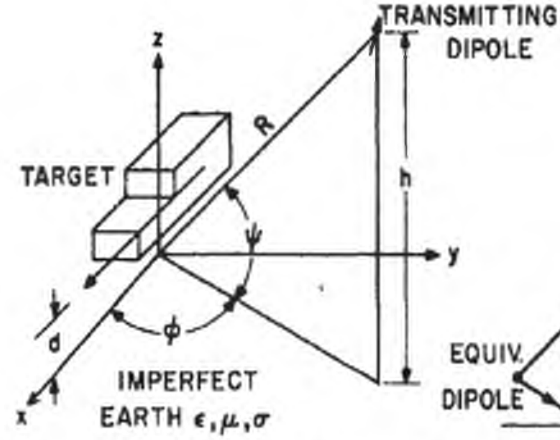

FIG. 8a GEOMETRY FOR CALCULATION OF SCATTERING FROM RESONANT OBJECT OVER AN IMPERFECT EARTH

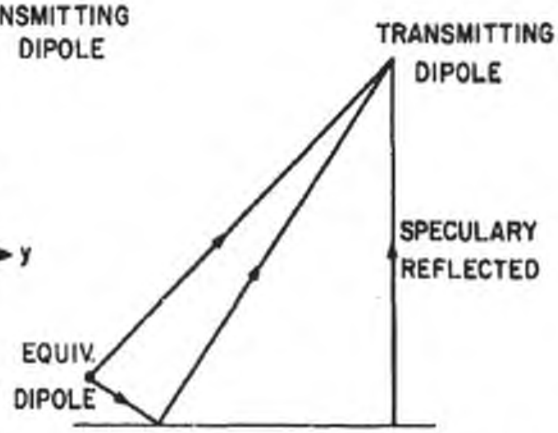

FIG. 8b COMPONENTS OF SCATTERED FIELD

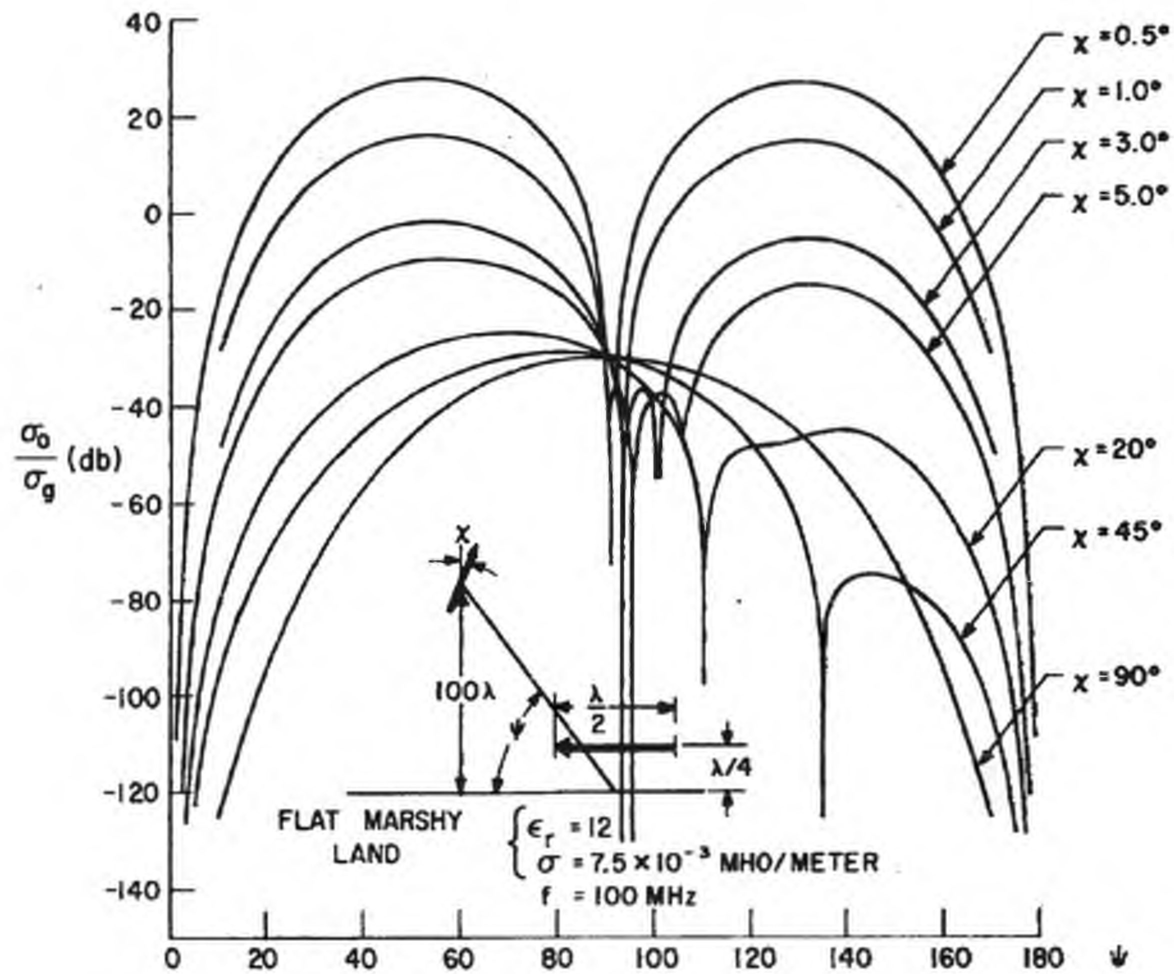

FIG. 8c - TARGET SIGNATURE AT 100 MHz OF A λ/2 DIPOLE LOCATED λ/4 ABOVE A FLAT MARSHY EARTH. TRANSMITTER POLAR ANGLE χ IS THE PARAMETER.

FIGURE 9a A THICK DIPOLE IN FOLIAGE (MODELLED)

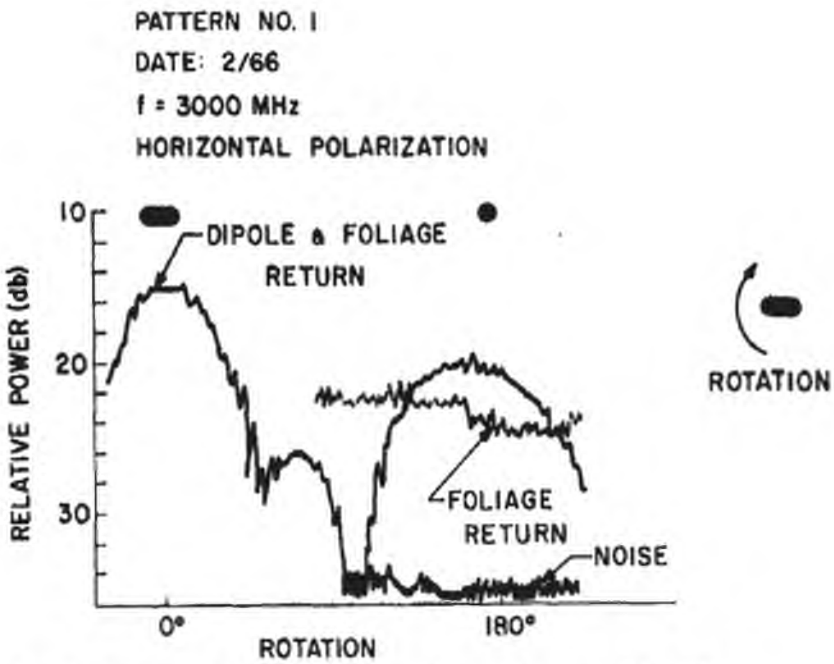

FIG. 9b RELATIVE CROSS SECTION OF DIPOLE IN FOLIAGE

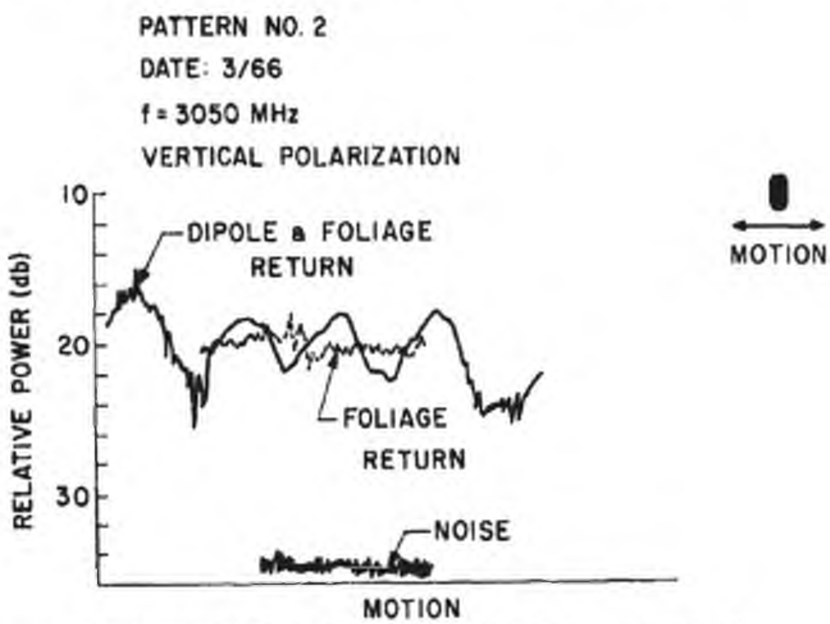

FIG. 9c RELATIVE CROSS SECTION OF DIPOLE IN FOLIAGE

NORMAN L. ROWE

Mr. Rowe, as project engineer in the Reconnaissance Division of the Air Force Avionics Laboratory, is responsible for the technical direction of various programs involving applied research and development of surveillance and reconnaissance techniques in the electro-optical area. Mr. Rowe majored in mathematics at Miami University, Ohio. He served two and one-half years in the Navy during World War II. His career with the Air Force started in 1949, and until 1960 he was involved in the development and applied research of various advanced radar and passive microwave techniques for reconnaissance and surveillance applications. In 1962, after completion of a two-year engineering liaison assignment on the sensor aspects of an advanced aerospace vehicle systems program, Mr. Rowe was reassigned to the Avionics Laboratory.

STATUS AND TRENDS OF LASER LINE SCAN SENSORS FOR NIGHT RECONNAISSANCE (U)

~~(CONFIDENTIAL)~~

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ABSTRACT

(UNCLASSIFIED)

Two concepts of laser line scan equipments for night reconnaissance are discussed and preliminary flight test results of one of the feasibility models is described. A brief history of line scan sensors and a synopsis of closely related efforts to laser line scan technology are included.

STATUS AND TRENDS OF LASER LINE SCAN SENSORS FOR NIGHT RECONNAISSANCE (U)

This paper will discuss two laser line scan night reconnaissance sensor investigations and will present some preliminary results of the flight test evaluation of one of the two feasibility demonstration models.

The laser line scan techniques to be considered involve the use of the properties of a focused c.w. laser, combined with the high sensitivity and low noise characteristics of photo-multipliers in a manner as depicted in FIGURE 1. In this concept, a pencil beam from a c.w. laser is deflected across the flight path to illuminate the ground on a point by point, line by line basis. The reflected energy is detected using a photo-multiplier combined with appropriate optics. The electrical signal generated thereby, is amplified and recorded to create a strip map of the terrain which had been overflown. FIGURE 2 is a block diagram of one such technique.

Before discussing present day equipments, let's briefly review some of the line scan history. Line scan sensors per se are not new. Shortly after World War II, IR line scan devices were developed and are still being advanced. Passive electro-optical line scan equipments using photo-multiplier detectors were flown as early as 1951 and are still being used. In both the IR and Passive E-O case, it is important to note that equipment resolution is determined by the receiver characteristics and that natural illumination or target radiation plays an important role with respect to operating parameters.

In 1962 (b)(6) [redacted] proposed a "Night Aerial Photographic System" based on the laser line scan concept. This was indeed an attractive way to obtain strip map imagery at night, and had the inherent advantage that the sensor resolution is determined by the laser beam divergence rather than the receiver characteristics. Having an active source, equipments using the line scan technique could be used without natural illumination. There was serious question as to feasibility, however. The concept was based on a c.w. light source and, at that time, available c.w. lasers had very low power outputs, typically, tens of milliwatts.

Under ARPA funding, a hastily constructed feasibility demonstration model was built and flown at altitudes ranging from 500 to 3,000 feet. FIGURE 3 is representative of the type of imagery obtained with that equipment. The helium neon laser used, had the tremendous output of about one tenth watt. The beam was collimated to about 0.7 milliradians. These results were encouraging and the technique was proven to be feasible. Incidentally, the obscured band running across the imagery just left of center, was caused by some sort of ground light within the field of view of the receiver. This characteristic indicated a need for a scanned aperture type receiver, if one expected to operate in areas where ground lights might be encountered.

So much for history. Based upon (1) the encouraging results of the NAPS-I equipment and (2) a study directed toward optimization of laser line scan techniques, an advanced version of a line scan equipment has been fabricated and is presently installed in a B-47. The equipment is commonly referred to as the MARK V.

FIGURE 4 is a conceptual view of that equipment. A rotating 8 sided mirror functions as the transmit beam scanner and as a part of a scanned aperture receiver. The illustration on the right hand side of FIGURE 4 is included to further illustrate the scanned receiver concept used. Some of the more pertinent parameters of the MARK V are:

WAVELENGTH	4880 & 5145 angstroms
OUTPUT POWER	1.0 watts
LASER BEAM DIVERGENCE	0.2 milliradians
SCAN ANGLE	60 degrees
SCAN RATE	3200 scans per second (maximum)
V/H RANGE	0.05 to 0.75 (1.5) radians per second
ALTITUDE RANGE	200 to 9,000 feet
RECORD	5 inch film
EFFECTIVE FOCAL LENGTH	4 inches

FIGURE 5 is a view of the principal unit containing the laser, scanner, optics and recorder. Not shown are two control boxes, laser heat exchanger, and a power supply unit.

Preliminary laboratory tests of the unit are encouraging and the unit is scheduled to be flown for the first time during the week of 13 June 1966. FIGURE 6 is an example of imagery obtained with the equipment during laboratory check-out against scale model terrain. The simulated altitude is about 1200 feet.

The basic concept of the MARK V appears to be sound, but it is expected that considerable maintenance will be involved during the flight test in order to keep the equipment operating. The laser in particular is expected to require much attention. It is planned to operate it with a reduced output of about 0.8 watts and even at the lower power, frequent cathode changes are expected to be required. This is due to the particular laser construction used on this device, however, and is not a basic problem to lasers in general. Better lasers are expected to be available shortly.

In the second program now almost completed, the Air Force is flight testing another version of a laser line scan equipment built with Hughes Aircraft IR&D funds. The test bed is again a B-47. FIGURE 7 shows a block diagram of that equipment. This unit differs from the previously described equipment primarily in the receiving and recording areas. Note that the line image formed by the optics is transformed to a circle for readout on an image dissector. The basic parameters of this device are as follows:

WAVELENGTH	4880 & 5145 angstroms
OUTPUT POWER	1.5 watts nominal
LASER BEAM DIVERGENCE	0.5 milliradians
SCAN ANGLE	90 degrees
SCAN RATE	4800 scans per second (maximum)
V/H RANGE	0.5 to 2.5 radian per second
ALTITUDE	500, 1,000, or 1,500 feet
RECORD	5 inch film
EFFECTIVE FOCAL LENGTH	2-1/4 inches

FIGURE 8 is a sample of imagery obtained with the Hughes equipment. The effect of ground lights is still in evidence, but obscuration is limited to only a small localized area.

Both techniques tried thus far, have both good and bad features as one might expect. Briefly, in the Perkin-Elmer case, the scanned receiver involves a high speed rotating mass. The recording technique used by Perkin-Elmer does have certain advantages inasmuch as there is a positive mechanical interlock between the transmit and record beams, however, this is accomplished with considerable optical and electronic complexity.

In the [redacted] case, a scanned receiver aperture is again realized but with high optical losses and electronic complexity. Also, in the Hughes approach, synchronism of the electronic image dissector readout with the transmit scanner beam has proven to be somewhat of a problem. Further, much care must be taken to adequately shield the image dissector from magnetic fields. In the earlier phases of the Hughes flight test program, changes of aircraft heading, with attendant changes in the direction of the earth's magnetic field relative to the aircraft, were enough to cause almost complete misalignment of the dissector readout. Recording from a CRT can be accomplished at low V/H ratios and moderate resolutions, but has limited growth potential for this application.

With regard to the covertness of the argon laser line scan equipment, several visual tests have been made by ground observers as the aircraft was operated overhead. There is a faint glow around the exit window in the aircraft, and the line scans appear as a faint moving band on the ground. Both of these are too weak to be photographed, however. When looking at the aircraft, one sees an instantaneous bright bluish-green flash as the equipment scans the observer's eye. This light is intense enough to be photographed at that instant. While not absolutely undetectable, the equipment is considered to be relatively covert, when compared to flash cartridge or strobe light techniques for photography. Lasers operating in spectral regions other than the visual are also being considered for completely covert operation.

Work is continuing in the line scan area. Under ARPA sponsorship, a laboratory investigation into more advanced laser line scan techniques is just getting underway at Electro-Optical Systems, Inc. This program will investigate such things as multi-spectral techniques to obtain color line scan imagery, and possible approaches for obtaining shadow and moving target information. Also, a separate program to investigate real-time displays for laser line scan imagery is just about to get underway.

In the laser area, various approaches to improve ionized lasers are being investigated and 5 to 10 watts of reliable laser power should be available in the near future. In another program, channel photo-multipliers are being evaluated. These devices will be applicable to line scan sensors in multiple channel receiver configurations.

In conclusion, laser line scan techniques have been proven feasible. Future sensors capable of obtaining strip maps with photographic resolutions of 60 line pairs per millimeter or better are possible, although considerable engineering development is still required.

ACKNOWLEDGEMENT

The author gratefully acknowledges the work and assistance of the many co-workers in the generation of the material presented here-in and in particular, the efforts of [redacted] and [redacted] in the preparation of the graphic material.

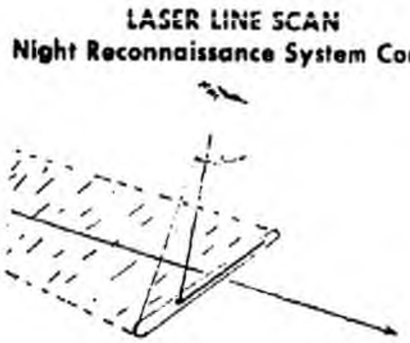

FIGURE 1

FIGURE 2

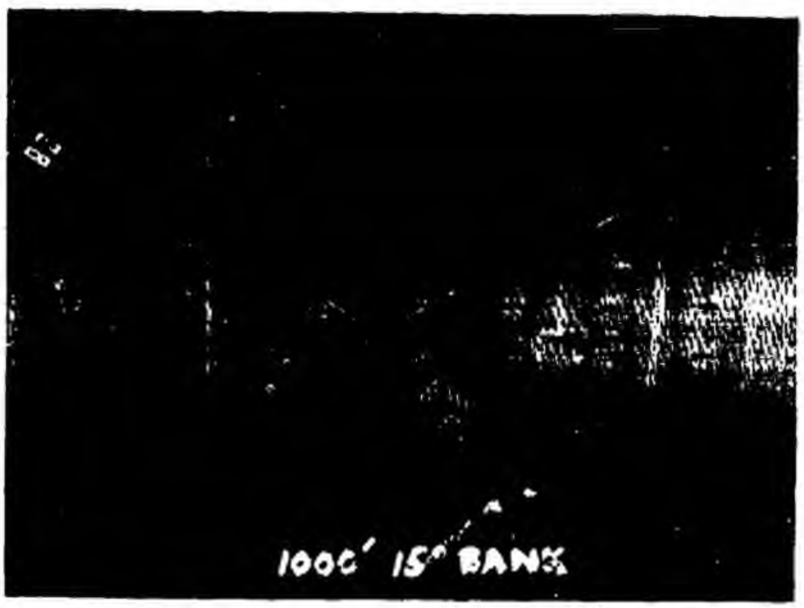

FIGURE 3 NAPS - I IMAGERY

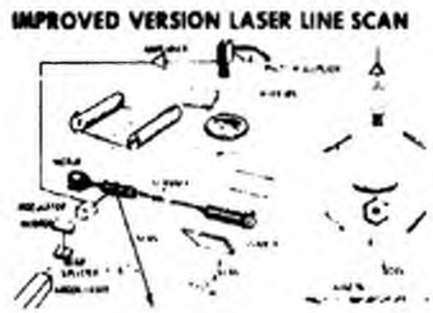

FIGURE 4

FIGURE 5 MARK - V PRINCIPAL UNIT

FIGURE 6 MARK - V IMAGERY (LABORATORY)

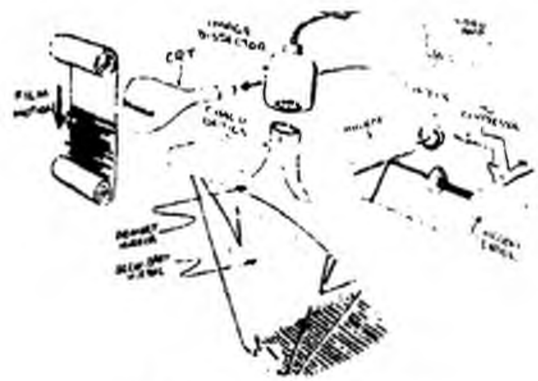

FIGURE 7 HUGHES CONCEPT

FIGURE 8 AIRBORNE IMAGERY (HUGHES)
ALTITUDE - 1100 FEET
SPEED - 175 KNOTS

(b)(6)

[redacted]

A COUNTERINSURGENCY COMMUNICATIONS SIMULATION
(Unclassified)

This research was supported by the Advanced Research Projects Agency (Project AGILE) and was monitored by the U.S. Army Research Office-Durham under Contract DA-31-124-ARO-D-312

[redacted]

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ABSTRACT
(Unclassified)

A computer simulation of communication system operation in a counterinsurgency environment has been developed by Defense Research Corporation. It was designed as a flexible tool for analyzing current and proposed communications systems. Inputs to the simulation include a map, routes for combat units, messages to be sent, and communications equipment characteristics and assignment to units. The simulation outputs are the operational status of communications links over time, link usage, message delays, and message backlogs.

The simulation operates on a time cycle, with an internal clock incremented each time a set of functions has been performed. Units are moved in straight line paths between specified route points and may send a message upon arrival at a point. Messages may also be generated at designated clock times, when other messages are completed, and on a random basis. Messages are processed through preparation, route selection, circuit loading, transmission, and final processing. Messages may be bumped on the basis of precedence. Input data define the communications links between units and the system switching capability. Links having inadequate received power may not be used. Propagation path loss is computed from smooth earth loss, rough earth loss, and vegetation loss. Smooth earth loss includes the space wave, surface wave, and over-the-horizon diffraction. The results of test case computer runs show the differences in link outages and message backlogs as terrain conditions are varied. Further development of the model is in progress.

1. INTRODUCTION

This paper describes a dynamic computer simulation of the performance of communication systems in a counterinsurgency environment. The simulation was developed under contract to the Advanced Research Projects Agency. It was designed to provide a flexible tool for (1) analyzing existing systems for non-obvious faults, (2) cheaply experimenting with system modifications, and (3) planning complete systems for new areas.

During the first year of this project, the basic elements of the model were formulated, programmed, and debugged. Future efforts will be devoted to refining the model and validating it through comparisons with field experience.

Covered in this paper are the structure of the simulation and the results of a test case designed to exercise it.

2. MODEL OPERATION

2.1 GENERAL

The major elements of the simulation are unit movement, message generation, message processing, and communication link status determination. The functioning of each element is governed largely by input data, so the simulation is quite flexible and can be used for a variety of tactical environments and communication systems.

The simulation is played on a map which is described by input data in terms of the earth and vegetation dielectric characteristics and the altitudes at grid line intersections. An arbitrary map may be selected and divided into grid squares of any width consistent with the roughness of the terrain. The map used in the test case is shown in Fig. 1 as an example.

Combat units may also be defined arbitrarily, and presently, up to ten out of a total of a hundred can be required to move during the course of simulation play. Routes for moving units are specified as a sequence of map coordinates, termed aiming points, described by the unit speed, time delay, and message requirement. The unit locations used in the test case are also indicated in Fig. 1.

Specific messages to be generated during play are provided to the simulation. Each message is described by its sender, addressee, type, length, and initiation time. Generation of these messages can occur when game time reaches the message time, when a unit reaches an aiming point, or when another message has been completed. Specification can also be made for messages to be initiated on a random basis.

Once generated, messages are processed through the communications system, which is completely described by input data. Message processing includes route selection, circuit loading and unloading, time delay calculations and determination of completion time. Recycling and bumping on the basis of precedence are also simulated.

The operational status of communication links between units is periodically determined. Smooth-earth, rough-earth, and vegetation path losses are computed, and link status is found by comparing transmitted power minus total loss with receiver sensitivity. Links having inadequate received power cannot be used during message processing.

Outputs of the simulation include a display of the inputs, status of links at regular time intervals, details of completed messages, and various other summaries.

2.2 PROGRAM LOGIC

A flow chart of the simulation logic is shown in Fig. 2. The simulation operates on a time cycle basis; an internal clock, representing current game time, is increased each time a set of simulation functions has been performed.

The simulation begins by reading input data, which include the communications system description (definition of links, link types, message types, etc.), specifications for background message generation, routing data for moving units, specific messages to be initiated during the course of the game, and link terminal equipment characteristics. Various parameters are set at initial values, the internal clock is set to zero, and the input data is printed out.

Next, the present status of each communication link is determined, through a calculation of propagation path loss, and printed out along with the current position of each moving unit. As long as the current game time is less than an input maximum value, the program proceeds with message generation.

To generate time-dependent messages, the program searches the input message list for those with initiation times lying within the current game time interval. Such messages are inserted in a master file for later action by the message processing submodel. Next, units are moved along their assigned routes in straight line path segments. Additional messages may be generated by units arriving at their aiming points. Random messages are then generated on the basis of input data which define average initiation rates.

Next, the message processing subroutines take action on the messages in the master file, calculate delays, and determine which messages are completed during the current time interval. After message processing, the program searches the master file for any messages which may have been completed. Completed messages are printed out, and written on tape for later summarizing by another program. They also may trigger the generation of further messages.

At this point, the game clock is increased by an input quantity which determines the clock cycle, and the program determines whether it is time to test the status of links again. This decision is based on an input parameter which specifies the number of clock cycles between link status checks. The functions from time-dependent message generation through the output of completed messages are executed each clock cycle. If it is now time to test link status, that operation is performed and the logical flow proceeds as described above. Otherwise, the program checks whether all messages in the input message list have been generated and completed and whether all units have arrived at their final aiming points. If both these conditions hold, the program proceeds to the summary output and the run terminates; otherwise, it returns to the generation of time-dependent messages.

The summary output provided at the end of the game consists of final link status and unit positions, the fate of messages designated by the input data as "key messages," the number of times each communication link was inoperative, and a listing of any uncompleted messages.

3. A TEST CASE

In order to insure that the simulation program was operating properly, and to investigate the effect of varying terrain characteristics, a test case was constructed and four basic runs were made. The terrain conditions used in these runs were (1) smooth earth without jungle, (2) smooth earth with jungle, (3) rough earth without jungle, and (4) rough earth with jungle. All other input data were held constant over the four runs.

The simulated tactical units comprised part of a brigade whose organization was patterned after U.S. doctrine. The brigade was assumed to have the mission of driving organized guerrilla forces out of a certain area. A map which included reasonably rough terrain, 11 km by 18 km in size, was chosen and the units were located on the map in a deployment realistic for counterinsurgency operations. Unit separations were somewhat greater than those encountered in conventional warfare, thereby placing greater strain on communications.

Routes were provided for five ground units and one aircraft. One unit was given a sequence of aiming points, speeds, and message requirements which simulated an area sweep temporarily halted by a guerrilla ambush. At the aiming point where the ambush was assumed to occur, a chain of messages was started where the initiation of each message after the first was contingent upon the completion of the previous one. The chain simulated a call for air support passed through several headquarters to an aircraft flying in a search pattern over the area. From the simulation output, the time delay could be seen between the start of the first message in the chain and the completion of the last.

Another simulated unit was defined to be a mechanized cavalry company traveling by road. This unit traversed a large area, and the fraction of the time it was out of range of various other units could be read from the computer output.

Finally, three units were routed to cover most of the map area. From the status of the communication links from a fixed unit to each moving unit, a maximum range contour line could be drawn around the fixed unit for each of the four simulation runs.

The brigade was assigned U.S. Army communications equipment typical of the 1950's. Tactical units were given VHF FM radios and the brigade-to-battalion links were equipped with HF AM sets. Early trial runs determined that VHF equipment was inadequate to reach brigade headquarters because of the large distances and rugged terrain involved.

Multichannel, radio relay links were provided between brigade and two infantry battalions. Five types of radio nets were assigned: command nets (at all levels of command down to platoon), administrative nets (at all levels down to company), an intelligence net and an air support net (between brigade and battalions), and an artillery fire control net. Random background message generation was specified between brigade and battalions, and between one company and its platoons.

When the simulation was run on the Control Data Corporation 3600 computer, the following ratios of game time to real time were attained:

Smooth terrain, no jungle	-	80:1
Hills and mountains, no jungle	-	32:1
Smooth terrain with jungle	-	45:1
Hills and mountains with jungle	-	11:1

The most interesting results from the four simulation runs are comparisons of link outages, message backlogs, and communications coverage area. From summaries output by the simulation program, these comparisons were plotted and are shown in Figs. 3, 4, and 5.

Figure 3 shows the percentage of game time the communications links had adequate received power in each test case run. One notices that in the best case, smooth terrain without jungle, all links worked at least 80% of the time and 95% of the links always worked. In the worst case, hills and mountains with jungle, only 70% of the links worked at all and only 7% were working throughout the simulation run.

In Fig. 4, contours are plotted within which a unit located at A2 was able to communicate with the units which moved throughout the map area. The smooth earth, no jungle contour was actually a circle of 17 km radius. With rough terrain and jungle, the coverage radius varies from 1 km to 2.7 km.

The number of messages in the message file is plotted vs game time in Fig. 5, along with the expected number of generated messages. In the worst case, the message arrival rate exceded the rate of message completions, and the file capacity of 200 messages was reached in about 150 minutes. The response of the system to fluctuations in the message generation rate can be seen in the other three cases. The message backlog was large with smooth terrain and jungle, but there is no significant difference between smooth terrain without jungle and rough terrain without jungle. In the latter case, multi-link routes could usually be found around terrain obstacles.

4. UTILIZATION AND FURTHER DEVELOPMENT

The simulation program transforms input data into output tables and can be used to assess the results of a single set of data, or, by iteration, to optimize the output with respect to a subset of the inputs.

The input data may be divided into (1) communication system descriptors and (2) physical and tactical environment. The communication system is defined by its equipment characteristics (transmitted power, wavelength, polarization, antenna heights and gains, etc.) and the assignment of equipment to units and nets--in short, who may talk to whom and how. The environment consists of a map described by an altitude matrix and vegetation characteristics, unit locations versus time, and the rate of message generation.

The basic simulation outputs are the status of each link versus time, message delays, message backlogs, and link and net usage. From these outputs, one may see directly the bottlenecks in the system--i.e., where more capability (range and capacity) is needed--as well as the areas of equipment under-utilization. The overall message-carrying ability of the system is also clearly defined in terms of message delays, and, if "acceptable" delays have been pre-specified, then the adequacy of the system may be determined. Within this context two applications of the simulation suggest themselves:

(1) Individual Equipment Assessments. The performance of existing and proposed military radio equipments can be quickly and economically ascertained with the aid of the model for a wide variation of terrain characteristics, distances, and antenna heights. Several tests of this nature will be conducted to determine the practical operational range of such equipment in jungle areas. The results of these tests will be correlated (where possible) with actual field test data.

(2) Communications System Assessments. For a fixed physical and tactical environment, the optimum equipment allocation may be found by iteration. This allocation could either (a) optimize system performance at a specified cost, or (b) minimize the cost required to provide adequate service. An alternative procedure would be to examine several environments and find the communication system which either (a) optimizes performance in the most difficult (or the average) environment for a fixed cost, or (b) provides adequate service in all environments at least cost.

A limitation of the present model is the minimum feedback between message processing delays and tactical action. Currently, only two forms of feedback are included: (1) a unit must remain at an aiming point until a specified message has been completed, and (2) some messages are only generated upon the completion of others, thus simulating the passage of information up and down the chain of command.

An expanded model is currently being developed which explicitly plays the insurgent forces. The submodels will of course be quite gross; only the detail necessary to reflect communications will be included. Move rates and attrition will be computed from terrain characteristics and combat action, intelligence will be collected and transmitted, and decisions based on intelligence levels will be made for attack, hold, retreat, commitment of reserves, and assignment of air support. The messages generated automatically will include intelligence reports, unit status reports, and orders. In this way, communication system performance will influence tactical action directly, and the progress of combat activity will provide another criterion for judging system performance.

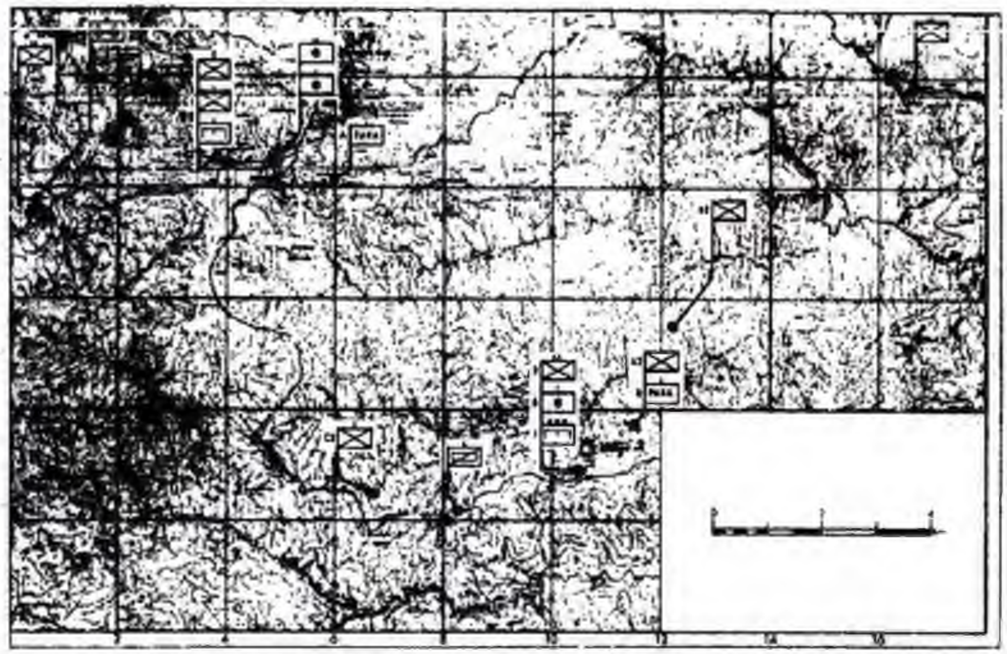

FIGURE 1. SITUATION MAP FOR CI COMMUNICATIONS SIMULATION.

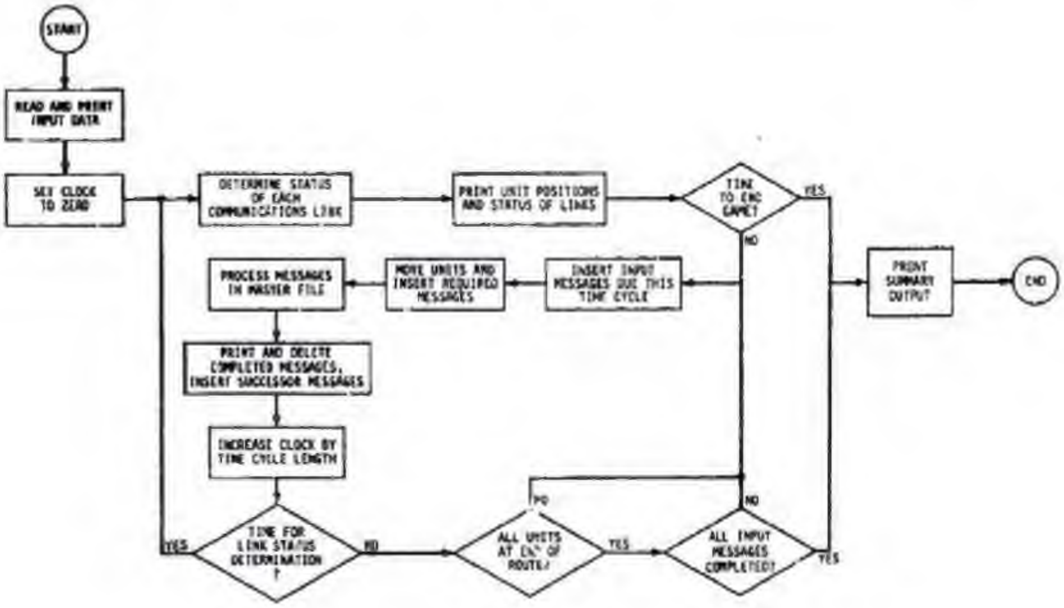

FIGURE 2. SIMULATION LOGIC.

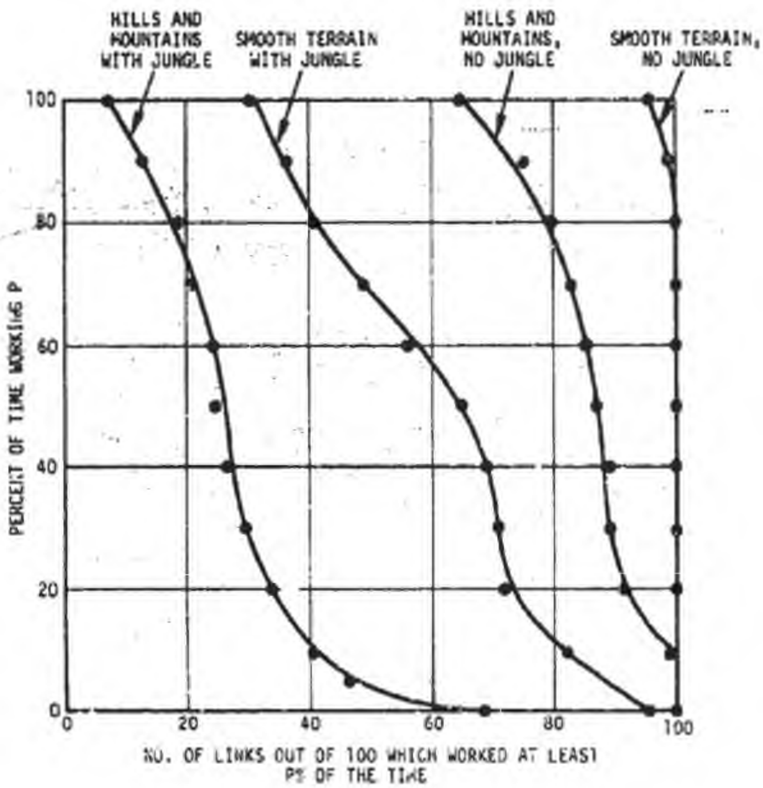

FIGURE 3. LINK PERFORMANCE.

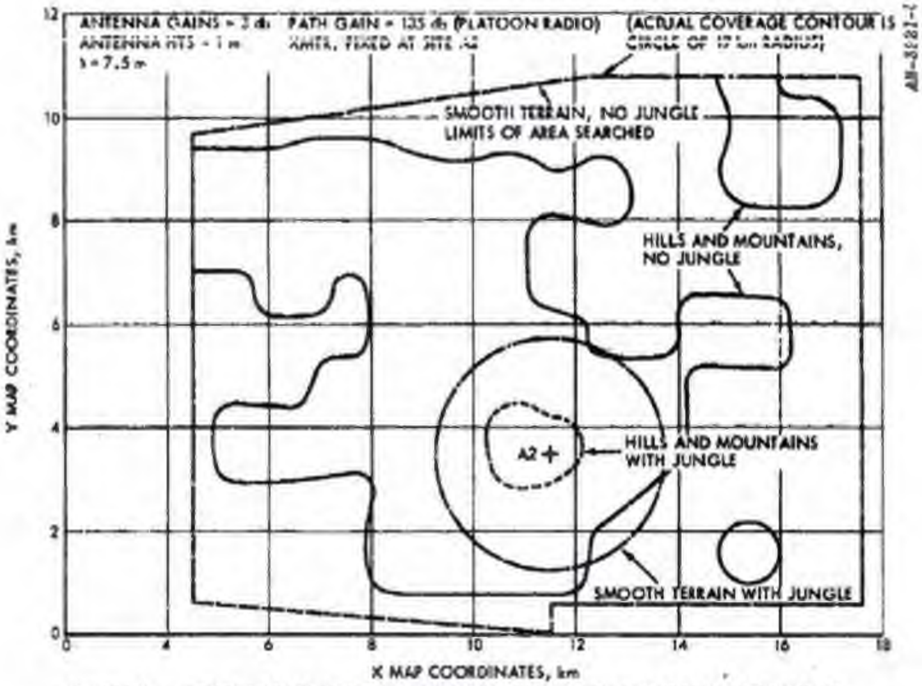

FIGURE 4. COMPANY RADIO COVERAGE CONTOURS FROM CI COMMUNICATIONS SIMULATION.

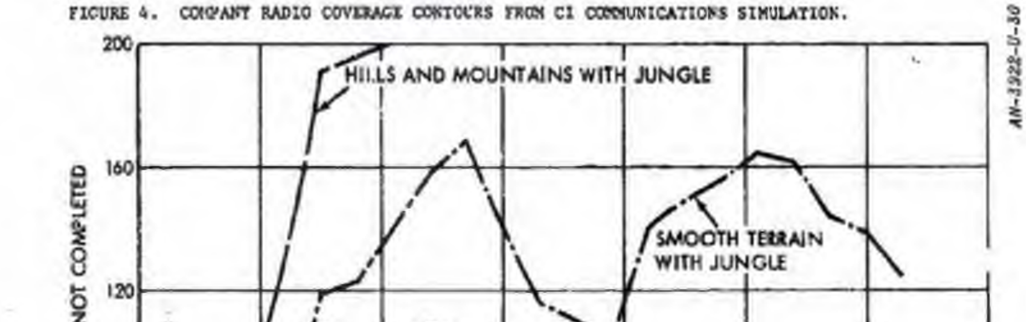

FIGURE 5. MESSAGE BACKLOG SUMMARY FROM CI COMMUNICATIONS SIMULATION

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TOWARD A MODEL OF REVOLUTIONARY POLITICAL RECRUITMENT (U)

(Unclassified)

[redacted]

Abt Associates Inc.
Cambridge, Massachusetts

ABSTRACT
(Unclassified)

A mathematical model of the political recruitment processes in the pre-violent phase of internal revolutionary conflict was developed from guerrilla warfare tactics, social influence theory, and data from small group experiments.

The model specifies optimum size insurgent groups for maximum recruitment rates, criteria for the choice of population groups as recruitment targets, and maximal rates of recruitment. The model implies tactics and strategies to minimize the rate of revolutionary recruitment, and vulnerabilities and countermeasures within the social system. The model offers one approach toward specifying indicators of the susceptibility of social systems to revolution, and describes the dynamics of the recruitment phase in a potentially predictive fashion. The propagandist-to-mass process is compared to the model.

The rates of movement between various groups in the population (revolutionary, non-revolutionary, anti-revolutionary) because of political recruitment are expressed in terms of structural variables.

Assuming the new recruits also recruit, the rate of recruitment increases exponentially with time and with the ratio of the sizes of the social unit to the recruiting group. The overall rates of recruitment are obtained from two forms of breakeven analysis, which show that the revolutionaries may increase their numbers without recruiting the whole recruitable population; and that to maintain the status quo, the government ideological appeal must more than offset the local revolutionary superiority in numbers, and is not a function of population size.

The optimum recruiting group in this case is generally the minimum group size needed to win by recruitment if the persuasivenesses are approximately equal. This optimum group size itself is a function of time, and decreases exponentially as recruitment proceeds.

Model construction can be useful in social science even when the result is a gross simplification of complex human behavior; a major use lies in demonstrating the inadequacies of complicated theories. In clarifying relations between variables and constants, in specifying processes, in defining the known, the recognized unknown, and the utter blanks, models are invaluable. To the extent that they enhance the testability of theories, weigh the significance of a multitude of variables, define the requirements for data, and uncover implicit assumptions, models are tools for progress as well as summation.

An earlier version of this paper was prepared by the author under contract to the Special Operations Research Office of the American University, Washington, D. C.

An attempt to utilize some of these advantages in the study of revolutionary political recruitment has led to a mathematical model. The model was formulated to serve four functions:

1) description of the rates of population movement among various groups (revolutionary, non-revolutionary, and anti-revolutionary) by political recruitment as a function of operational parameters;

2) specification in a form suitable for testing of theoretical notions and empirical data from diverse sources, which might explain the recruitment process itself;

3) to allow mathematical manipulation to calculate the size of the optimal recruiting group, the maximum rate of recruitment, and simple prediction of the outcome from structural and tactical variables; and

4) to compare the relative effectiveness of revolutionary political recruitment with that of government recruitment and mass-media appeals.

For the purposes of model-building the major relevant variables identified in the literature and their levels of operation were conceptualized for recruitment as shown in Figure (1).

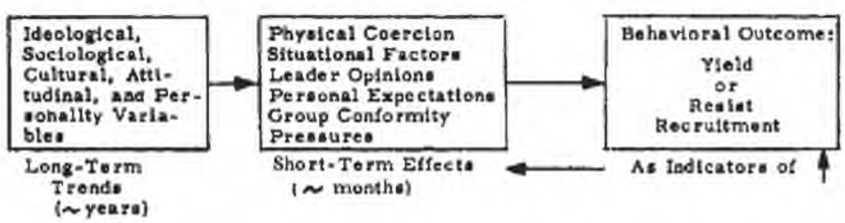

FIGURE 1

POLITICAL RECRUITMENT VARIABLES:

LEVELS OF OPERATION AND TIME OF EFFECTS

In these terms, the model was constructed from "short-term effect" variables in order to maximize indicator sensitivity and to investigate the dynamics of the recruiting process. Thus, it was hoped that the indirect coupling of the long-term variables could be ignored in favor of direct effects.

Considering its late appearance as an indicator of revolutionary conflict, the coercion factor was eliminated as a variable by limiting the scope of the model to the pre-violent phases of internal revolutionary conflict. Because of focus on pre-violent revolutionary conditions, no extensive analysis was made of situational constraints on the attainment of optimal recruiting groups. Nor were quality statements of recruiting targets included in the model. Obviously, these may be significant factors in some recruitment situations, and must be included in any attempts to generalize the model.

THEORETICAL AND EMPIRICAL BASES

The model axioms are derived from the following theoretical statements, empirical generalizations, and logical assumptions:

> The revolutionary political recruitment situation is generally a face-to-face encounter between unanimous recruiting group and a smaller number of potential recruits in an ambiguous and conflictful political climate.

Research in the social psychology of persuasion and influence, particularly in small groups, has found that unified groups exert strong forces for the adoption of the group opinion, almost irrespective of the content of that opinion.* In some experiments, unambiguously false decisions have been elicited from subjects exposed to pressure from a unified group.** Obviously, there is considerable disparity between the consequences for experimental subjects and the consequences for potential recruits in a full-blown revolutionary conflict. The life and death scale does not seem so serious an objection, however, from the viewpoint of the potential recruit, for whom either side presents the risk of death. If the revolutionaries are successful, under the "If you aren't with them, you're against them" rule of thumb, remaining neutral may be more dangerous than active participation for either side. The unambiguous decisions required in the experimental case are entirely lacking in the revolutionary situation, which should greatly aid recruitment.***

A recent review of the literature summarized experimental findings as follows:

> Individuals appear to be more susceptible to conformity pressures when expressing social opinions and ideological attitudes and when dealing with abstractions that are not rooted in concrete experience than when they are dealing with factual materials with which they are well acquainted or with personal preferences. Regardless of the materials being dealt with, however, increases in susceptibility appear when an individual is uncertain as to his own beliefs, uninformed with respect to the facts of the situation, or when objective cues that could aid him in maintaining his orientation to the situation are reduced or eliminated. Then he distrusts himself and he can be influenced by others.
>
> Tendencies toward conformity and conversion are heightened when an individual is with others, at least three in number, where the others are in uniform agreement and where their reactions represent only small departures from the position believed by the individual to represent his own convictions. If the others present are personally acquainted with the individual, and are persons whom he respects, additional conformity pressures are created. Furthermore, if the individual is required to act in his own name and the situation is such that he is not required to commit himself to a position prior to the period when the conformity pressure is applied, greater influence in the conformity direction can be exercised.****

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*See References, 1, 2, 3.

**See References, 4, 5, 6.

***See References, 3.

****See References, 7.

These content effects are further enhanced by the necessarily face-to-face nature of revolutionary political recruitment, which has been shown to be many times more effective than appeals through a propagandist-to-mass relation.*

Finally, the requirement for action, as opposed to judgment in the experimental situation, appears to allow for inaction as a potential response. It is assumed here that this only increases the time requirement for recruitment and is mitigated by the perception of the outcome as a "Compromise".**

Initial public conformity behavior (i.e., yielding) leads to attitude change through dissonance-reducing mechanisms.

Public commitment to a new position adopted under moderate force has been shown to lead to internal reorganization of the individual attitude structure such as seeking out supporting evidence for the new position.*** Further, the act of yielding in the recruiting situation, especially if perceived as an unforced "compromise", should serve as an isolating mechanism from normal primary group contacts. This conformity effect should be further enhanced if the recruiting agents are from within the social unit.**** Finally, experiments have shown that influence effects publicly resisted on one item will generalize privately to a subsequent item.*****

In the case of a recruiting group versus a social unit (more than one person), the dynamics of the exchange of influence and opinions may be modeled on the exchange of fire in warfare. Further, if the guerrilla tactic of dividing opponents to attain a local superiority is successful, the same tactic in recruiting should be also.

Since the social influence experiments have shown that attempting to influence more than one naive subject has markedly less effect, as a first approximation, the situation is viewed as an exchange of influence attempts between the groups, and of attempts to increase the unanimity effect. This situation may be expressed mathematically by the Lanchester Square Law:

$$\frac{dN}{dt} = -AM; \quad \frac{dM}{dt} = -BN \qquad (1)$$

where $\frac{dN}{dt}$ and $\frac{dM}{dt}$ represent the rate of change of the size of two forces fighting one another, each proportional to the strength of the opposing force, and A and B are the efficiencies of forces M and N. The Lanchester Square Law shows that a small force can defeat a large force by splitting it into units individually inferior and defeating these in detail. The same relationship may also show that a small revolutionary faction may recruit much of a large anti- or non-revolutionary population, by isolating some of the population in groups small enough to "defeat" forensically (i.e., recruit).******

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*See References, 8.

**See References, 2, 3, 4, 5.

***See References, 9, 10.

****See References, 8.

*****See References, 11.

******See References, 12.

This relationship may be expressed mathematically by

$$\frac{dN}{dt} = AMN/n ; \frac{dM}{dt} = BNM/m \qquad (II)$$

where n and m are the sizes of the small groups into which N and M have been divided respectively.*

If data show the model to be valid, this description of group influence processes will be the major relation supported.

The model bases reviewed above tacitly imply two points of major qualitative change in the nature of the revolutionary political recruitment process: first, the transition from an individual to a group recruitment target; and second, the transition from a face-to-face recruiter-recruited relationship to a recruiter-to-mass relationship. These changes have been incorporated in the model development and will be treated as follows:

A. Face-to-face recruitment of an individual by a revolutionary group
   1. Indigenous revolutionaries (Case 1.1)
   2. Exogenous revolutionaries (Case 1.2)
   3. Competing revolutionaries (Case 1.3) and anti-revolutionaries

B. Face-to-face recruitment of a group by a revolutionary group
   1. Non-revolutionary target population (Case 2.1)
   2. Non-revolutionary target population with competing revolutionaries and anti-revolutionaries (Case 2.2)
   3. Revolutionaries and anti-revolutionaries recruiting from each other via a non-revolutionary transition phase. (Case 2.3)

C. Anti-revolutionary recruitment in a mass situation versus face-to-face revolutionary recruitment (Case 3.1)

The tactical relationships under investigation may be visualized as shown in Figure II. Thus, membership in a revolutionary or anti-revolutionary group may be independent of social structure grouping.

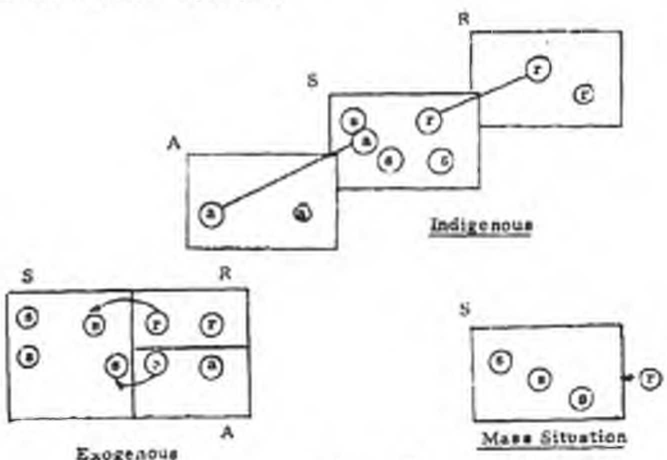

FIGURE II
TACTICAL AGGREGATIONS

* See References, 12.

THE REVOLUTIONARY POLITICAL RECRUITMENT MODEL

The variables are: the number of people in various groups of population (revolutionary, non-revolutionary, anti-revolutionary); the size of the isolable social units; the persuasiveness or ideological appeal of these groups for each other; and time. The following symbols will be employed:

R	=	The number of revolutionaries at any time
R_o	=	The number of revolutionaries at initial time (t=o)
r	=	The number of revolutionaries in the recruiting group
r_o	=	The number of revolutionaries in the optimum recruiting group
A	=	The number of anti-revolutionaries at any time
A_o	=	The number of anti-revolutionaries in initial time
a	=	The number of anti-revolutionaries in the anti-recruiting group
a_{opt}	=	The number of anti-revolutionaries in the optimum anti-recruiting group
N	=	The number of non-revolutionaries at any time
N_o	=	The number of non-revolutionaries at initial time
n	=	The number of non-revolutionaries in the non-revolutionary group
s	=	The easiest social unit to isolate in number of members
S	=	The social unit made up of s's if any exist
p	=	The persuasiveness of the groups in units of men/min/man of the revolutionaries
P	=	The persuasiveness of the groups in units of men/min/man of the non-revolutionaries
q	=	The persuasiveness of the groups in units of men/min/man of the anti-revolutionaries
i	=	The ideological appeal of the non-revolutionaries in units of men/min
I	=	The ideological appeal of the revolutionaries in units of men/min
t	=	The time elapsed since the beginning of the recruiting phase ($t=o$; $R=R_o$)
t_p	=	The time to persuade <u>s</u> by <u>r</u> or <u>s</u> by <u>a</u>
t_w	=	The time required for either complete polarization of society into partisan camps, or for one side to win by recruitment alone
be	=	Subscript indicating "calculated from breakeven analysis"
f( )	=	Symbol indicating "function of"
.g.	=	Symbol indicating "greater than"
.l.	=	Symbol indicating "less than"

The membership of the various groups is determined solely by what fraction of the population will recruit actively for, against, or not at all for, the revolutionary cause.

<u>General Assumptions:</u>

1. Revolutionaries can choose time, place, and circumstances of recruitment.
2. Superior numbers will after some time persuade.
3. Persuaded s will become members of r.
4. Revolutionaries can maintain the situation for t_p.

Case 1.1

For an S divided into R's and N's where $s=1$, the experiments of Asch provide valuable empirical data on which to base the model.* His task was the unambiguous judgment of the length of lines relative to other lines. In a group situation where the successive judgments were made aloud, trials on which the group made the wrong choice prior to judgment by the experimental individual resulted in 33% mistakes by the subject compared to a control person's 2%. Further, 4/5 of the experimental subjects made one or more mistakes. Ratios of r/s greater than 3/1 led to no significant increase in the percent yielding to group pressures (up to 9/1 reported).

In this case, the revolutionaries are assumed indigenous to S and will not be guarded against, prior to contact with the potential recruit. Further, in the actual recruting situation the potential recruit is not exposed to any counterpropaganda or external support.

Assumptions:

1. R in S.
2. Any A in S will not be recruited since partisanship studies suggest that this will be difficult, if not impossible.
3. For $s=1$, $r_o = 3$, as in Asch; r .g. 3 is not further aid in recruitment.
4. Recruitable proportion is given by the fraction who yield in the Asch situation given sufficient time = 4/5.
5. Non-recruitable proportion is given by the Asch non-yielders for any t_p = 1/5.
6. Any other psychological differences from the Asch situation are negligible.
7. $t_p = f(I, i)$ since the tactics are defined, $\neq f(r, s)$.**

The convertible population is defined then as $= 4/5\ (N_o - A_o)$ and since $r_o = 3$ is both the minimum and the optimum, the maximum rate

$$-dN/dt = dR/dt = 4/5(R/3)\ (1/t_p) \qquad (1)$$

shows R to increase exponentially as

$$R = R_o \exp (4/15)(t/t_p) \qquad (2)$$

Since $s = 1$,

$$t = s/I = 1/I;\ \text{not a } f(r) \qquad (3)$$

Which, when substituted into (2), gives

$$R = R_o \exp (4/15)(It) \qquad (4)$$

Integration of (1) using the convertible population to define the end of the recruitment phase (t_w), when the population becomes essentially polarized (3 groups) gives

$$t_w - (4/15)\ I\ (\ln(1+4/5\ (N_o - A_o)/R)) \qquad (5)$$

While the numbers used here are certainly fictitious, the general form of the solution probably describes this recruitment process. The most likely problem would appear to be the likelihood that t_p is indeed an $f(r)$. Maximum rate also depends on the form of t_p over the

*See References, 4, 5.

**Persuasiveness is defined as a function of ideological appeal (itself a function of the long-term variables) and tactics (=disposition of men and social unit isolability).

$\therefore$ P = i + tactics

whole population; either one would expect an exponentially increasing function as the easiest persuade first, or almost a constant, since once a gives his assent to anything his recruitment follows fast. If the former should be true, the maximum rate would probably obtain without recruiting all those who theoretically could be. Further, under the assumptions here, it makes no difference to the rate whether recruitment concentrates on one S after another or as many S's as possible. The need to consolidate an S against government reprisals would probably modify this result in practice. Counter-measures are obviously very difficult unless the government is willing to recruit in the same manner, which suggests maintaining more than one representative in the appropriate social unit S and in this case three or more would be best. Government propaganda has no effect except to increase t_p.

Case 1.2

If the revolutionaries are external to S, and the members are militant N's or A's a further countermeasure is available in the form of a "buddy" system. With no s allowed to be alone with r, the initial phase of the recruitment becomes that of case 2. In this case, the maximum rate is attained by recruiting a minimum group for each S and allowing this cadre to recruit the rest. This strategy benefits from both the greater persuasiveness of the indigenous members and avoiding a suspicion-creating label.

Case 1.3

If the anti-revolutionaries adopt the same strategy, the Lanchester equations describe the process

$$-dA/dt = dR/dt = R/15RI - R/15Ai \qquad (6)$$

and the breakeven condition implies, for R to win,

$$IR_o^2 \text{ .g. } iA_o^2 \qquad (7)$$

which results in a polarized society (R, A, N). Using the initial rates and assuming that at the outset both groups try to recruit the non-revolutionary rather than each other, the following fractions describe the polarized condition,

$$\frac{R_o \exp I}{A_o \exp i} \ (4/5N_o), \ \frac{A_o \exp i}{R_o \exp I} \ (4/5N_o), \ N_o/5 \qquad (8)$$

from which point R's and A's must try to recruit each other. The result suggests, however, both that no one group will recruit all the people and the society will always have a hard-core to recruit the easily persuaded as soon as the dominant group relaxes, which argues strangely that "other than a political solution must be found." However, these results are much more favorable to the government cause, which should hold more resources and people at some initial stage, if alerted and active soon enough. The revolutionaries are favored with the prediction that given sufficient ideological appeal they can overcome any initial handicap (see a later section on this constant).

Case 2.1

When the easily isolable social unit is larger than two in number, the available data suggest that the results obtained above no longer apply. Asch shows that with two experimental subjects the group no longer causes a significant number of misjudgments even when the subjects are out-numbered as badly or worse than in the individual case. Numerous studies, especially those on the voting behavior of cross-pressured individuals in a context, not necessarily unified, of strong partisan opinion, support the notion of numbers at some point producing persuasion [*]. In the voting case, however, the results were often inactivity and the stakes were not life and death. These results and the lack of better alternatives make the rather crude psychology of the Lanchester equations, where messages/min are analogous to firepower, worth pursuing (compare with Case 1.1 in form).

In this case, s is greater than two, and the society is initially fractionated into two groups R and N (or A). N outnumbers R, who adopts the strategy suggested by the Lanchester equations where the opponent is locally outnumbered. Both sides recruit in small groups face-to-face with the recruited.

Assumptions:

1. s small enough that r+s is still a face-to-face situation, or else s can be broken into face-to-face groups with the same r/s ratio.

2. N is naturally divided into groups n=s, which R recruits sequentially in groups of r.

3. Breakeven in recruitment defines a dynamic equilibrium where losses due to recruitment are proportional to initial strength and neither side succeeds in attaining or maintaining a superior fraction of the population. (Note: this allows an inferior to increase its numbers even though it will not win the recruitment struggle; also there exists another kind of breakeven for recruitment, in which the initial fractions are maintained--the condition for this is independent of the initial force strength pr=Ps.)

4. t_p=f (ideological appeal and tactics=persuasiveness).

5. The non-revolutionaries have an appeal for the R's; $P \neq o$.

6. Definition of membership stated in Case 1.1 holds here.

Deitchman's article shows the kind of relationship envisaged here, where the size of r necessary to win is a function of the size of the groups, the initial strengths, and the relative persuasiveness of the two sides.[**] Examination shows that in contrast to the Lanchester case the numbers of the two sides vary as exponentials of exponentials as a result of the serial nature of recruitment, and since t_p=f(r). Thus the optimum recruiting group size is itself a function of time.

The descriptive equation in this case is

$$-dN/dt=dR/dt=pRn/s - PRN/r \qquad (9)$$

and since during any session, the men lost politically by the winning side are regained, the overall relation is

$$-dN/dt=dR/dt=Rs/rt_p \qquad (10)$$

and

$$R=R_o \exp(st/rt_p) \qquad (11)$$

[*] See References, 8, 13.

[**] See References, 12.

Breakeven:

(no change): $pr = Ps$ (12)

(no winner): $prR_o = PN_o s$ (13)

From N's point of view:

$$\ln(N/N_o) = (P/r-p/s)(s/rt_p)\exp(s/rt_p)t \quad (14)$$

Note: the direction of net gain is indicated by the sign of the first term,

which is a decreasing function of e^t if r^t greater than the breakeven value. Optimization of r in a general fashion requires integration of (14) within the limits of t_p, substitution from (11), differentiation with respect to t, and then with respect to r, and results in a cubic equation of 25 terms whose coefficients are permutations of p, s, R_o, N_o, t, and exp(s/r) over several powers of s. Examination of (9) indicates what is required: the rate is expressed as a difference of two hyperbolic curves, which for an R increase implies that the 1/r curve lies closer to the axis. The optimum r will be the one that satisfies the appropriate breakeven condition and maximizes the distance between the curves. If $t_p \neq f(r)$, the smallest r greater than PNs/pR is the optimum. Equation (10) suggests a more complicated optimization function if $t_p = f(1/r)$. Another line of reasoning suggests that the smallest r sufficient towin is the optimum. The models of attitude change derived from dissonance theory show that the most change occurs with the minimum force sufficient to change at all (assumes that becoming a recruiter requires considerable change). More consideration of this problem will follow later.

Another approach to an analytic solution may be obtained by assuming that the processes described by the Lanchester equation also apply within the group. Thus, one can rederive (14) for the situation within the group (limits of t_p and s, r constant), substitute for t_p and obtain

$$dR/dt = (R_o/(Ps-pr))(1/1-e^{s/r})\exp(s/(Ps-pr)(1/(1-e^{s/r}))) \quad (15)$$

Differentiation with respect to r and setting equal to zero allows maximization yielding.

$$(s/r)\exp(s/r) = p/P \quad (16)$$

Numerical analysis under constraint of r_o .g. r_{be} (no change): p = P shows that the maximum is unattainable since the curves do not cross and $r = r_{be}+1$. (increasing logarithmic and decreasing hyperbolic). For p and P variable and only requiring that r .g. s and pr .g. Ps, the optimum is given by

$$r_o = s/\ln(pr/Ps) \quad (17)$$

Assuming that this solution closely approximates the general solution, the optimum for a winner is given by

$$r_o = s/\ln(prR_o/PN_o s) \quad (18)$$

which with r .g. s, N .g. R, and sufficiently favorable ratios of persuasiveness in the favor of the revolutionaries has a maximum which satisfies the breakeven condition(no winner). The ratios of persuasiveness required to allow maximization seem very unlikely since the tactics of both sides are the same and should over-ride the ideological appeal under the assumptions of the model. Generally, the $r_o = r_{be}+1$.

An interesting consequence of r as a function of t is that the optimum group size for recruitment changes during the course of the recruitment phase. Substituting R and N for N and R in (13),

$$r = r_o (P/p)(Ns/R) = r_o (1/p)(N_o s/R_o)(1-e^{st/r_o})/(1+e^{st/r_o}) \tag{19}$$

which decreases with time.

Finally, the maximum theoretical rate with r defined by (19) is

$$dR/dt = (sR_o/rt)\exp(st/rt_p) \tag{20}$$

Case 2.2

If the population is divided into three groups (R, A, N) with both R and A recruiting from N according to 2.1, the usefulness of the countermeasure for the gove nment can be seen. Assume R and A do not recruit from each other. The condition is described by

$$dN/dt = -(pRN/s) - (qAN/s) \tag{21}$$

$$dR/dt = pRN/s;\ dA = qAN/s \tag{22}$$

which allows an initial rate approximation of N by

$$N = N_o \exp(p(pR_o + qA_o)\,t/s) \tag{23}$$

This implies that the time required to complete the polarization of the society will be

$$t_w \cdot 1.\ 1/((pR_o + qA_o)/s)\ (3) \tag{24}$$

which assumes that the time required for N to decrease to N_o/e^3 under exponential recruitment will include the end of the recruitment phase. This approach gives the following fractions of N_o in the R and A forces respectively

$$R_o p/s(e^{p/s})N_o \ :\ A_o q/s\,(e^{q/s})\,N_o$$

which would be very favorable to the government if the persuasiveness ratio is only reasonably unfavorable. The next phase reduces to that described in 2.1 and the final outcome will be decided by the ratio of the persuasivenesses to each other.

Case 2.3

A more general formulation of the above problem of three groups would allow R and A to recruit from each other, if the transition state is membership in N. This results in the following equations.

$$dN/dd = -pRN/s + qAR/r = qAN/s + p\,RA/a \tag{25}$$

$$dR/dt = pRN/s = qAR/r \tag{26}$$

$$dA/dt = qAN/s = pRA/s \tag{27}$$

and the conditions for breakeven (no winner) imply that the ratio of r/a is a function of r/s or in another form

$$r_{be} = \frac{(qA_o/pR_o)\ as}{(s-N_o/R_o)\ ((p-P)/p)(s)} \tag{28}$$

where equations (18), (19), and (20) allow calculation of the optimum size and the maximum theoretical rate, using r_{be} from (28) for a $r_o = r_{be}+1$ if (18) has no solution.

Under these conditions, intelligence of what the other side is doing will be very important, since the optimum strategy for the revolutionaries would be to convert as many s's composed of N's as possible before recruiting from those composed of A's.

Case 3.1

In the case of recruitment by revolutionaries face-to-face and of non- or anti-revolutionaries in mass situations, the results of the following analysis show the extreme disadvantage to the anti-revolutionaries. A first approach would be to consider that the situation is analogous to the guerrilla ambush, since the revolutionaries are sure of their target and concentrating their propaganda firepower, while the opponents are not sure where their targets are. This would require that the factor to replace persuasiveness in the above equations should be the predisposition of the population to join the anti- or non-revolutionary cause, and would lead to a linear law of recruitment for them. Unfortunately, not only is such a factor hard to visualize or express, but also such relations would suggest that the revolutionaries avoid loss of men to such recruitment by decreasing the concentration of their recruiters, which is contrary to the assumptions of the model and the notion that recruiters could maintain their own group by social pressure in numbers.

A crude approach which favors the government would be to assume that the persuasiveness exerted in the face-to-face situation is diluted by the population's size. This implies the following equations:

$$dN/dt = -pRN/s \tag{29}$$

$$dR/dt = -PN/r \tag{30}$$

and the revolutionaries increase exponentially while the government increases linearly and to win have to have

$$N_o \text{ .g. } (p/P)\,(r/s)\,R_o^2 \tag{31}$$

R will increase as in (32) with the optimum $r_o = r_{be}+1$ from (31), since within any group the government will offer no competition and the recruitment rate of the revolutionaries is very much greater than the government.

$$R = R_o\,(Ps/pr)\,\exp(pN_o t/s) \tag{32}$$

The Prime Constants: Persuasiveness and t_p

This model has assumed that the persuasiveness of a group and the time required to persuade a group s by r are constants. A fruitful moment might be spent looking at what these constants really subsume and how they might vary in reality.

The following authors (noted in parentheses) have suggested the following factors also contribute to persuasiveness:

1. degree of uncertainty (Simmel) --peaks during conflict [*]
2. status of the persuader (Hovland) --R status increases [**]
3. calculation of reward to accrue as a function of how many will share it (Gamsen)--decreases if R winning [***]
4. saliency and value of the groups to member--depends on who appears to be winning (Hovland) [**]

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[*] See References, 14.

[**] See References, 15.

[***] See References, 16.

5. centrality of revolutionary activity in the attitude structure of the population (Osgood)--f (political culture) *

6. group solidarity (Durkheim and Lipset)--decreases in general population and increases in R, accelerating trend **

Also, the cognitive comparison of the perceived risks versus the perceived rewards should be included; as should the kind of group s is--a village would be very different from a family. Also, the presence of inconvertible members in s as suggested by the Asch data would probably have a large influence on the susceptibility of others in his group.

A major criticism of this model revolves around t_p and the assumptions of the model, as proposed by Deitchman, for recruitment. First, the form of t_p follows from the notion of so much time needed to recruit s during which r loses a number of men to the opposite side, and in the added time to recruit them a few more are lost and so on; we can approximate t_p by a series which converges, or as below

$$t_p . 1. (s/pr) (1 + qs/pr)^2 \cdot \text{(higher order terms)}$$

The problem with this notion lies in our assumption that increased numbers will at some point yield superior persuasiveness and that this social pressure is mediated by a unified context. Hence, it is difficult to see why in any group where r is large enough to convince there should be any loss of r at all, in fact if it should occur one would expect that the pendulum would swing in the other direction and s would recruit r. This objection also applies to the optimum size calculations which are biased in the increase direction because Lanchester saw a savings in men would accrue to the winning side if the battle were short, which does not apply in the recruitment case, because winning means no one is lost.

CONCLUSIONS

The model has theoretical significance as an approach to the prediction of outcomes of a group persuasive situation, and in attempting to describe the dynamic interactions within a group. Also, it identifies the following problems:

> What is an easily isolable group? What situational factors are important? What specifies the breakpoint between a face-to-face and a mass situation? What are the revolutionary training practices in use now, and how do they clarify the relevant factors in describing the transition from trainee to active recruiter?

While every step forward raises more questions than it answers, the model does offer some practical applications as it stands. First, it suggests definite tactics for both sides and provides a simple formula for the calculation of the optimum size recruiting group, given any initial ratio of insurgents to government recruiters, and the size of the group target. The simplicity of the equation should allow empirical tests to "fit" the value of the persuasiveness over time. The breakeven conditions can be used to predict the course of the revolutionary recruitment by assessing whether the rebels stand to win by recruitment alone, and what the predicted rate of recruitment would be from the tactics in use. The success of the recruitment process could thus become one indication of the imminence of the outbreak of violence. For the government the model affords some guides for the allocation of resources, by assessing the revolutionary recruitment threat. For contingency planning the requirements for revolutionary recruitment specified would allow rank ordering by vulnerability of various target groups in the society.

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POTENTIAL SCOPE OF APPLICATION OF THE ARL SEPARATOR FOR TURBINE POWERED VEHICLES (U)

(Unclassified)

(b)(6) [redacted]

Aerospace Research Laboratories (OAR)
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ABSTRACT

(Unclassified)

This work describes an inertial particle separator designed for use on turbine powered ground vehicles and its potential spectrum of application for helicopters and fixed wing aircraft. Performance data is presented on the existing experimental and projected devices slated for ground vehicles. In addition, simple approximate scaling laws are presented in order to apply present performance knowledge to geometrically scaled units. Dust separator requirements for particular ground vehicles are given and possible air vehicle requirements are suggested. The spectrum of aircraft application is concluded to depend primarily upon the dust separator requirements.

1. INTRODUCTION

In the early part of 1961, theoretical studies were made at the Aerospace Research Laboratories to determine if vortex and curved flows were basically capable of removing sub-micron particles from a flowing particle-gas mixture. Based on these early studies [1] the first reverse flow swirl chamber was constructed. A schematic, which illustrates the basic mode of fluid particle motion is shown in Figure 1. The first reverse flow swirl chamber was found to be capable of separating particles two microns in diameter [2]. The previous theoretical analysis predicted the device should be capable of separating 2.5μ dust particles. Based on the close agreement between theoretical analysis and experimentation, improved versions of the original swirl chamber were designed, built and subjected to extensive aerodynamic and performance test [3],[4],[5]. A schematic representation of one of the newer swirl chambers (vortex chamber) is shown in Figure 2. This multiple injection chamber was found to be capable of separating 90% of water droplets in the range of 0.25 to 0.30 microns [3].

Although the swirl chambers under investigation at the Aerospace Research Laboratories (ARL) find their primary application in the field of nuclear energy conversion and propulsive devices, other potential applications have emerged as research has progressed. For example, the chambers have possibilities in providing a dust free atmosphere for clean rooms and for the removal of solid contaminants from industrial smokes to lessen the air pollution problem. However, the primary application to which this paper is devoted, is to the prevention of dust ingestion in turbine powered vehicles. In particular, the remaining portion of this paper is concerned with an ARL dust separator for use on turbine power ground vehicles and aircraft. Ground vehicles include tanks and jeeps; aircraft include both fixed wing and rotary aircraft with the primary emphasis on the latter. The work in the dust separator field is funded in part by the Army Tank Automotive Center (ATAC) in Warren, Michigan.

2. TURBINE ENGINE DUST INGESTION PROBLEM

In 1963 and 1964, General Electric conducted field tests (at Eglin AFB, Florida, Yuma, Arizona, etc.) on T-58 turbine powered helicopters and found that the engine would fail due to excessive blade erosion after only 80 minutes of operation in the dusty environment[6]. Dust ingestion rates were found to be 40 lbm/hr and higher. Testing by [redacted] for the Army on an Overland Train[7] gas turbine powered vehicle found engine failure occurred after approximately 200 hours. If however, the engine was protected even by a relatively crude separator, it still continued to operate after 470 hours. Testing by ATAC showed that turbine powered vehicles and even diesel and gasoline engines were subject to premature failure when operated in a dusty environment without dust protection. This problem of premature engine failure is further aggravated when two or more vehicles operate in the same vicinity. As might be expected, engine failure rates initially rise rapidly.

Although the above mentioned tests were conducted in various dusty environments, they only gave indications as to the scope of the problems that might be encountered in actual combat conditions. For example, the past year in South Vietnam has shown that turbine engine and rotor blade life on helicopters was reduced one-half and two-thirds, respectively. These premature engine failures coupled with the additional maintenance requirements has cost approximately $100,000,000 (1965).

Premature engine failures, due to dust ingestion, led representatives of the Army Tank Automotive Center to Aerospace Research Laboratories to see if the basic knowledge obtained under the swirl chamber research program could be applied to solve the dust ingestion problem. Subsequent theoretical studies showed that the ARL swirl devices had the potential to meet the extremely stringent turbine dust separator requirements and a research program was initiated to determine the most important separator parameters. Some possible general requirements for a dust separator are: a) Efficient particle separation of micron sized particles; b) Low constant total pressure drop through the device; c) Self-cleaning and little or no maintenance requirements; d) Useable for mobile installations; e) No replenishment requirements, e.g. water for liquid scrubbers; f) Light weight and low cost; and g) Compact. The list could undoubtedly be expanded to cover various particular applications. As might be expected, certain requirements must be "weighed" more heavily than others depending upon the specific application. For example, the separation efficiency required for a straight turbine is usually considered to be 100% of all particles greater than 10-20μ. Regenerative turbines, however, seem to require at least 100% separation of all particles greater than one micron. In addition to the selection of the dust separator requirements and priority listings, it is necessary to consider the areas of turbine vehicle operation. This is because engine failure rates are related not only to the amount of dust ingestion, but also to particle size. Typical sand distributions for beaches, rivers, deserts, and various areas in the United States and Viet Nam are shown in Figures 3 and 4 and are summarized in Table I. It is particularly important to note that beach and river sands are "far larger" than the sand found at deserts or, in general, in unprepared landing areas. Thus, if the turbine powered vehicle must operate in various areas one may insist on a high separation efficiency of "small particles". If a "high" separation efficiency is necessary, then one must sacrifice high performance of one or more of the previous separator requirements. Thus, the device could possibly decrease in compactness and/or the total pressure drop through the device could increase. Other trade-offs are also possible depending upon the degree of separation efficiency required; however, there is only a range where trade-offs can be practically accomplished. For example, the separation efficiency cannot be continually increased by monotonically increasing the total pressure drop through the device [9]. The range of trade-offs is usually based on previous experience and approximate analytical models.

The present in-house research program is designed to obtain a separation efficiency of approximately 100% for dust particles above one micron with a total pressure drop of approximately six inches of water. Scavenging air should be restricted to approximately one per cent of the through flow while the flow rate per unit separator frontal area is approximately 1.5 lbm/sec ft^2. The overall length of the separator unit will be approximately six inches. This device is slated for experimental tests by ATAC on both a turbine powered jeep and tank. The past and projected test schedule is shown in Figure 5. Description of the various devices can be found in reference ten and in later sections of this paper. The device slated for application to the turbine powered vehicles is the clustered separator.

The projected or desired performance parameters of the ARL separator for ATAC is based on the previous considerations of this section, theoretical and experimental analysis, and practical considerations. Unfortunately, the separator cannot be merely removed for a turbine powered jeep or tank and added to the inlet section of a turbine powered aircraft. This is because of the aircraft's relatively high mass flow rates per unit engine "frontal area". Selected examples of various turbines are shown in Table II. One immediately notes that all aircraft (in Table II) require approximately 2-13 lbm/sec ft^2. Since the projected separator under consideration at ARL is only slated for 1.5 lbm/sec ft^2, a simple transference from a ground vehicle to an air vehicle is not possible. Transference is possible, however, if because of system requirements, the separator efficiency, compactness (flow rate per unit frontal area), and/or total pressure drop can be sufficiently relaxed from the present ARL program. The next section deals with the underlying concepts of the ARL separator, some of its physical geometries, and some simple concepts for transference of present dust separators to turbine powered aircraft operating in dusty environments.

3. THE ARL SEPARATOR AND ITS APPLICATION

Figure six schematically represents the first chamber designed specifically to test dust separator concepts. The device was found to be capable of separating approximately 90% of a standardized extra fine Arizona road dust (see Table III for distribution) with a total pressure drop of approximately 7 1/2 inches of water. The total flow rate is approximately 130 cfm and only one-half of one per cent of scavenging air is required to effectively remove the separated dust from the chamber. The device is approximately six inches in diameter (at the end plates) and twenty-five inches long. It is important to realize that this chamber is merely an experimental model designed for testing ease. The separator planned for use by ATAC will be a clustered version of the experimental models. Simply stated, the clustered separator is merely composed of many geometrically scaled down experimental models that function in parallel. The basic particle-fluid flow patterns common to the scaled devices are illustrated in Figure 7.

The gas-particle mixture is admitted tangentially at an outer radius by means of an inlet scroll (mixture can also be admitted by means of vanes, see Figure 8). The mixture then proceeds in an axial direction towards the end plates of the chamber continually centrifuging the particles toward the outer wall. Upon reaching the vicinity of the end wall, continuity requires that the "small" particles entrained with the fluid flow radially inward. Concurrently, the larger particles are removed from the chamber by either an injector or an ejector. The remaining fluid particle mixture travels radially inward and accelerates to continuously higher velocities ($Vr \approx$ constant) and reaches a maximum somewhat inside the exit radius. Continuity then requires the fluid to turn and proceed in the axial direction towards the exit of the separator (inlet of turbine). While traveling from the end wall to the exit of the device, the particles are gradually centrifuged out to larger radii. Ideally, in the region of the exit nozzle all the particles proceed radially outward aided by both centrifugal forces and a reversed secondary flow field. Actually, however, some particles are not centrifuged to an adequate radial distance and thus enter the exit of the separator (inlet to the turbine). The particles that are carried radially outward into the incoming particle-gas mixture are swept toward the injector (ejector) region of the device. (This particle enriched flow appears to enhance the separation capability by tending to increase particle agglomeration and thereby increase the average apparent particle size). Upon reaching the vicinity of the end wall some of the particle enriched flow is ejected out of the separator and the cycle continues. Extended discussions on the flow reversal concepts can be found in reference eleven. The application of the concepts of the reversed flow swirl chambers to a dust separation device of necessity led to a systematic study to determine the most important separator parameters which affect the following major performance characteristics.

1. Separation efficiency (η_s); Effects of a) Inlet scrolls versus inlet vanes (Figures 6 and 8); b) End wall admission (Figure 9); c) Reverted geometries (Figure 10); d) Geometric scaling for multiple units.

2. Reduction of the total pressure drop through the separator (ΔP_t); Effects of a) Radial outward diffusion of core flow downstream of the exit; b) Axial length of exit tube.

3. Minimum dust ejection energy (ξ); Effects of a) Radial distance between core and dust

ejection region; b) Mode of scavenging air admission.

4. Maximization of the volume flow per unit frontal area (compactness): Effects of a) Ratio of exit diameter to chamber diameter; b) Ratio of axial length to exit diameter; c) Ratio of axial to tangential velocity of the core flow. It is important to note that there is a cross coupling or an inter-dependence between some of the parameters and the performance characteristics. The degree of inter-dependence is in general determined by experiment. The experimental results to date have shown that the reversed flow separators are capable of separating extremely fine particles (approximately 2 μ) with scavenging air requirements below one-half of one per cent. The low scavenging air requirement is primarily due to the outer radius ejection method. Here the particles are removed at the chambers' outer wall making use of the fluid's kinetic energy. Since the particles are in a region of relatively high static pressure, there is also no need for an excessive amount of injector (ejector) air to "pump" the particles from the separator.

Relatively low pressure drops (approximately 7 inches of water) are obtained by recovering a large portion of the swirl energy through the use of dual cell geometries and vaneless radial diffusers where applicable. The vaneless diffusers not only recover a large amount of the swirl energy, but also increase the total through flow through the device by preventing backflow of the fluid. The elimination of backflow also tends to increase the rotational velocity of the core and thereby enhance particle separation. Higher flows can be obtained in some devices through the use of end wall bleeds (see Figure 9).

Application of the present knowledge, obtained on the previously mentioned devices, to a variety of turbine powered vehicles can be accomplished through the use of various scaling laws. Unfortunately, the pure application of the scaling laws does not reveal if the performance of a scaled separator will be adequate for the particular application. For example, in order to meet the high flow rates per unit engine frontal area (see Table II) inlet-exit diameters must be increased while holding other dimensions fixed. By monotonically increasing the inlet-exit diameters the core rotational velocity and particle residence time decrease while the total through flow increases (operating at the same total pressure drop) and thus, the separation efficiency must decrease. The decrease in separation efficiency depends upon the desired flow increase, e.g., the scrolled inlet and outlet devices inlet and exit geometries were geometrically scaled to yield areas of 1.5 and 2 times larger than the original device. Separation efficiencies dropped from 75% to 65% to 60% for the extra fine 0-5μ Arizona road dust. The corresponding flow rates were 500, 750, 1000 cfm (chambers were known as the Q, 1.5Q and 2Q separators). If a higher flow rate is desired with a 60% separation efficiency, then the chambers' other dimensions must also be scaled or changed. If, however, higher separation efficiencies are required, the chambers can be scaled down (must remain outside the region of boundary layer domination). Thus, when the "Q" chamber was scaled geometrically to yield one-third the mass flow rate (known as the Q/3 chamber) the separation efficiency increased to 90% on the 0-5μ extra fine dust. In general, the scaling of all the dimensions of a separator will result in the new flow rate being directly proportional to the square of the scale factor (under conditions of equal total pressure drop). The decrease in the separation efficiency, however, is directly proportional to the three-halves power, more specifically the separation efficiency is:

$$\eta_s = 1-\beta\,[n_o d_o^3 + n_1 d_1^3 + \cdots + n_e K(s)^{3/2}]$$

Where β and K are quasi-constants of the particle-fluid flow for the separator n_o is the number of particles of diameter d_o, and n_e is the number of particles of diameter d_e. The subscript "e" indicates the largest particle the chamber cannot separate. The symbol "s" is the scale factor. As might be expected, the equation is only valid for spherical, unagglomerated particles for a separator having a sharp cut-off. Even in view of its shortcomings it is useful for predicting the separation efficiency trends.

If the aforementioned scaling laws are applied to the dust separators under investigation at ARL, one quickly realizes that the scaled devices become "large" (compared to the engine) and have relatively high separation efficiencies (100% of all particles on the order of 10 microns). Thus, application to turbine powered helicopters and fixed wing aircraft seem unfeasible (with the exception of the light observation helicopter); however, if one can relax the separation efficiency requirement, the separators' overall chamber volume per unit mass flow rate decreases and the devices have the potential for application to many turbine powered aircraft. The vehicles to which the ARL separator can be applied depend primarily on how the separation efficiency requirement is relaxed. Again, the greater the degree of relaxation (from the ARL-ATAC requirements), the larger the spectrum of application.

4 CONCLUDING COMMENTS

The early work at the Aerospace Research Laboratories was aimed at developing a device which had the capability for removing sub-micron particles from a flowing gas-particle mixture. Subsequent research in swirl flows led to the design of vortex chambers which have the capability to separate 90% of water droplets in the range of 0.25-0.30 microns. As the basic research progressed various possible applications emerged. One such possible application was a dust separator for use on turbine powered vehicles. Initial application of the ARL dust separator is for turbine powered jeeps and tanks under test by the Army Tank Automotive Center. The clustered device for the Army will be capable of separating 100% of dust particles greater than one micron with scavenging air requirements being limited to less than one per cent. The total pressure drop will be approximately 6 inches of water. In addition to turbine powered ground vehicles the ARL separators have the potential for use on helicopters and fixed wing aircraft. The spectrum of aircraft application will depend on the dust separator requirements in each application. In addition, if the space allowed for a separator is not limited to some engine "frontal" area, then a higher degree of separation efficiency can be obtained for a particular engine. For example, small clustered separators could be installed both at the outer cowling of an engine and at the frontal region (or some combination). These "small" separators could be used only during the landing and take-off of helicopters or during the prop reversal phase of C-130 type aircraft operating in unpaved areas.

Through the use of an ARL separator, engine life should increase to a point where other factors besides dust and sand determine when a turbine engine must be overhauled or replaced. For example, if the ARL separator can be applied to C-130 aircraft operating in unpaved runways, engine life expectancy can be increased substantially above the present four to six landings [12],[13].

The results obtained from testing the ARL separators show an overall separation capability equal to or greater than commercial separators. In addition, scavenging air requirements, for self cleaning, are one to two orders of magnitude less than commercially available units. Pressure drop and flow rates per unit separator frontal area are expected to be comparable to commercial units. Because of the high performance, the ARL separators have the potential for use on a variety of turbine powered vehicles. The envelope of turbine powered aircraft application will depend primarily on the dust separator requirements.

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6. ACKNOWLEDGMENTS

The author wishes to thank [redacted] for their timely discussions and criticisms. In addition I must not forget [redacted] and [redacted] for their stimulating noon hour discussions on vortex flows. Special reference should also be made to Mrs. Marcia Homan who typed this paper under "normal procedures". Further thanks are also extended to the scientific and technical personnel of the Aerospace Research Laboratories for their able assistance in the laboratory.

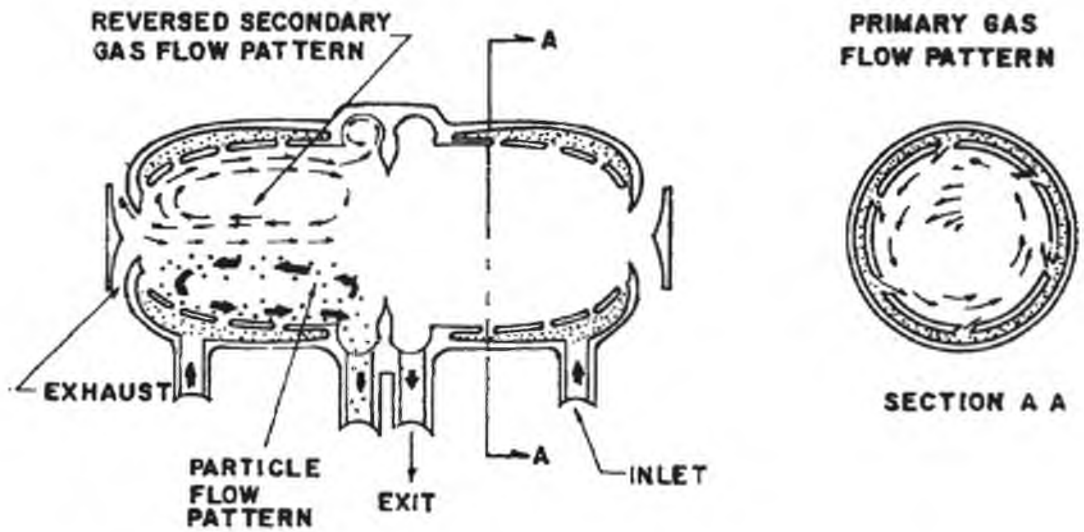

FIG.1. SWIRL CHAMBER WITH REVERSED SECONDARY FLOW

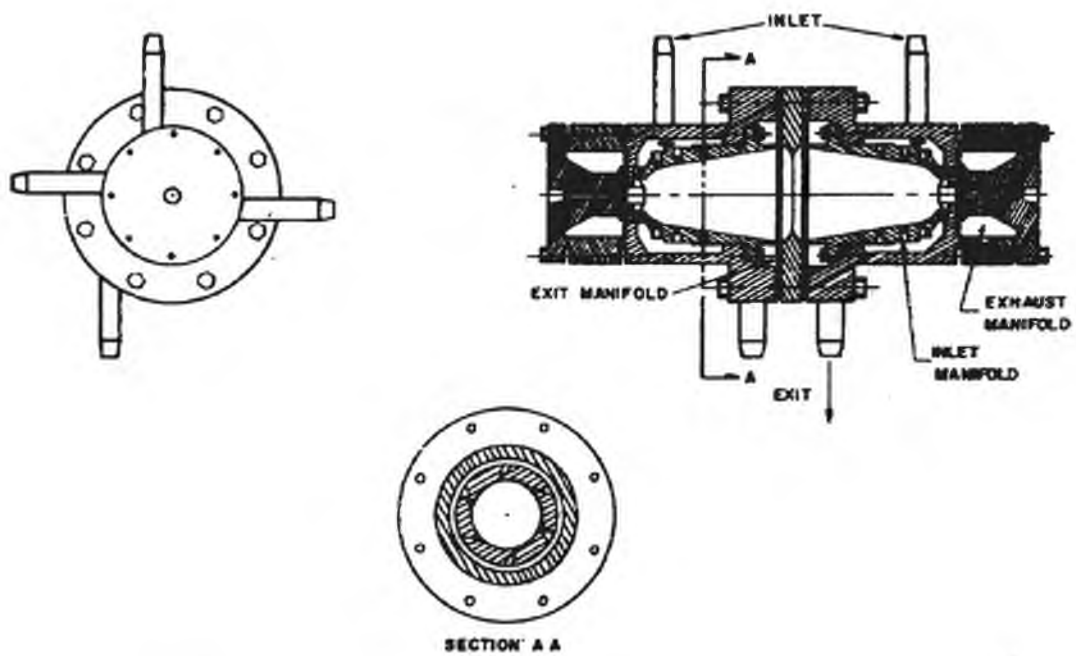

FIG. 2 INTERNAL GEOMETRY HIGH PRESSURE SWIRL CHAMBER
MULTIPLE INJECTION

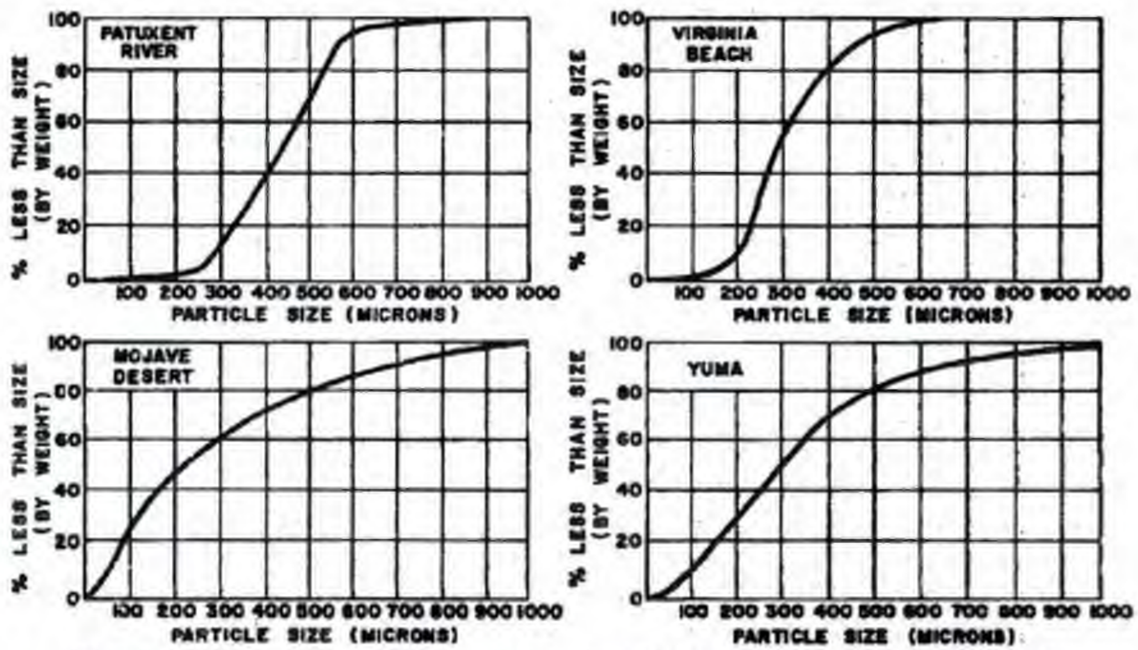

FIG. 3 SAND PARTICLE SIZE DISTRIBUTION FOR VARIOUS AREAS IN THE UNITED STATES (8)

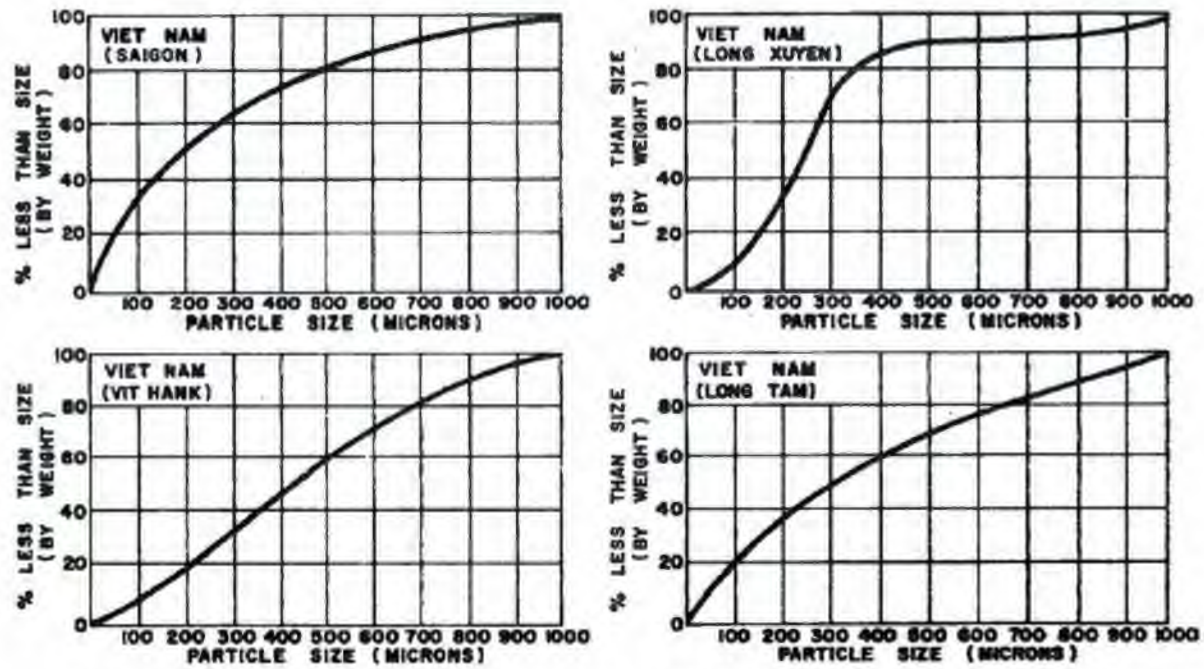

FIG. 4 SAND PARTICLE SIZE DISTRIBUTION FOR VARIOUS AREAS IN SOUTH VIET NAM (8)

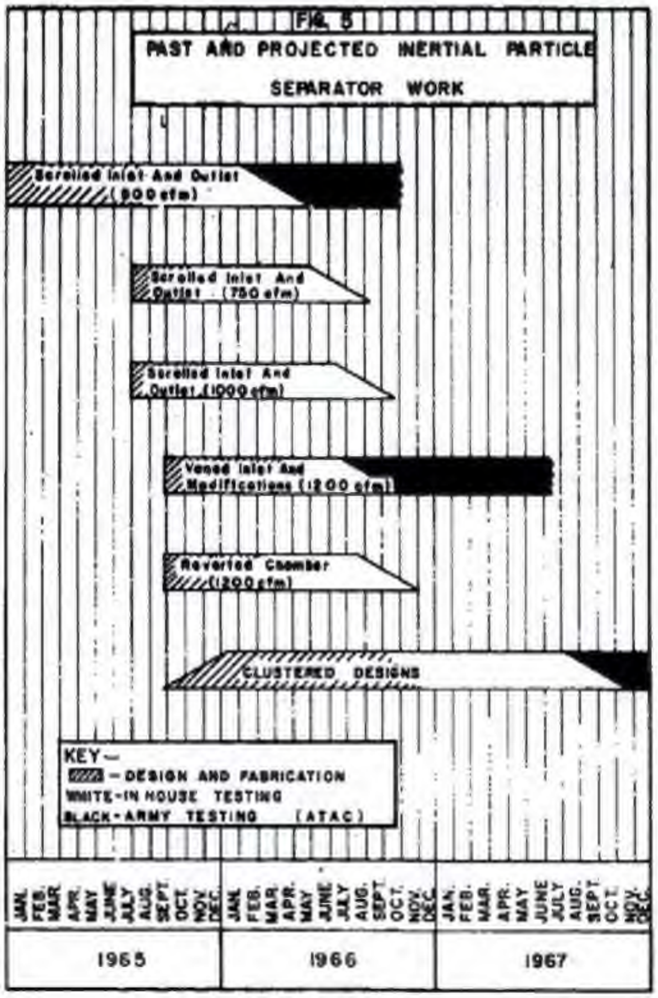
FIG. 5
PAST AND PROJECTED INERTIAL PARTICLE SEPARATOR WORK
Scrolled Inlet And Outlet (500 cfm)
Scrolled Inlet And Outlet (750 cfm)
Scrolled Inlet And Outlet (1000 cfm)
Vaned Inlet And Modifications (1200 cfm)
Reverted Chamber (1200 cfm)
CLUSTERED DESIGNS
KEY—
– DESIGN AND FABRICATION
WHITE-IN HOUSE TESTING
BLACK-ARMY TESTING (ATAC)
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
1965
1966
1967

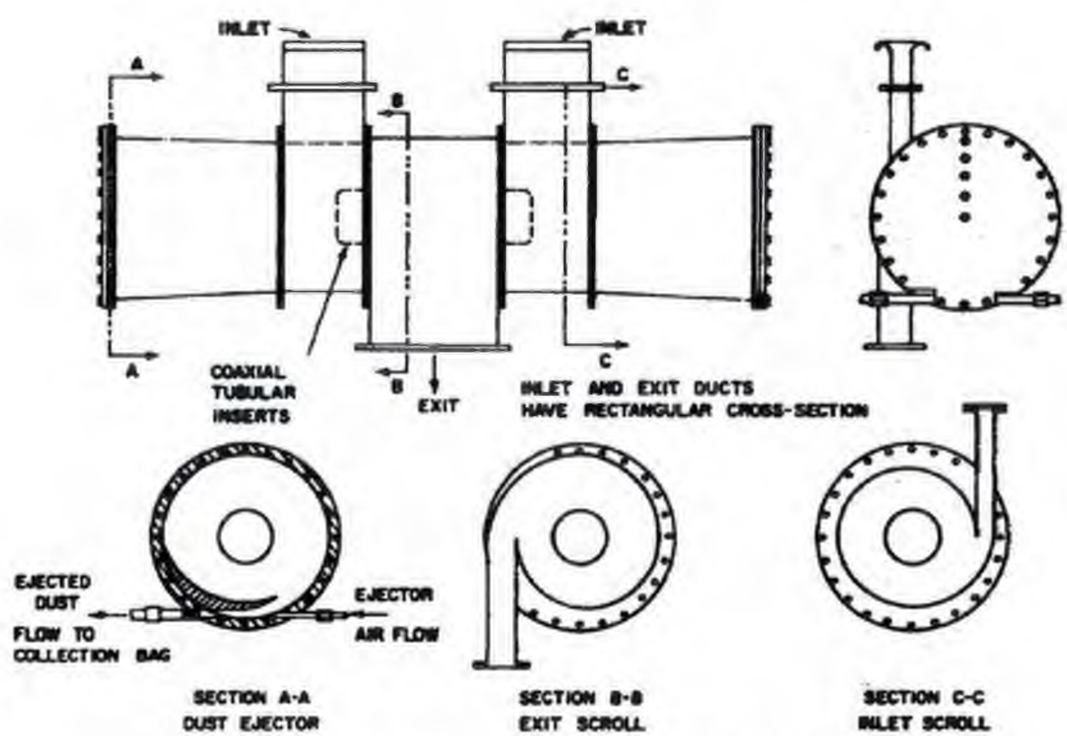

FIG. 6 ARL DUST SEPARATOR (MARK I)
SCROLLED INLET AND OUTLET

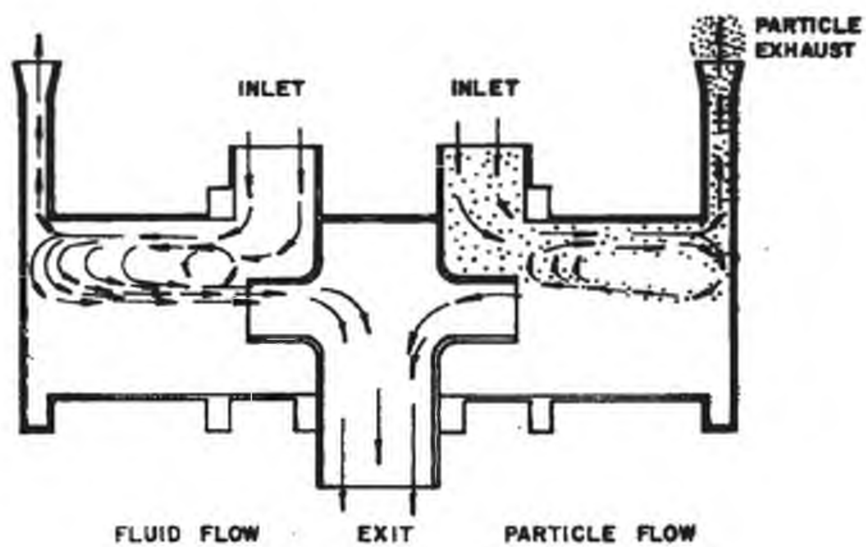

FIG. 7 BASIC FLUID AND PARTICLE FLOW FIELD INSIDE THE ARL SEPARATOR (SIMPLIFIED)

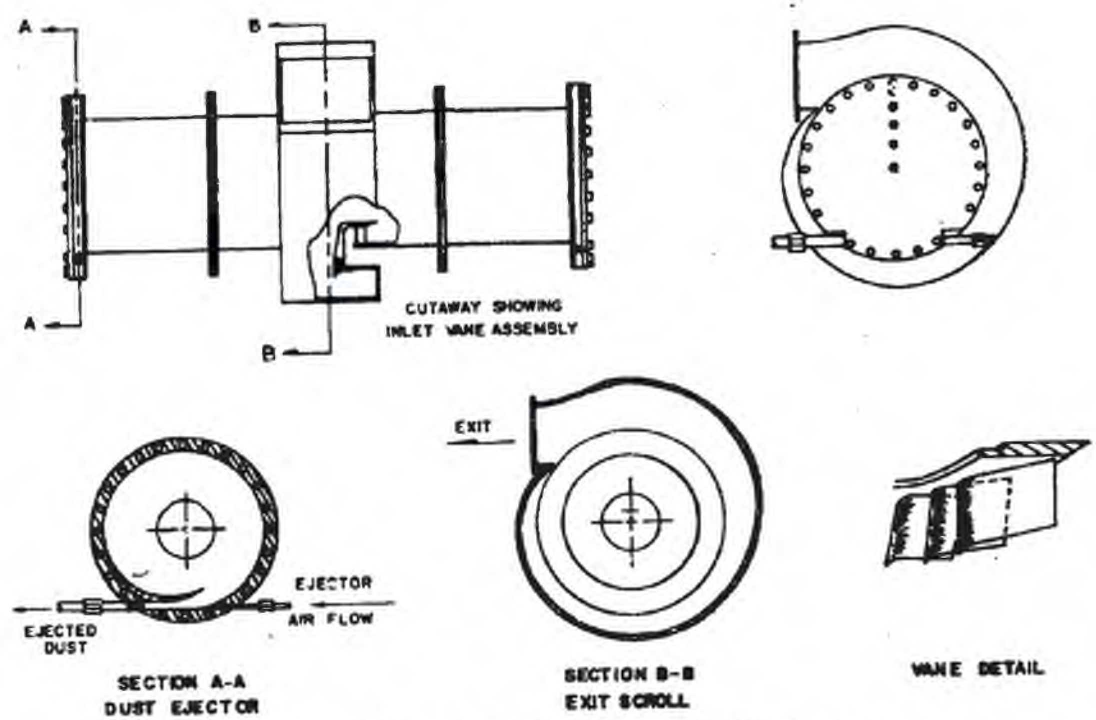

FIG. 8 ARL DUST SEPARATOR MK II
VANE INLET - SCROLL OUTLET

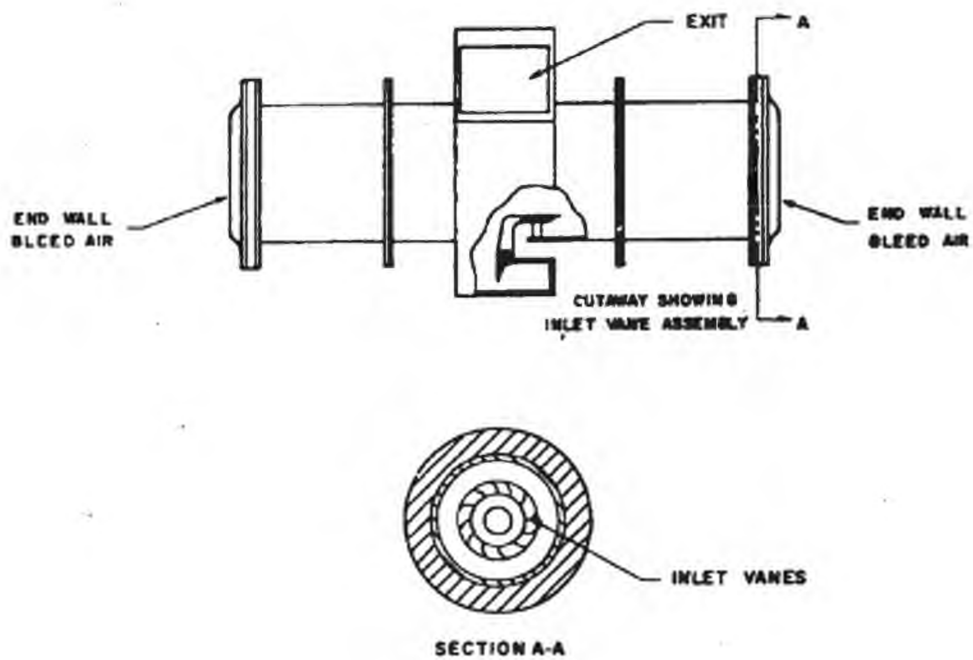

FIG.9 ARL DUST SEPARATOR MARK II
VANE INLET SCROLL OUTLET
END WALL BLEED

TABLE I PARTICLE DISTRIBUTION FOR VARIOUS LOCATIONS[8]										
AREA	PERCENT PARTICLE SIZE (MICRONS)									
	0-44	44-53	53-74	74-88	88-105	105-149	149-210	210-420	420-590	590-1000
PATUXENT RIVER	0	0	0.1	0.1	0.1	0.4	1.2	46.3	46.3	5.5
VIRGINIA BEACH	0	0	0	0	0.27	1.2	10.0	72.9	13.7	2.1
MOJAVE DESERT	6.8	4.5	8.4	5.4	4.7	11.6	9.0	22.2	13.4	14.5
YUMA	2.0	2.4	2.4	3.6	3.1	7.5	10.3	42.9	14.7	8.4
VIET NAM:										
SAIGON	13.2	5.2	6.2	4.0	3.6	11.6	12.2	23.2	9.5	10.5
LONG XUYEN	2.8	1.1	2.5	3.0	4.6	19.0	27.0	26.6	1.9	10.3
VIT HANK	4.1	1.1	1.7	1.2	1.2	4.9	7.0	27.0	20.4	31.1
LONG TAM	8.6	2.4	3.8	4.0	2.0	5.8	8.6	21.5	14.6	27.7
DA NANG	0.25	0.25	1.1	1.0	1.0	7.1	15.9	48.4	15.1	9.9
QUINHON	0	0	0	0	0	0	0.5	39.2	46.8	13.5

TABLE II SELECTED TURBINES & THEIR VARIOUS USES

TURBINE ENGINE	ENGINE UTILIZATION	MASS FLOW RATE ENGINE DIAMETER	FLOW RATE PER UNIT ENGINE AREA
T 34 PRATT WHITNEY	CARGO AIRCRAFT C-133	62 lbm/sec 34 inches	9.85 lbm/sec ft^2
T 53 LYCOMING	HELICOPTERS Army UH-1 (IROQUOIS) USAF YH-40 & HH-43 FIXED WING Army OV-1	10.45 → 12.2 lbm/sec 23 → 23.7 inches	3.63 → 3.99 lbm/sec ft^2
* T 55 LYCOMING	HELICOPTER Army CH-47 (CHINOOK)	21.5 → 23 lbm/sec 24.25 inches	6.72 → 7.19 lbm/sec ft^2
T 56 ALLISON	CARGO AIRCRAFT C-130	32.5 lbm/sec 26.9 → 27.25 inches	8.23 → 8.06 lbm/sec ft^2
T 58 GENERAL ELEC.	HELICOPTERS CH-3 & UH-1-F	12.6 → 13.95 lbm/sec 16 inches	9.02 → 9.97 lbm/sec ft^2
T 63 ALLISON	HELICOPTER Army Light Observation OH-4A Bell OH-5A Hiller OH-6A Hughes	2.75 → 2.98 lbm/sec 14 → 15 inches (Dia. here is 4" less than width of eng)	2.57 → 2.45 lbm/sec ft^2
T 64 GENERAL ELEC.	VTOL AIRCRAFT XC-142 (Tri-Service)	24.5 lbm/sec 20 inches	8.23 → 8.06 lbm/sec ft^2

TABLE III

Arizona Road Dust Size Analysis

(by mass)

0-5μ Road Dust

Particle Size (Microns)	Percentage less than size: Stated by A-C (percent)	Percentage less than size: Analysis by ATAC* (percent)
10		100
5	96.3	99.7
4		97.6
3		92.8
2	90.7	79.9
1		46.0
0.8		35.6
0.6		
0.5	11.1	
0.4		13.3
0.3	1.9	
0.2		4.1

*ATAC - Army Tank Automotive Center, Warren, Michigan
Report - CRN 15403-RA (Part 4, 1 September 1964)

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A MATHEMATICAL FRAMEWORK FOR THE DYNAMIC INSURGENT SOCIETY
(Unclassified)

(b)(6) [redacted]

Defense Research Corporation
Santa Barbara, California

ABSTRACT
(Unclassified)

This paper addresses itself to a possible application of the systems methodology of science to the development of predictive models of societal behavior.

In essence, it puts the dynamics of insurgent situations into the framework of differential game theory. The "insurgency/counterinsurgency" conflict then becomes a resource allocation problem for both sides, where, within the constraints of available total resources expressed in some common currency, each side searches for policies obtaining optimum outcomes in the mini-max sense.

It is clear that the problems associated with filling in this framework, i.e., defining the interaction functions, are nontrivial. Nevertheless, the approach shows promise and is considered worthy of further pursuit.

1. INTRODUCTION

An alternative title to this paper might have been "What Systems Science Has to Do with the CI Problem." We propose to answer this question by relating historically the evolution of system theory in the past three decades and its application to realistic problems.

Prior to and during World War II, great effort was expended in evolving a theory of "feedback" control; the idea, although simple, is responsible for an entirely new era of technology. The key element of this theory is that one may view the behavior of a complex system (e.g., gun control, economic, etc.) as governed by a set of differential relations some of which may be altered or controlled at will. For example, the change in U.S. economy over a one-month period is in part determined by the current <u>state</u> of the economy and in part by the control or influence of Government. We represent this graphically in Fig. 1. The box labeled "CHANGE RELATIONS" describes the way in which current economy state and government influences combine to effect the change of state while that marked "Σ" merely adds the change to the current state to yield "next month's economy."

It is perhaps desirable that the government influence should be designed to have a "stabilizing" effect on the economy so that a certain amount of observation and planning must go into deciding what influences are to be brought to bear. This is represented graphically in Fig. 2, where the box labeled "Government Planning and Decision" represents the decision process relating "current" state to the next government influence. Notice, however, that the diagram indicates that the state is "fed back" via government planning into influencing the change of state; as such the government decision-making amounts to a "feedback controller" in system theory. Furthermore, armed with a reasonable knowledge of the change relations, and the economy state, system stability theory may be employed to structure the decision-making process in such a way as to reduce economic volatility. Thus we see that system science can be and perhaps has been applied to the stabilization of economy.

If we allow that system theory circa 1940 offers something of interest to government economic planning, then let us review advances in this theory with an eye toward further applications. During the 50's optimal feedback control of systems was given great attention; in this problem one seeks a "feedback controller" which achieves some goal in the most efficient manner. For example, in the controlled economy, if "maximum prosperity" were set as a five-year goal and it were desirable to achieve this aim with a limited government influence, then system optimization theory would provide a means again for structuring the government planning and decision block. The new structure would, of course, depend upon the desired goal, the nature of the economy behavior, and the quantitative measure of influence.

To draw on this example even further, suppose that the economy changes could be effected by two agencies, perhaps government and anti-government; we depict this situation in Fig. 3 by the economy dynamics inside the dashed line. We suppose that these agencies have opposing aims--perhaps government to increase prosperity and anti-government to decrease prosperity. If both agencies have limited influences and/or resources, we may well ask again for a structure of the government decision-making block which will maximize prosperity with limited influence even in the face of an opposing agency. The situation depicted in the figure clearly amounts to a dynamic conflict and the decision structures sought are optimal tactics to achieve some goal. As a dynamic conflict the problem posed is encompassed by differential game formalism, a subject recently receiving greater attention among system theorists, and perhaps to be the most significant systems theoretical advance of this decade.

2. THE MATHEMATICAL MODEL

Since differential games provide an analytical foundation for dynamic conflict, it is reasonable to suppose that these techniques might be usefully applied to the insurgency problem. It is the purpose of this paper to suggest how this might be done.

First, it is necessary to establish a variable which measures the state of the society with which we are concerned. We can, for example, divide a country into a number of regions where the vector

$$\bar{x}(t) = x_1(t), x_2(t), \ldots\ldots, x_I(t)$$

consists of elements $x_i(t)$, $i = 1, 2, \ldots I$, giving the total number of "pro-government people" in the *i*th region at time t. One can imagine that the country is divided into regions on a somewhat natural basis (i.e., urban-industrial, rural-agricultural, etc.) rather than simply laying down some arbitrary rectangular grid. Natural division aids in defining the dynamics of change, region by region, and helps simplify the analysis problem.

Let us now structure our dynamic changing society in terms of the rate of change of pro-government elements in the society and write

$$\frac{d\bar{x}}{dt} = f[\bar{x}, \bar{y}, \bar{z}, t], \quad \bar{x}(0) = \bar{a}; \quad 0 \leq \bar{x}(t) \leq \bar{p}(t)$$

The above represents a lot of different things packed into one differential equation; so let us examine the elements of the equation one by one.

The condition $\bar{x}(0) = \bar{a}$ represents the initial distribution of pro-government people in our society. Specifically, the element $x_i(0) = a_i$ gives the number of pro-government people in the *i*th region at time zero.

The inequality $0 \leq \bar{x}(t) \leq \bar{p}(t)$ represents a bound on state space. Specifically, the element $0 \leq x_i(t) \leq p_i(t)$ restrains the number of pro-government people in the *i*th region at the time t to lie somewhere between zero and the total population of the *i*th region, $p_i(t)$. The physical aspects of the nonlinear differential equation can be illustrated schematically as follows (Fig. 4). The diagram portrays the pressure exerted on the *i*th region by forces of change (pro- and anti-government forces) and the current pro-government populations in the other I-1 areas. The pressure results in a rate of change $\frac{dx_i}{dt}$ of the pro-government population in the *i*th region.

Such a nonlinear problem involving large numbers of variables is extremely difficult to treat as it stands. To aid in the analysis it becomes expedient to linearize the problem, i.e., to assume that some specific time history $\bar{x}^*(t)$, $0 \leq t \leq T$, represents a nominal or mean expected time profile of the pro-government population and to investigate the behavior of the solution for small departures from the nominal. Repeated applications of the foregoing scheme lead to the so-called "Method of Linearization and Successive Approximation" solution of the original nonlinear problem. The linearized form of the original equation becomes

$$\frac{d\bar{x}}{dt} = A(t)\bar{x}(t) + \sum_{j=1}^{J} B^j(t)\bar{y}^j(t) + \sum_{k=1}^{K} C^k(t)\bar{z}^k(t); \; \bar{x}(0) = \bar{a}, \; 0 \le \bar{x}(t) \le \bar{p}(t)$$

The first term on the right-hand side of the differential equation obtained by ignoring the two summations gives the homogeneous form of the differential equation as

$$\frac{d\bar{x}}{dt} = A(t)\,\bar{x}(t)$$

or

$$\begin{pmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \\ \cdots \\ \dot{x}_I(t) \end{pmatrix} = \begin{pmatrix} a_{11}(t) & a_{12}(t) & \cdots & a_{1I}(t) \\ a_{21}(t) & a_{22}(t) & \cdots & a_{2I}(t) \\ \cdots & \cdots & \cdots & \cdots \\ a_{I1}(t) & a_{I2}(t) & \cdots & a_{II}(t) \end{pmatrix} \begin{pmatrix} x_1(t) \\ x_2(t) \\ \cdots \\ x_I(t) \end{pmatrix}$$

Thus, the matrix A(t) represents the sensitivity of the society to itself and the solution of the homogeneous equation describes the dynamics of our changing society in the absence of either pro- or anti-government actions.

For example, in an extremely backward, nonindustrialized country with poor transportation and/or poor lines of communication between various regions, the A(t) matrix will have values only along the diagonal elements. That is, $a_{mn}(t) = 0$, if $m \neq n$. The members of such a society know little if anything about what is happening in the country except in the region in which they reside. For example, suppose

$$\frac{dx_1}{dt} = a_{11}(t)\, x_1(t); \quad x_1(0) = a_1, \; 0 \le x_1(t) \le p_1(t)$$

Figure 5 shows the possible behavior of $x_1(t)$.

If the country in question is undergoing an industrial revolution, the elements of the A(t) matrix can be expected to grow away from the diagonal with time as people in one region become more sensitive to what is happening elsewhere in the country.

In a society such as that currently existing in the United States, for example, all of the elements of the A(t) matrix might be expected to have nonzero values. The people in New York are quite sensitive to what happens in Los Angeles and vice versa.

Next we consider the elements of the two summations on the right side of the differential equation. They involve two sets of choice vectors, namely,

$$\overrightarrow{y}^j(t) = \left\{ y_1^j(t),\ y_2^j(t),\ \ldots,\ y_I^j(t) \right\} \ ; \quad j = 1, \ldots, J$$

and

$$\overrightarrow{z}^k(t) = z_1^k(t),\ z_2^k(t),\ \ldots,\ z_I^k(t) \quad ; k = 1, 2, \ldots, K$$

The y elements represent choices available to the pro-government forces at work in the society and the z elements represent, likewise, the choices available to the anti-government forces at work in the society. The superscripts denote the type of resource utilized by the conflicting forces. For example, if $\overrightarrow{y}^1(t)$ represents pro-government propaganda, then $y_i^1(t)$ is the amount of pro-government propaganda devoted to the ith region at time t. The matrix $B^1(t)$ then represents the sensitivity of the society to pro-government propaganda. Similar comments can be made about all of the resources of both sides in the conflict. Basically, then the matrices are:

A(t)	Responsiveness of the society to itself
$B^j(t)$	Responsiveness of the society to the jth type of pro-government resource
$C^k(t)$	Responsiveness of the society to the kth type of anti-government resource.

As might be expected, neither side can produce a change in the structure of the society without incurring an expense. The price that the pro-government faction is forced to pay for expending its resources at time t_m is

$$P_y(t_m) = \sum_{j=1}^{J} \sum_{i=1}^{I} a_j(t_m)\, y_i^j(t_m)$$

where

$a_j(t_m)$ = per-unit cost of jth type of pro-government resources at time t_m

$y_i^j(t_m)$ = amount of pro-government resources of the jth type used in the ith region at time t_m

likewise

$$p_z(t_m) \sum_{k=1}^{K} \sum_{i=1}^{I} \beta_k(t_m) z_i^k (t_m)$$

where

$\beta_k(t_m)$ = per-unit cost of the kth type of anti-government resource at time t_m

$z_i^k(t_m)$ = amount of anti-government resource of the kth type used in the ith region at time t_m

We might now consider some time interval, T. A five-year plan, for example, could be broken down into monthly intervals so that $p_y(t_m)$ and $p_z(t_m)$ represent total expenditures during the mth month while

$$P_y(T) = \sum_{m=1}^{N} p_y(t_m)$$

and

$$P_z(T) = \sum_{m=1}^{N} p_z(t_m)$$

give the total budgets to be spent by pro-government and anti-government forces during the time period T, respectively.

Finally, we establish a score function that measures the successfulness of the pro- and anti-government factions as

$$S(T) = \sum_{i=1}^{I} x_i(T)$$

where S(T) represents the total pro-government population of the country at time T, and each side, subject to its budgetary constraints, operates in accordance with the max-min operation on S(T).

$$\underset{\substack{\vec{y}^{j}(t_m) \\ \{j = 1,2,\ldots,J;\ m = 1,2,\ldots,M\}}}{\text{MAX}} \quad \underset{\substack{\vec{z}^{k}(t_m) \\ \{k = 1,2,\ldots,K;\ m = 1,2,\ldots,M\}}}{\text{MIN}} \quad [S(T)]$$

in an attempt to obtain the most favorable score.

The optimal choices for both sides must be assumed to take the form of feedback control as a function of the state of the society in contrast to pre-programmed control; otherwise, the game does not exist. This fact is clear because a programmed choice by one side destroys the game and presents the opponent with the ordinary optimization problem.

For convenience as well as ease of physical realizability we shall assume that both sides will employ linear feedback control so that

$$\vec{y}^{j}(t) = Y^{j}(t)\ \bar{x}(t)$$

and

$$\vec{z}^{k}(t) = Z^{k}(t)\ \bar{x}(t)$$

and the minimax problem then becomes one of selecting the coefficients of matrices

$$Y^{j}(t) \quad j = 1, 2, \ldots, J$$

and

$$Z^{k}(t) \quad k = 1, 2, \ldots, K$$

The framework of the problem may now be envisaged conceptually by a block diagram (Fig. 6).

3. DETERMINATION OF THE SYSTEM MATRICES

Several means suggest themselves for determination of the elements of the system matrices A(t), B(t), and C(t). The past history of the country can be examined for a determination of what has transpired up to now. This information can be extrapolated to give future trends by those most knowledgeable and possessing the greatest amount of skill or expertise in various disciplinary matters including scientific, social, political, military, and economic areas, to mention a few.

If the past history appears inadequate, it is possible that tests might be conducted in some region in order to obtain better estimates of the system structure.

Above all, the approach should be flexible. If we must have a plan today, we do the best we can with the available information. This does not mean that we have to live with the a priori plan forever. We must be responsive to change when situations develop along unforeseen lines. A rather large-scale computer program could be developed which was adaptable to changes. Perhaps we update the system periodically, say every six months or a year or as often as may be necessary.

In any event, we continually strive to do the best job we can, at least on the basis of some analytical formulation of the foundations of conflict.

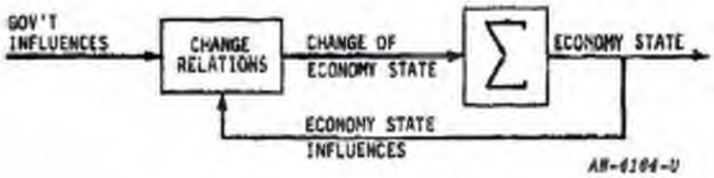

FIGURE 1. ECONOMY DYNAMICS

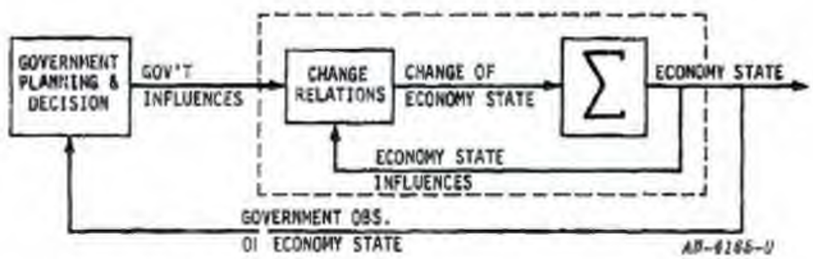

FIGURE 2. FEEDBACK CONTROL OF ECONOMY DYSAMICS

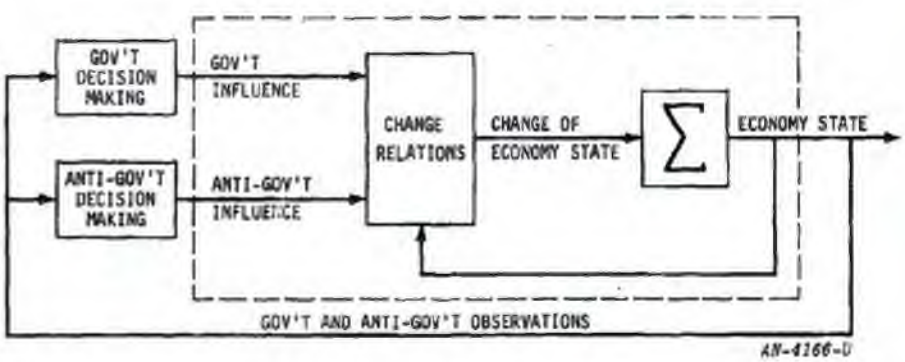

FIGURE 3. ECONOMY IN A DYNAMIC CONFLICT

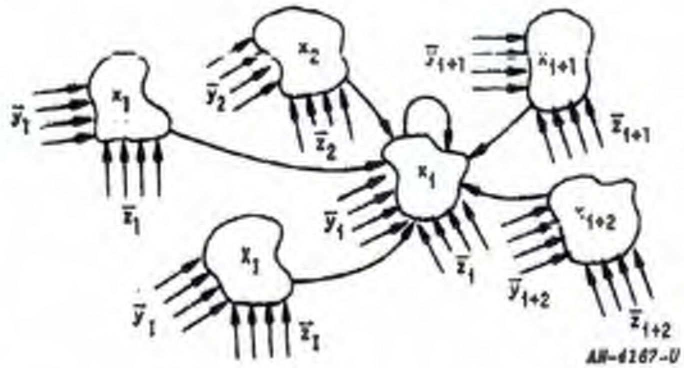

FIGURE 4. FORCES ON A DYNAMIC CHANGING SOCIETY

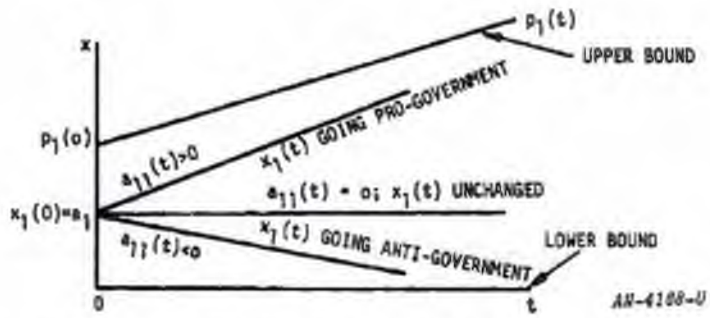

FIGURE 5. TYPICAL BEHAVIOR IN THE ABSENCE OF OUTSIDE INFLUENCES

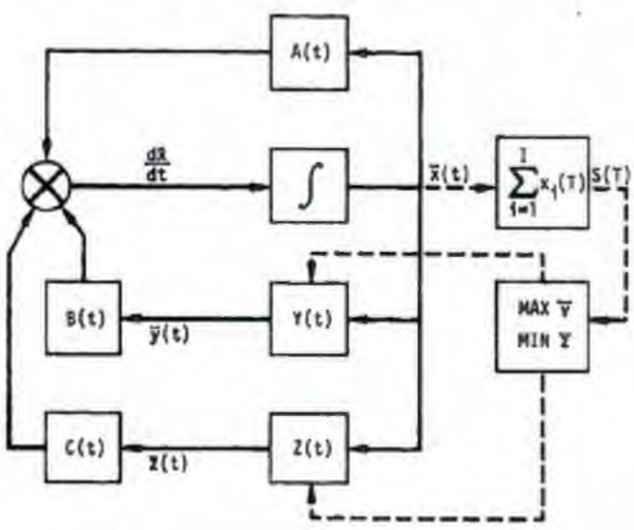

FIGURE 6. COMPUTER MODEL OF SOCIETY IN CONFLICT

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A CONDUCTING-SLAB MODEL FOR ELECTROMAGNETIC PROPAGATION WITHIN A JUNGLE MEDIUM
(Unclassified)

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ABSTRACT
(Unclassified)

A theoretical determination of the path loss in radio propagation through jungle is obtained by considering the jungle as a homogeneous conducting dielectric slab on a flat earth. An exact integral is obtained for the vertical component of the electric field within the jungle due to a vertical electric dipole within the jungle. An analytic evaluation of the integral leads to an approximate expression for the field and an estimate of the error. When this accuracy is insufficient, a numerical evaluation of the integral is performed. The combination of analytic and numerical techniques leads to the evaluation of the electric field and thereby path loss to any accuracy desired. Experimental measurements of path loss in a Thailand jungle are compared with the calculations. The results agree within a standard deviation of 6 db when the jungle conductivity is taken as 0.15 millimho/m.

1. INTRODUCTION

The practical difficulties associated with radio communications in regions of dense vegetation have been recognized for some time.[1] The vegetation has a high water content so that the jungle medium is lossy. If the radio waves propagated along a direct path through the medium the received signal would be exponentially attenuated.[2] With reasonable values of the conductivity ($\sigma = 100$ μmho/m) the attenuation is approximately 0.2 db/m at one megacycle and is even greater at higher frequencies. Such a high attenuation would effectively prevent radio communication over distances greater than a few thousand feet. Since radio communication does exist over greater distances than this, albeit quite poorly on occasion, there has been speculation that the radiation propagates for the most part in the air above the jungle.

This paper derives from first principles expressions for the propagation between two antennas immersed in a jungle-like medium. The theory is compared with experiments conducted in a Thai jungle by Jansky and Bailey[3,4] and the apparent anomaly referred to appears to be explained.

The electrical properties of a jungle are extremely complicated. Most of the space is occupied by air with properties close to the vacuum. The trees and other vegetation have a higher conductivity and dielectric constant and are distributed more or less randomly over the surface. Fortunately, at long wavelengths the propagation characteristics of an electromagnetic wave are not sensitive to this fine detail. An electromagnetic wave propagating through a medium is only sensitive to some average properties of the medium where the average is taken over regions whose linear dimensions are of the order of a wavelength.[2]

We therefore, consider an approximation to the jungle consisting of a uniform slab of fixed height with permittivity ϵ_j and conductivity σ_j bounded by a flat earth surface with permittivity ϵ_g and conductivity σ_g and above by the air with vacuum properties. This picture is reasonable provided:

1. The fluctuation in the number of trees, etc., in an area one wavelength squared is small compared to the total number of trees in this area.
2. If the height of the jungle is larger than a wavelength it is necessary that, within the jungle, the average electrical properties do not vary significantly with height.
3. The transition region between the air above and the jungle must be small compared to a wavelength.

These conditions are probably sufficient to guarantee the qualitative validity of the theory. For quantitative validity it would also be necessary that the terrain be reasonably level over the range and that the properties of the jungle be reasonably uniform over the range.

In this study it was intended to determine the range of validity of this idealized slab model by comparing the results of calculations with experimental data. For the wavelength region studied so far (wavelength from 3 to 50 meters) we have obtained satisfactory agreement between theory and experiment.

The problem of the propagation of electromagnetic energy through a many-layered medium has been studied extensively.[5,6,7] For this general class of problems it is relatively easy to obtain a formal solution to the problem in which the field strength at the receiver is represented by an integral. We have obtained such an integral representation for the particular geometry of our problem.

Unfortunately, the integral representation of the solution is sufficiently complicated that considerable effort is required before numerical results can be obtained in a form suitable for comparison with experiment. We have performed these calculations with sufficient precision so that any discrepancy between the mathematical results and the experimental data is due either to inadequacies in the physical model or uncertainties in the experiment.

At larger ranges it is possible to obtain an approximate analytical evaluation of the integral and an estimate of the error involved in the approximation. This asymptotic solution corresponds to a lateral wave propagation mode, or "treetop" mode. This mode may be described in terms of a wave packet (ray) which propagates up to the treetops, striking the boundary near the critical angle for total internal reflection. It then propagates in the air until it reenters at an angle near the critical angle. The field is attenuated exponentially only along a path from the transmitter to the treetops and from the treetops to the receiver. While propagating through the air the field falls off as $1/r^2$.

This asymptotic formula is capable of explaining most of the experimental data. At the smaller ranges the error becomes too large. For this region the original integral was evaluated by numerical quadrature. As a check on the consistency of the two procedures the numerical quadrature was carried up to ranges where the asymptotic formula was valid. In the region of overlap the two methods gave identical results. Examples where all of these numerical techniques are required are given in Sec. 3, and the transition regions are discussed.

In Sec. 2 the formal mathematical solution is presented and it is demonstrated that this solution is consistent with our description of the lateral waves.

In Sec. 3 the path loss for a variety of experimental data is compared with the theoretical predictions. To date we have considered only the cases where both the receiving and transmitting antennas were in the jungle medium. There is a considerable amount of data for this case and it is in this situation where the greatest difficulties in communication might be anticipated. The calculations considered only the case of vertical polarization, a frequency range from 6 to 100 Mc/sec, and a range up to one mile. Within these restrictions the available data provided by Jansky and Bailey was considered. The theoretical results depend most critically on the jungle conductivity and this was the only parameter varied. The theoretical and experimental results agree to within a standard deviation of 6 db when the jungle conductivity is taken as 0.15 millimho/m. This agreement is considered satisfactory. Jansky and Bailey performed independent measurements corresponding to the same range, height of antennas, and frequency with results varying by as much as 13 db.

The average conductivity of the Thailand jungle has not been measured, and there are very few measurements of this kind available for any jungle. The value we have obtained is reasonable and is consistent with experimental results[8] obtained in California.

The slab model predictions appear to provide a satisfactory correlation with the experimental data. Indeed the model works well for wavelengths shorter than we had at first anticipated and we intend to extend our calculations to still shorter wavelengths in order to determine when and if the model seriously breaks down. We also intend to consider horizontal polarizations and cases where one or both of the antennas are above the jungle.

2. PHYSICS OF THE SLAB MODEL

The mathematical problem posed by the idealized physical situation possesses an exact formal solution. It suffices to consider only the formula for the z-component of the electric field, since the other field components are readily obtained from E_z. The z component of the electric field at the receiver is given by

$$E_z = P \int_{-\infty}^{+\infty} \alpha^3 H_o^{(1)}(\alpha R)\, F(\alpha)\, d\alpha \text{ volt/m} \tag{1}$$

where $P = \frac{\pi i f}{n^2}$ (power radiated in kw)$^{1/2}$ and f is the frequency in Mc.

For both the receiving and transmitting antenna in the jungle

$$F(\alpha) = \frac{1}{x_j}\left[e^{-x_j X} + \left(V_g e^{-x_j Y} + V_a e^{-x_j (2H-Y)} + V_a V_g e^{-x_j (2H+X)} + V_a V_g e^{-x_j (2H-X)}\right) \Big/ \left(1 - V_a V_g e^{-x_j 2H}\right)\right] \tag{2}$$

where

$$V_a = \frac{x_j - n^2 x_a}{x_j + n^2 x_a} \qquad V_g = \frac{n_g^2 x_j - n_j^2 x_g}{n_g^2 x_j + n_j^2 x_g}$$

where $n^2 = \epsilon + 18\, i\sigma$ (millimho/m)/f(Mc). (See Fig. 1.) This integral represents the solution in the jungle as a superposition of cylindrical waves which are successively reflected from the jungle-air and jungle-ground interfaces with reflection coefficients V_a and V_g respectively. The variable of integration, α, is the cylindrical propagation constant.

Distances are measured in units $c/\omega = 150/(\pi f) = 1/K_o$

and $R = K_o r$, $H = K_o h$, $X = K_o |z - z_o|$, $Y = K_o (z + z_o)$, $Z = K_o z$, $Z_o = K_o z_o$.

The attenuation factors for different paths are described in terms of the variables

$$x_j = \sqrt{\alpha^2 - n_j^2}, \quad x_a = \sqrt{\alpha^2 - 1} \quad \text{and} \quad x_g = \sqrt{\alpha^2 - n_g^2}$$

and the square roots are defined so that the real parts of the x's are positive.

The various terms in Eq. (2) have a simple interpretation. The first term $e^{-x_j X}$ represents the field produced by the dipole in the absence of the interfaces. The next term proportional to $V_g e^{-x_j Y}$ represents those plane waves which are reflected an odd number of times with the first reflection occurring at the ground. The remaining terms represent cases where there is an odd number of reflections with the first reflection at the air interface, an even number of reflections with the first reflection at the air interface, and an even number of reflections with the first reflection at the ground interface. The numerators represent the results of the first one or two reflections respectively and the denominator sums the contributions from all subsequent pairs of reflections from the ground and air interfaces.

For most values of the parameters the integrand in Eq. (1) is strongly peaked at $\alpha = 1$ corresponding to a ray, called the lateral wave, propagating at the angle of total internal reflection. In such cases the integral may be approximated by a simpler integral describing this ray. The new integral can be evaluated easily by a Gaussian quadrature. An approximate analytical evaluation of the new integral can also be performed. Such solutions are presented in Appendix III and the domains of their validity are discussed.

When the methods described above break down, it becomes necessary to evaluate the original integral, Eq. (1), numerically. This is a difficult task because the integrand is oscillatory. Methods for accurately evaluating such oscillatory integrals are available and they were applied to this type of problem for the first time in this study.

When the solution can be expressed in terms of the superposition of a set of plane waves with propagation vectors lying in a small region of k-space it is most appropriate to interpret the solution in terms of a wave packet which suffers successive reflections. In order to gain some insight into the nature of these solutions we consider the behavior of a wave packet after a single reflection.

Consider a wave packet with average propagation vector $\vec{k}^o$ incident on a plane boundary as in Fig. 2. For simplicity we assume the fields are independent of y. The incident wave packet can then be described by

$$E_z^{inc}(x,z,t) = \int dk_x dk_z \, A(k_x,k_z) \exp i(k_x x + k_z z - \omega t) \tag{3}$$

where ω is a function of k_x and k_z and the function A is strongly peaked at $\vec{k} = \vec{k}^o$. If we expand the phase factor about the point $\vec{k} = \vec{k}^o$, we obtain

$$E_z^{inc}(x,z,t) = e^{ik_x^0 x + ik_z^0 z - i\omega^0 t} f\left(x - \frac{\partial\omega}{\partial k_x} t,\ z - \frac{\partial\omega}{\partial k_z} t\right) \tag{4}$$

where $d\omega/dk_x$ and $d\omega/dk_z$ are components of the group velocity evaluated at $\vec{k}^0$ and

$$f(\alpha,\beta) = \int dk_x dk_z\ A(k_x, k_z)\ \exp i \left[(k_x - k_x^0)\alpha + (k_z - k_z^0)\beta\right] \tag{5}$$

The reflected wave is given by

$$E^{ref}(x,z,t) = \int dk_x dk_z\ A(k_x,k_z)\,|V(k_x,k_z)|\exp i\ (k_x x - k_z z - \omega t + \phi(k_x,k_z)) \tag{6}$$

where the reflection coefficient is $|V|e^{i\phi}$. If we assume that the amplitude of the reflection coefficient varies sufficiently slowly so that it may be taken outside the integral we obtain

$$E^{ref}(x,z,t) = |V(k_x^0,k_z^0)|\ e^{i(k_x^0 x - k_z^0 z - \omega^0 t + \phi(k_x^0,k_z^0))}$$

$$\cdot f\left(x - \frac{\partial\omega}{\partial k_x} t + \frac{\partial\phi}{\partial k_x},\ -z - \frac{\partial\omega}{\partial k_z} t + \frac{\partial\phi}{\partial k_z}\right) \tag{7}$$

where f is the same function that occurs in Eq. (4) and the derivatives are again evaluated at $\vec{k}^0$.

Consider now an incident wave packet which first strikes the boundary at $t = 0$ and at this time is nonvanishing only for negative x and z. These conditions require

$$f(\alpha,\beta) = 0 \quad \text{if} \quad \alpha > 0 \quad \text{or} \quad \beta > 0.$$

By examining Eq. (7) we see that the reflected signal will not appear in region I (illustrated in Fig. 2), until a sufficient time has elapsed so that the second argument of f is negative at $z = 0$. This time delay is given by

$$\delta T = (\partial\phi/\partial k_z)\ /\ (\partial\omega/\partial k_z).$$

When the field reappears, the wave packet has traveled a lateral distance δL obtained by setting the first argument of f equal to zero. The transverse displacement is given by

$$\delta L = -\partial\phi/\partial k_x + (\partial\omega/\partial k_x)\ \delta T.$$

This lateral mode, or "treetop mode," dominates at large distances because it propagates mainly in the lossless medium rather than in the jungle. The effect will be a large one only when the phase ϕ is a rapidly varying function of either the frequency or angle. In our problem this occurs at the critical angle θ_c of total internal reflection. At $\theta = \theta_c$, $\delta L = \infty$ and is a rapidly varying function of the difference $\theta - \theta_c$.

By looking in detail at the dependence of δL on θ it is possible to demonstrate that the field strength varies as $\delta r^{-1/2}\ \delta L^{-3/2}$ which is consistent with the analytically obtained dependence of $1/r^2$.

The above analysis is by no means novel or original. The phenomenon is a general characteristic of wave motion and whenever the phase of a wave is a function of any parameter there will be a displacement in the corresponding "canonically conjugate" parameter. In electrical network theory the time delay associated with a phase change which varies rapidly with frequency is very familiar. In quantum mechanics the rapid energy variation of a phase shift at a resonance is associated with the time the particle spends in the resonant state. The lateral displacement of a light beam has been observed for rays near the critical angle, and this kind of a wave is well known in seismology.

In our discussion it was necessary to make the assumption that the magnitude of the reflection coefficient varied slowly with angle. Such an assumption is correct for a lossless medium but is not valid if there are significant losses. Such losses would change the shape of the wave packet. Other effects, such as a spherical divergence of the wave packet, which change the shape of the wave packet have also been ignored. The formal solution correctly contains all these effects. As a result these considerations are an aid in the understanding of the analytical calculations but do not in any sense replace them.

The formal solution is originally expressed as an integral over real α. In this form the numerical quadrature described in Appendix II is appropriate. The integral may also be considered as a contour integral in the complex plane. By deforming the contour, contributions from discrete poles and branch cuts may be identified and separately considered. This is discussed in detail in Appendix III. The pole terms correspond to damped waveguide modes. For sufficiently large r the contributions from the branch cuts correspond to the lateral waves as described above. At smaller r the contribution from the branch cuts has a more complicated behavior than described above and represents an extension of these simple ideas.

3. SAMPLE CALCULATIONS AND PRELIMINARY COMPARISON WITH EXPERIMENT

Figure 3 is a plot of calculated E_z(rms) vs range for a frequency of 0.88 Mc. For this low frequency, the numerical integration described in Appendix II must be used throughout the range of interest. Figure 3 illustrates three distinct stages of the behavior of E_z vs r. For $r < 10^2$m, E_z decreases exponentially. In this region the waves remain in the jungle and are described mathematically by the pole terms. For $10^2\text{m} < r < 10^3\text{m}$, E_z decreases as $1/r$. The pole terms are now negligible compared to the lateral wave which has a 1/r dependence at short ranges. For $10^3 m < r < 10^4 m$, the r dependence of the lateral wave is in a transition region which will lead to the final dependence of $1/r^2$ given by Eq. (40), Appendix III for $r > 10^4 m$.

Figure 4 illustrates this transition for f = 2 Mc. The points marked with an x are the result of the Gaussian integration of the lateral wave described in Appendix III. For this frequency, the lateral wave is the dominant contribution throughout the range of interest. However, it is best evaluated by the method of Appendix II for $r < 5 \times 10^3 m$. From Fig. 4, the lateral wave falls off slower than $1/r^2$, then faster than $1/r^2$, and finally settles to a $1/r^2$ range dependence.

The remainder of this section is concerned with a preliminary comparison of the calculated electric field with the experimental results of [redacted] The only case under consideration at this time is that of vertical polarization with both transmitter and receiver within the jungle. The frequency range of this comparison is from 6 to 100 Mc.

The distance from the transmitter is limited to one mile. For ranges larger than this the transmitting and receiving antenna were often separated by intervening hills, and the results do not directly apply.

The simple expression [Eq. (40), Appendix III] for the lateral wave is accurate to 3 db in the regime covered by the following graphs. The points on the graphs, however, are calculated by the Gaussian integration and are accurate to 0.1%.

For comparison purposes the calculated electric field is transformed into basic path loss,[4] L_b, by the equation

$$L_b = 139.0 - 20 \log E_{rms} + 20 \log f$$

where f is the frequency in megacycles and E_{rms} (microvolt/meter) is calculated for a point dipole radiating one kilowatt into empty space.

Figure 5 shows a series of curves of L_b vs r (miles) for various receiver heights at a given frequency, f, and transmitter height, z_0. The straight lines are calculated values for the input parameters,

$h = 40$ ft

$\epsilon_g = 15$, $\sigma_g = 10$ millimho/m

and $\epsilon_j = 1.02$

$\sigma_j = 0.1$ millimho/m for the solid line and

$\sigma_j = 0.2$ millimho/m for the dashed line.

Figures 6 through 12 are additional graphs for other combinations of f and z_o. In all graphs the experimental points are denoted by the letters A and B. These points denote measurements along two different winding trails (A and B) at the Thailand jungle test site. The scatter of the experimental data points is believed due to the lack of homogeneity of the jungle and the variation in environment of the antenna. The environment of the transmitting antenna can cause an azimuthal asymmetry in the radiation patterns. Also, the jungle character of the ray path at each azimuth may be different. Thus, there will be an azimuthal asymmetry in the electric field. Since the trails are not straight, each measurement taken at a different range is also at a different azimuth. Finally, the receiving antenna is in a different environment at each measurement.

Since the calculated electric field depends most critically on the jungle conductivity, this was the only quantity varied in the calculations. The curves for the two values of conductivity generally bound the experimental points for all values of receiver and transmitter height and frequency with the exception of the f = 25.5 Mc, z_o = 21 ft case (Fig. 7). Jansky and Bailey,[4] on pp. 4.6 - 4.8 of Report 6, call attention to an apparent inconsistency in their data at 25.5 Mc and low transmitter height and observe that a 10 db decrease in their path loss would make their results more reasonable. This 10 db decrease in measured path loss will bring the experimental points into the neighborhood of the calculated values.

The difference between the calculated and measured path loss is plotted statistically in Fig. 13 for the two conductivities. The points of Fig. 7 were not included. These plots show the lower conductivity to predict a path loss which is too low by 4 db and the higher conductivity to predict a loss high by 5 db. The important result is the standard deviation of 6 db. This illustrates the utility of the slab model. The calculation has a 68% chance of being within 6 db of the measurement for all antenna heights, ranges and frequencies between 6 and 100 Mc when the jungle conductivity is taken as approximately 0.15 millimho/m.

4. CONCLUSIONS

A simple slab model of the jungle is capable of explaining the experimental propagation data over a wide range of parameters. The calculations performed so far have considered only vertical polarization and both antennas in the jungle. We are continuing the study to include horizontal polarization and cases where either or both of the antennas are above the jungle. A comparison with the experimental results of [redacted] and other experimental groups, where available, will be made and the regimes of validity of the slab model will be determined.

APPENDIX 1. DERIVATION OF THE FIELD EXPRESSIONS

The integral representation of the fields can be obtained simply. For the sake of completeness we include an outline of the derivation following that given by Wait.[7]

The free-field equations are

$$\nabla \times E = \frac{i\omega}{c} H \tag{8}$$

$$\nabla \times H = \left(-\frac{i\omega\epsilon}{c} + \frac{4\pi\sigma}{c}\right) E = -\frac{i\omega}{c} n^2 E$$

where $\omega = 2\pi f = cK_o$ is the angular frequency of the radiation. The fields can be expressed in terms of the Hertz vector Π

$$E = \nabla \times (\nabla \times \Pi) \tag{9}$$

$$H = -iK_o n^2 \nabla \times \Pi \tag{10}$$

if Π satisfies the equation

$$\nabla^2 \Pi + n^2 K_o^2 \Pi = 0. \tag{11}$$

Because of the cylindrical symmetry of the problem (with vertical polarization), Π is in the z-direction.

The solutions of Eq. (11) which are regular at the origin and independent of azimuth angle are

$$\Pi = J_o (\alpha R) e^{\pm xZ} \tag{12}$$

where R is measured in units of c/ω and $x^2 = \alpha^2 - n^2$, and the real part of x is greater than zero.

The solution to our problem satisfies the free-field equations everywhere except at the antenna where it has a singularity characteristic of a point dipole. By superposition the solution has the form

$$\Pi_a = \int_0^\infty a_a(\alpha) J_o(\alpha R) e^{x_a(H-Z)} \alpha d\alpha \tag{13}$$

$$\Pi_j = \int_0^\infty \left[a_o e^{-x_j Z} + a_j(\alpha)\, e^{x_j(H-Z)} + b_j(\alpha)\, e^{-x_j(H-Z)} \right] \frac{\alpha J_o(\alpha R)}{x_j}\, d\alpha \tag{14}$$

$$\Pi_g = \int_0^\infty b_g(\alpha)\, e^{-x_g(H-Z)} J_o(\alpha R)\alpha\, d\alpha \tag{15}$$

where the coefficient a_o is a measure of the dipole moments of the transmitting antenna and the other symbols have the same significance as in Section 2.

By using Eqs. (9) and (10) the field components can be determined as linear functions of the four unknown functions $a_a(\alpha)$, $a_j(\alpha)$, $b_j(\alpha)$, $b_g(\alpha)$. The requirement that the tangential components of the electrical and magnetic field be continuous at the boundary leads to four algebraic equations which determine these coefficients. The algebra is straightforward and leads to

$$E_z = 2P \int_0^\infty \alpha^3 J_o(\alpha R) F(\alpha R)\, d\alpha \tag{16}$$

where P and F(αR) are as given in Eq. (1) in the text. It is convenient to have the range of α extend from $-\infty$ to $+\infty$. To do this we note that $F(-\alpha) = -F(\alpha)$ and

$$J_o(\alpha R) = \frac{1}{2}\,[H_o^{(1)}(\alpha R) - H_o^{(1)}(-\alpha R)].$$

With these substitutions we obtain Eq. (1) of the text.

APPENDIX II. EXPLICIT EVALUATION OF THE FIELD INTEGRAL

The explicit evaluation of the field integral given by Eq. (1) of Section 2 cannot be achieved by conventional quadrature techniques because of the rapid oscillation of the Bessel function for large αR. Thus even though the function F(α) converges in general within modest ranges of α, most numerical integration procedures would lose all significance whenever R became appreciable because of the cancellation of the individual quadrature terms with one another. For any well-behaved F(α) the integral is easily shown to tend to zero as R tends to infinity. Via numerical quadrature, this would be manifest by a large number of terms of essentially equal magnitude (though different sign) being added together to yield a residual which may be made as small as desired by letting R become large. Irrespective of the number of significant figures a given digital computer is capable of handling, there will always exist an R beyond which a mechanical quadrature will result in a total loss of significance. There is, however, a means of numerically evaluating the integral in question without meaningful loss of accuracy for any value of R so long as computing time is no obstacle.

In other words, a numerical attack upon the integral is always possible, but becomes more time-consuming as R increases. The broad range of validity for the analytic methods of Section 3, however, insures that these contingencies do not arise. Of particular note concerning the numerical evaluation described herein is its exact agreement with the results of Section 3 in the regime beyond which the latter approach was shown to be accurate. Thus two essentially independent evaluations of the integrals concerned yield identical results, thereby providing a self-consistency check rarely available in similar work. In regimes where the methods of Section 3 are no longer accurate, those described in this appendix are used; and conversely, where these numerical quadratures become too time-consuming, the analytic methods of Section 3 are of sufficient accuracy to be used.

A mechanical quadrature of the field integral is achieved by first noting that the source term contribution may be evaluated explicitly. Thus

$$E_z = E_z^{prim} + A \int_0^{\infty} [f_1(\alpha) + f_2(\alpha)]\, J_0(\alpha R)\alpha^3 d\alpha \qquad (17)$$

where

$$E_z^{prim} = A \frac{e^{in_jQ}}{Q} \left[n_j^2 + \frac{1}{Q} \left\{ \frac{R^2-2(Z-Z_o)^2}{Q^2} \quad in_j - 1/Q - \frac{n_j^2(Z-Z_o)^2}{Q} \right\} \right]. \qquad (18)$$

and

$$Q = \sqrt{R^2 + (Z-Z_o)^2} \quad , \qquad (19)$$

with $f_1(\alpha)$ and $f_2(\alpha)$ given in appendix I.

When α^2 becomes somewhat larger than the modulus of n_j^2, the dominant behavior of $f_1(\alpha)$ is controlled by the exponential factor

$$e^{-x_jY} \rightarrow e^{-\alpha Y} \qquad (20)$$

whereas $f_2(\alpha)$ is dominated by the factor

$$e^{-x_j(2H-Y)} \rightarrow e^{-\alpha(2H-Y)} \quad . \qquad (21)$$

Thus given h, z, z_o, and f (See Sec. 2 for nomenclature) an upper limit of α (called α_{max}) may be chosen beyond which the integrand of Eq. (17) contributes a negligible amount. This α_{max} will be sufficient for a complete range of R. If R is fixed, on the other hand (i.e., the generation of height gain curves is required), α_{max} must be varied in such a way that α_{max} Y is greater than a fixed constant. Since Y and H are directly proportional to the propagation frequency, α_{max} is easily frequency scaled.

All that remains, therefore, is the evaluation of

$$E_z^{sec} = A \int_0^{\alpha_{max}} [f_1(\alpha) + f_2(\alpha)] \, J_o(\alpha R)\alpha^3 d\alpha \tag{22}$$

where $f_1(\alpha)$ and $f_2(\alpha)$ are complex functions. Separating each into real and imaginary parts, the secondary field may still be written in terms of finite integrals along the real α-axis as

$$E_z^{sec} = A \left[\int_0^{\alpha_{max}} g_1(\alpha) \, J_o(\alpha R)\alpha^3 d\alpha \; + i \int_0^{\alpha_{max}} g_2(\alpha) \, J_o(\alpha R)\alpha^3 d\alpha \right] \tag{23}$$

where $g_1(\alpha) = \mathrm{Re}[f_1(\alpha) + f_2(\alpha)]$ and $g_2(\alpha) = \mathrm{Im}\,[f_1(\alpha) + f_2(\alpha)]$.

The severe oscillations of $J_o(\alpha R)$ do not occur until αR is well beyond unity. Indeed at this point $J_o(\alpha R)$ can be accurately replaced by the first two terms of its asymptotic expansion, viz.

$$J_o(\alpha R) \sim \sqrt{\frac{2}{\pi \alpha R}} \left[\cos\,(\alpha R - \pi/4) + \frac{\sin(\alpha R - \pi/4)}{8\alpha R}\right]. \tag{24}$$

This expansion will provide an approximation to $J_o(\alpha R)$ better than one part in 10^4 when $\alpha R > 30$. Choosing $\beta = 30/R$ the integrals of Eq. (23) may be divided into two parts, viz.

$$\int_0^{\alpha_{max}} d\alpha = \int_0^{\beta} d\alpha + \int_{\beta}^{\alpha_{max}} d\alpha \;, \tag{25}$$

with the asymptotic representation of $J_o(\alpha R)$ being used in the last integral. The integrals from 0 to β may be very accurately generated using standard Gaussian quadratures whereas the integrals from β to α_{max} are most amenable to solution by Filon's method.[9] This latter method, described in considerable detail in references 9 and 10, was developed to handle mechanical quadratures of the type

$$\int_a^b f(x) \cos Rx \, dx \tag{26}$$

Upon substituting (24) into (23) for $\alpha > \beta$, the resulting integrals may be cast into one of the forms

$$\int_{\beta}^{\alpha_{max}} F_1(x)\cos(Rx - \pi/4)dx \text{ or } \int_{\beta}^{\alpha_{max}} F_2(x)\sin(Rx - \pi/4)dx \tag{27}$$

The interval from β to α_{max} is then divided into 2n equal intervals of size $\delta = (\alpha_{max} - \beta)/2n$ and the values of the independent variable α at these points are indicated by $x_o, x_1, \cdots, x_{2n}$. Introducing the variable $\theta = \delta R$, one obtains

$$\int_{x_o}^{x_{2n}} F(\alpha)\cos(\alpha R - \pi/4)d\alpha = \delta\left[p(\theta)\left\{F_{2n}\sin(Rx_{2n} - \tfrac{\pi}{4}) - F_o\sin(Rx_o - \tfrac{\pi}{4})\right\} + q(\theta)C_{2n} + r(\theta)C_{2n-1}\right] + R_n \tag{28}$$

and

$$\int_{x_o}^{x_{2n}} F(\alpha)\sin(\alpha R - \pi/4)d\alpha$$

$$= \delta\left[p(\theta)\left\{F_o\cos(Rx_o - \tfrac{\pi}{4}) - F_{2n}\cos(Rx_{2n} - \tfrac{\pi}{4})\right\} + q(\theta)\, S_{2n} + r(\theta)S_{2n-1}\right] + R_n' \tag{29}$$

where the generalized Simpson coefficients p, q, and r are given by

$$p(\theta) = \frac{1}{\theta} + \frac{\sin 2\theta}{2\theta^2} - \frac{2\sin^2\theta}{\theta^3} \tag{30}$$

$$q(\theta) = 2\left(\frac{1+\cos^2\theta}{\theta^2} - \frac{\sin 2\theta}{\theta^2}\right) \tag{31}$$

$$r(\theta) = 4\left(\frac{\sin\theta}{\theta^3} - \frac{\cos\theta}{\theta^2}\right) \tag{32}$$

In addition, one has

$$C_{2n} = \sum_{i=0}^{n} F_{2i}\cos(Rx_{2i} - \pi/4) - \frac{1}{2}\left[F_{2n}\cos(Rx_{2n} - \pi/4) + F_o\cos(Rx_o - \pi/4)\right] \tag{33}$$

$$C_{2n-1} = \sum_{i=1}^{n} F_{2i-1} \cos (Rx_{2i-1} - \pi/4) \qquad (34)$$

$$S_{2n} = \sum_{i=0}^{n} F_{2i} \sin (Rx_{2i} - \pi/4) - \frac{1}{2} [F_{2n} \sin (Rx_{2n} - \pi/4) + F_o \sin (Rx_o - \pi/4)] \qquad (35)$$

$$S_{2n-1} = \sum_{i=1}^{n} F_{2i-1} \sin (Rx_{2i-1} - \pi/4). \qquad (36)$$

The remainder terms are given by

$$R_n = \frac{2}{45} Rh^5 \sum_{i=1}^{n} F^{(3)}_{2i-1} \sin (Rx_{2i-1} - \pi/4) - \frac{nh^5}{90} F^{(4)} (\xi) - O(Rh^7) \qquad (37)$$

$$R_n' = \frac{2}{45} Rh^5 \sum_{i=1}^{n} F^{(3)}_{2i-1} \cos (Rx_{2i-1} - \pi/4) - \frac{nh^5}{90} F^{(4)} (\xi) - O(Rh^7) \qquad (38)$$

As is evident from expressions (37) and (38), the error is proportional to R times the interval size to the fifth power. Thus for very large R the interval size h must be decreased appropriately to maintain accuracy. This in turn results in increasingly long periods of computation. The true practical usefulness of Filon's method is therefore in some doubt. Although postulated to be a panacea for large R, the method is actually most useful from the practical point of view for small θ, i.e., for hR small. With a computer, however, the method does yield a convergent solution as the interval size h tends to zero. This should be contrasted to any other mechanical quadrature scheme which, irrespective of the smallness of the integration step size, will in general not converge for any reasonably large value of R.

APPENDIX III. ANALYTIC SOLUTIONS

In order to obtain an asymptotic expansion of the fields we first note that $H_o^{(1)}$ has the asymptotic expansion

$$H_o^{(1)} (\alpha R) = \sqrt{\frac{2}{\pi\alpha R}}\, e^{-i\pi/4}\, e^{i\alpha R} \left(1 + \frac{1}{8i\alpha R} + O\left(\frac{1}{R^2}\right)\right)$$

valid for $|\alpha R| >> 1$. This may then be inserted into Eq. (1) of the text and the resulting integral can be evaluated as a contour integral.

The integrand vanishes on an infinite semi-circle in the upper half α-plane because of the $e^{i\alpha R}$ term in $H_o^{(1)}$. The original contour which lay along the real axis is therefore deformed to this semi-circle. One is left with integrals along two branch cuts and contributions from poles that were crossed (Fig. 14).

The poles correspond to transmission modes through the jungle which are exponentially damped. The cut at $x_g = 0$ ($\alpha = n_g$) corresponds to the lateral wave at the jungle-ground boundary. This wave is highly attenuated because of the high conductivity of the ground and is negligible. The cut at $x_a = 0$ ($\alpha = 1$) corresponds to the lateral wave at the jungle-air boundary. This wave is not exponentially attenuated and is therefore the dominant contribution after one damping length of the pole terms. There is no branch point at $x_j = 0$ ($\alpha = n_j$) since F is even in x_j.

The poles are the normal modes of propagation through a waveguide and would be the dominant contribution if the waveguide were not a lossy jungle. In this case these pole contributions are negligible for distances greater than a jungle wavelength. The cut at $\alpha = 1$ corresponds to that part of the source radiation which is transmitted from the jungle to the air above and then propagates through the air. This is analogous to the usual ground or surface wave of radio propagation except in this case the lower boundary is jungle rather than ground.

The contribution from the cut at $\alpha = 1$ is evaluated by transforming to the variable s by the transformation $\alpha = 1 + is^2$; $-\infty \leq s \leq \infty$. This transformation describes the contour of the α-plane which runs from $\alpha = 1 + i\infty$ to $\alpha = 1$ on the left of the cut as the negative real s axis and the contour in the α-plane which runs from $\alpha = 1$ to $\alpha = 1 + i\infty$ on the right side of the cut as the positive real s axis.

By taking

$$x_a = \sqrt{\alpha^2 - 1} = s(i + 1)\sqrt{1 + is^2/2}$$

the correct sign for x_a on each side of the cut obtains.

With this transformation the branch cut contribution is

$$E_z^b = P\sqrt{\frac{8}{\pi R}}\, e^{i\pi/4}\, e^{iR} \int_{-\infty}^{\infty} ds(1 + is^2)^{5/2}\, s\, e^{-Rs^2}\, F(\alpha(s))\left(1 + \frac{1}{8iR(1+is^2)} + \cdots\right) \tag{39}$$

The functions F(s) and $(1 + is^2)^m$ where $m = -1$ and $5/2$ are expanded in Taylor series about $s = 0$. Only terms of the integrand that are even in s survive. The result is

$$E_z^b = \frac{\sqrt{2i}\, e^{iR}\, P}{R^2}\left[F_o' + \frac{29iF_o'}{8R} + \frac{F_o'''}{4R} + O\left(\frac{1}{R^2}\right)\right]$$

where the subscript "o" means the derivatives are evaluated at $s = 0$. The expression for E_g^b is an asymptotic expansion in R. The $\frac{1}{R}$ terms in the bracket provide an estimate of the error involved when using the first term alone. The result is then

$$E_{rms} = \frac{|PF_o'|}{R^2} = \frac{9 \cdot 10^{10} \sqrt{Power}}{\sqrt{2}\, \pi f \; |n^2-1| r^2} \quad K\,(Z,\, Z_o,\, H)\ \mu volt/m \tag{40}$$

where

$$K(Z,Z_o,H) = \left| \frac{\left[e^{x_j^o Z_o} + V_g^o e^{-x_j^o Z_o}\right] \left[e^{x_j^o Z} + V_g^o e^{-x_j^o Z}\right]}{\left[e^{x_j^o H} - V_g^o e^{-x_j^o H}\right]^2} \right|$$

and

$$V_g^o = \frac{n_g^2 x_j^o - n_j^2 x_g^o}{n_g^2 x_j^o + n_j^2 x_g^o}\ , \quad x_g^o = \sqrt{1 - n_g^2} \quad \text{and} \quad x_j^o = \sqrt{1 - n_j^2}\ .$$

The fractional error is

$$E = \left| \frac{29i}{8R} + \frac{F_o'''}{4RF_o'} \right| = \left| E_1 + E_2 + E_3 + E_4 + E_5 \right| \tag{41}$$

where

$$E_1 = \frac{-3h}{rx_j^o} \left[\frac{1 + V_g^o e^{-2x_j^o H}}{1 - V_g^o e^{-2x_j^o H}} \right]$$

$$E_2 = \frac{\left(3n_j^2 - 1\right)}{R}$$

$$E_3 = \frac{12 n_j^4 V_g^o e^{-2x_j^o H}}{R\left(n_j^2 - 1\right) \left(1 - V_g^o e^{-2x_j^o H}\right)^2}$$

$$E_4 = \frac{3}{2Rx_j^o} \left[\frac{Y\left(e^{x_j^o Y} - V_g^{o2} e^{-x_j^o Y}\right) + XV_g^o \left(e^{-x_j^o X} + e^{x_j^o X}\right)}{e^{x_j^o Y} + V_g^{o2} e^{-x_j^o Y} + V_g^o \left(e^{-x_j^o X} + e^{x_j^o X}\right)} \right]$$

$$E_5 = \frac{3b_j^2 n_g^2 (n_g^2 - n_j^2)}{R\, x_j^o x_g^o (n_g^2 x_j^o + n_j^2 x_g^o)^2} \times \left[\frac{e^{-x_j^o X} - e^{x_j^o X} + 2V_g^o e^{-x_j^o Y}}{e^{x_j^o Y} + V_g^{o\,2} e^{-x_j^o Y} + V_g^o \left(e^{-x_j^o X} + e^{x_j^o X} \right)} + \frac{2e^{-2x_j^o H}}{1 - V_g^o e^{-2x_j^o H}} \right]$$

This expression is too complicated to be useful if a quick estimate of the error involved in using Eq. (40) is desired. Comparison with a numerical evaluation of the branch-cut integral, Eq. (39), shows that the discrepancy between Eq. (40) and the exact evaluation agrees with the estimated error only at the high frequencies ($f \geq 25.5$ Mc). At $f < 25.5$ Mc, the discrepancy is greater than the estimated error by a factor of three in some cases. It would therefore be desirable to replace the error expression, Eq. (41), by a simpler and more accurate error bound. Numerical work shows that the expression for the error may be approximated by the following formula:

$$E = \left| \frac{3\, n_j^4}{R(n_j^2 - 1)} \right| + \left| \frac{3\,(H - Y/2)}{R\, x_j^o} \right| \tag{42}$$

for frequencies in the range $6 < f < 100$ Mc. However, this expression is overly pessimistic at the high frequencies and is too small for $f < 6$ Mc. An accurate error bound at all frequencies can be obtained by simply using three times E (expression 41). More extensive numerical comparisons will be necessary in order to determine simpler expressions for accurate error bounds in all frequency regions.

Both expressions (41) and (42) show the error to be inversely proportional to r. The error decreases as the range increases. Thus the long-range behavior of the electric field is accurately given by expression (40).

When $E = 1$, expression (40) is no longer accurate but the integrand of Eq. (39) is still well-behaved so that a Gaussian integration of Eq. (39) is easily effected. In this regime, the branch cut is still the dominant contribution. However, it is evaluated numerically to an accuracy of 0.1% rather than by the asymptotic expansion.

For $E > 1$, the Gaussian integration fails to converge. In this regime a numerical integration of the original integral is used. The numerical integration is accomplished by a machine code, described in Appendix II, which evaluates the total field, that is, the contribution from the cuts and all poles. We thus are in a position to make an accurate numerical evaluation of E_z for all values c[illegible] input parameters.

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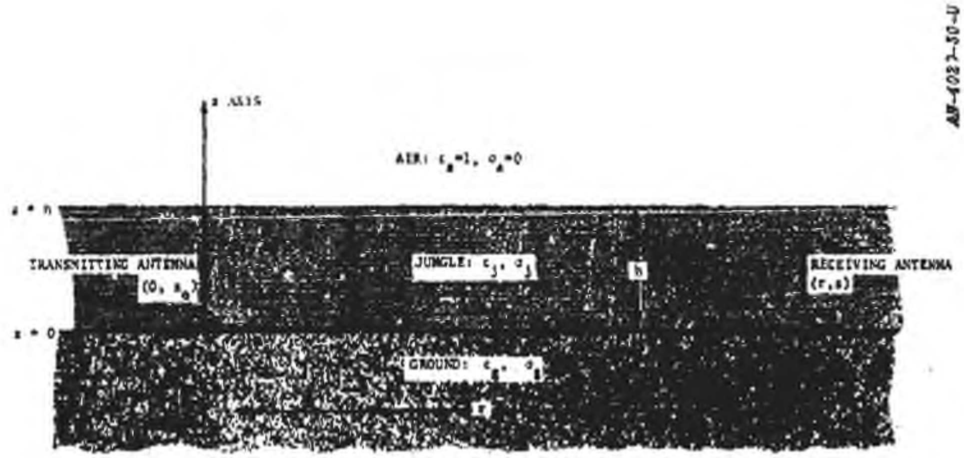

FIGURE 1. THE STRATIFIED MODEL OF THE JUNGLE COMMUNICATIONS MEDIUM

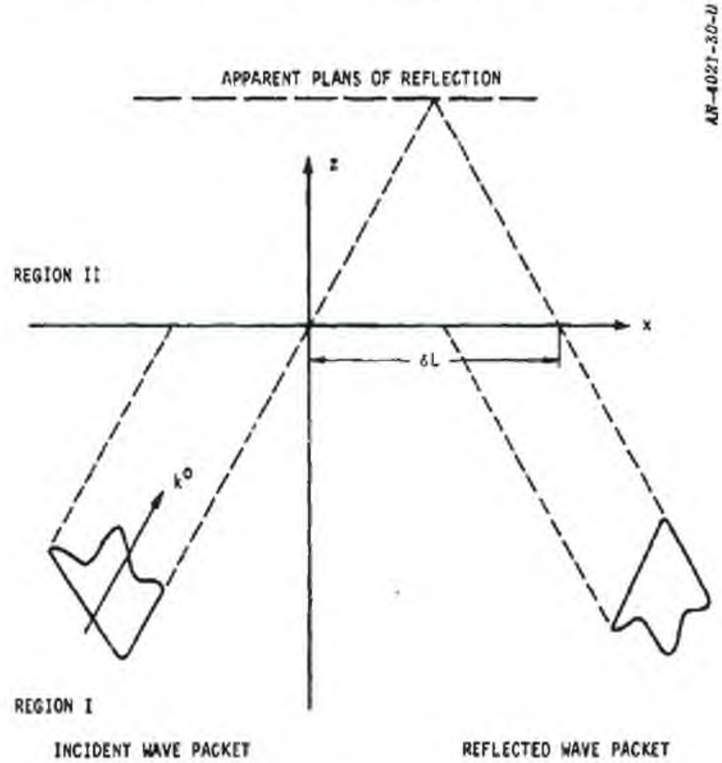

FIGURE 2. DISPLACEMENT OF WAVE PACKET

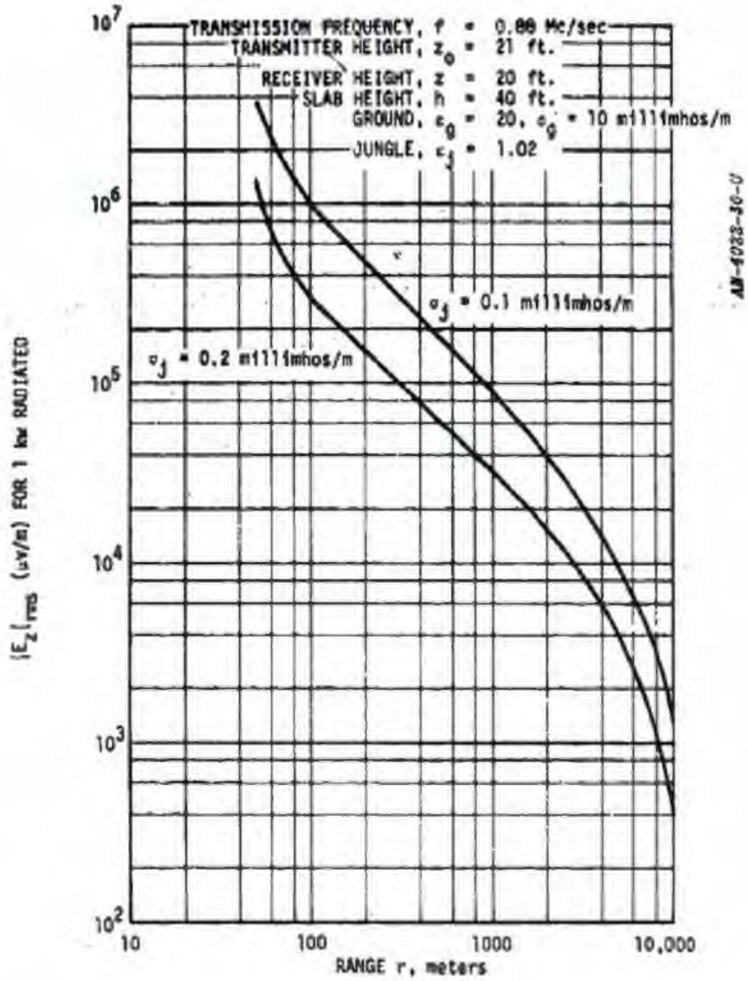

FIGURE 3. SAMPLE CALCULATED FIELD FOR f = 0.88 Mc/sec

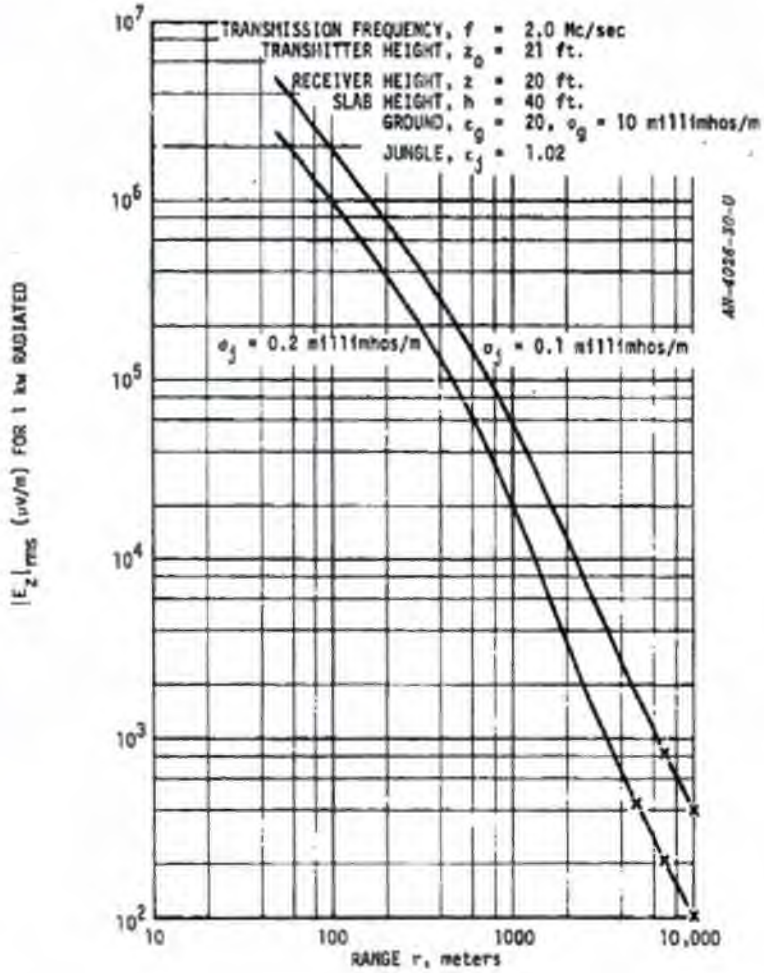

FIGURE 4. SAMPLE CALCULATED FIELD FOR f = 2.0 Mc/sec

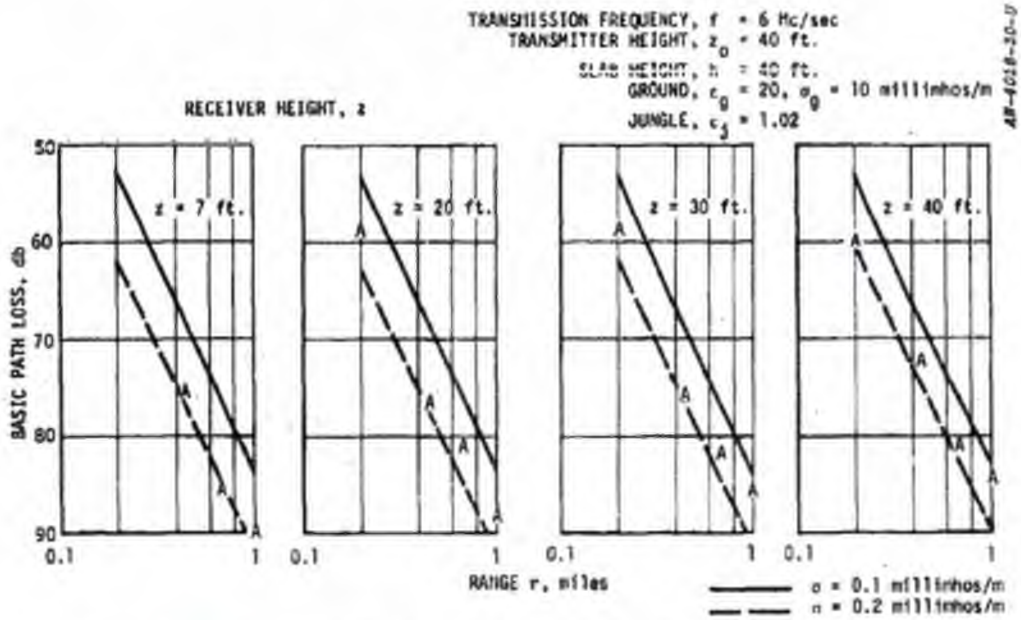

FIGURE 5. COMPARISON OF PREDICTED AND MEASURED PATH LOSS, f = 6 Mc/sec, z_0 = 21 ft

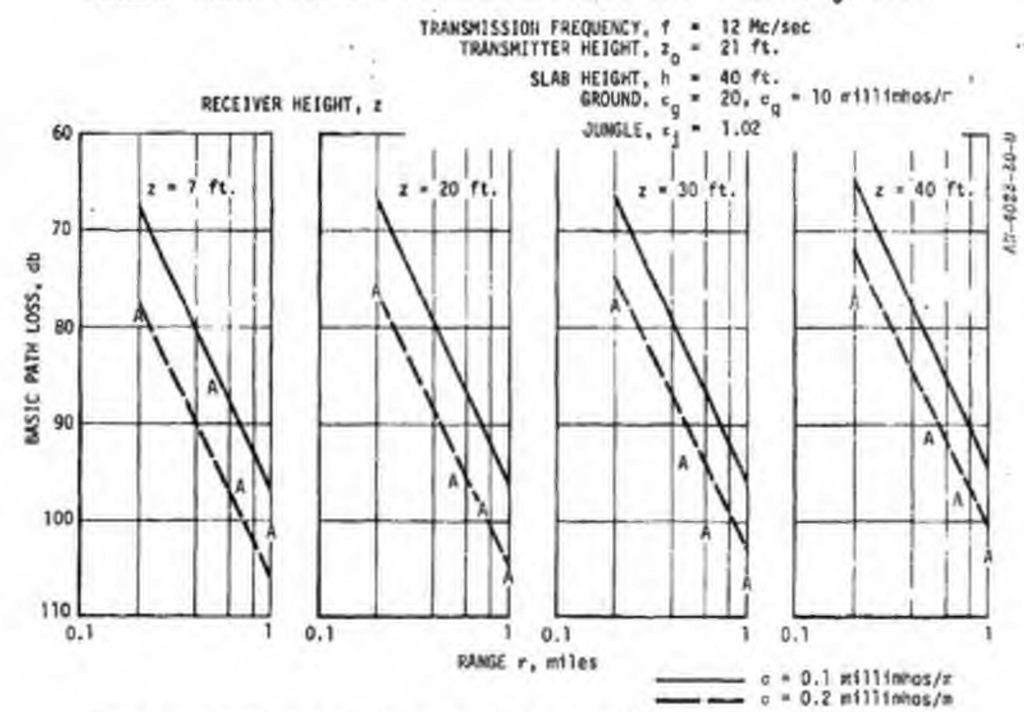

FIGURE 6. COMPARISON OF PREDICTED AND MEASURED PATH LOSS, f = 12 Mc/sec, z_0 = 21 ft

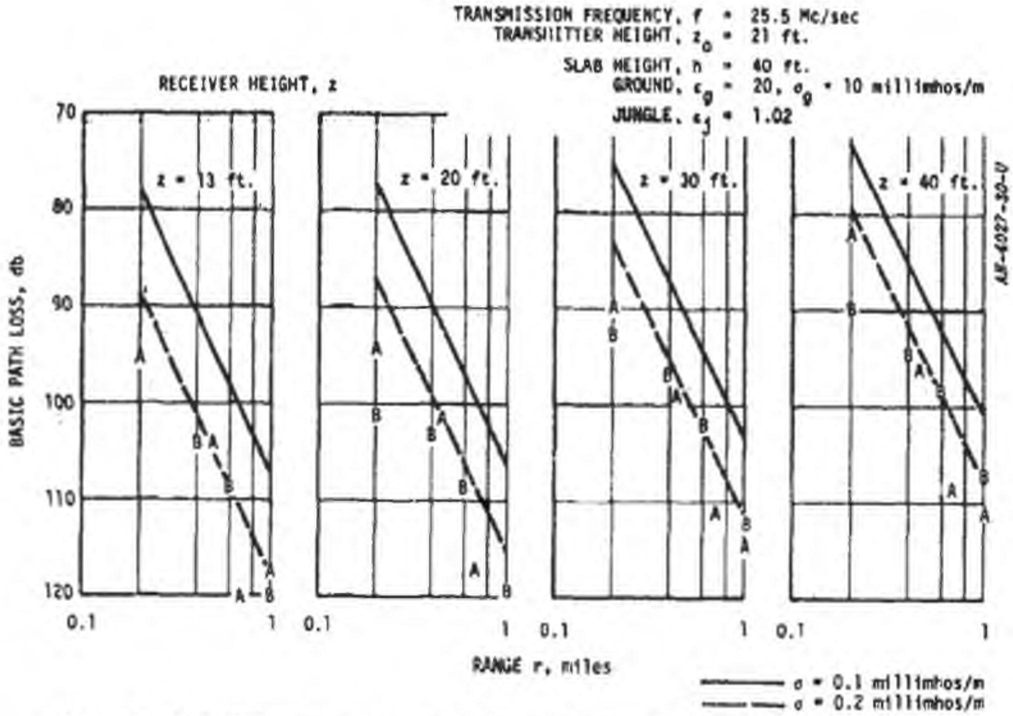

FIGURE 7. COMPARISON OF PREDICTED AND MEASURED PATH LOSS, f = 25.5 Mc/sec, z_o = 21 ft

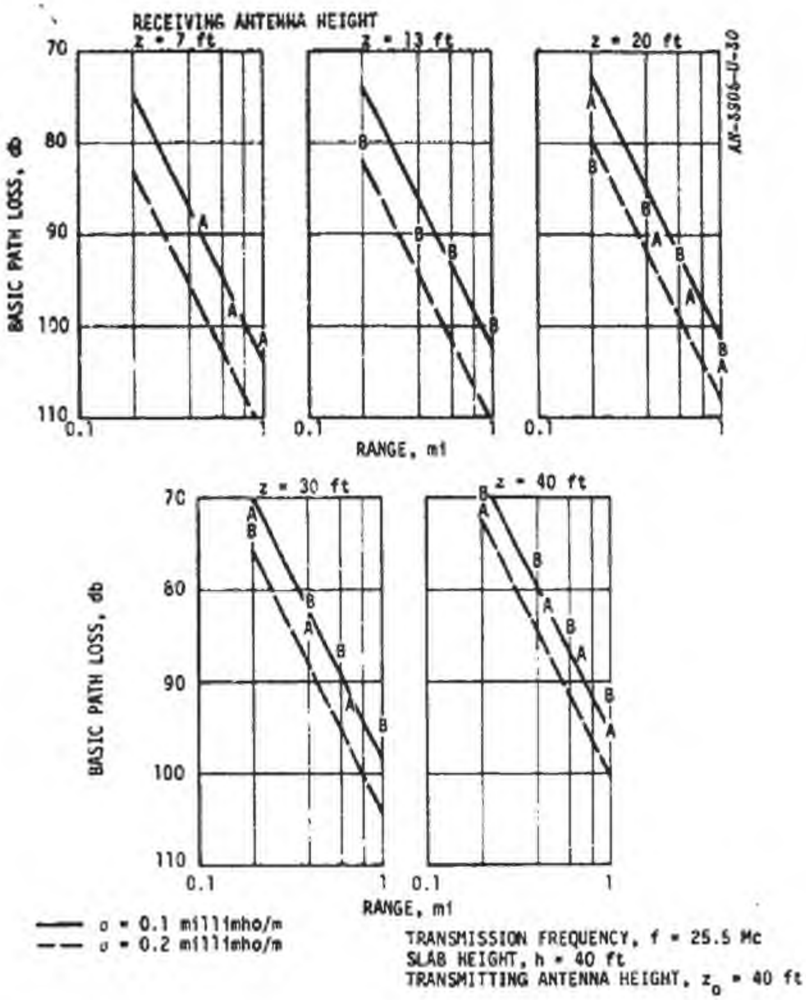

FIGURE 8. COMPARISON OF PREDICTED AND MEASURED PATH LOSS, f = 25.5 Mc/sec, z_0 = 40 ft

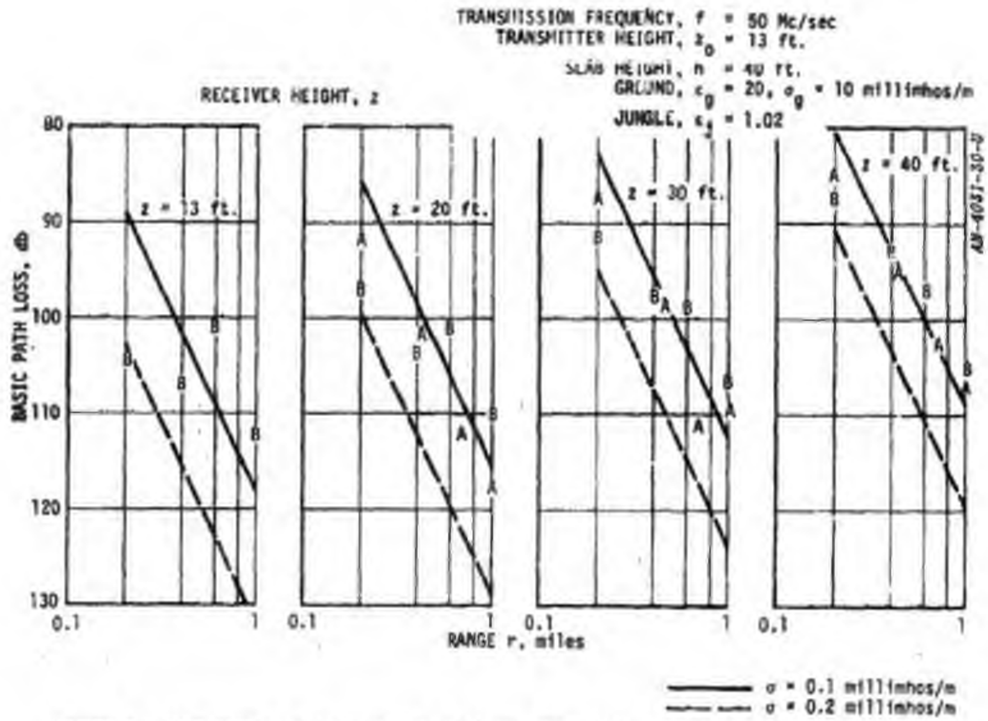

FIGURE 9. COMPARISON OF PREDICTED AND MEASURED PATH LOSS, $f = 50$ Mc/sec, $z_o = 13$ ft

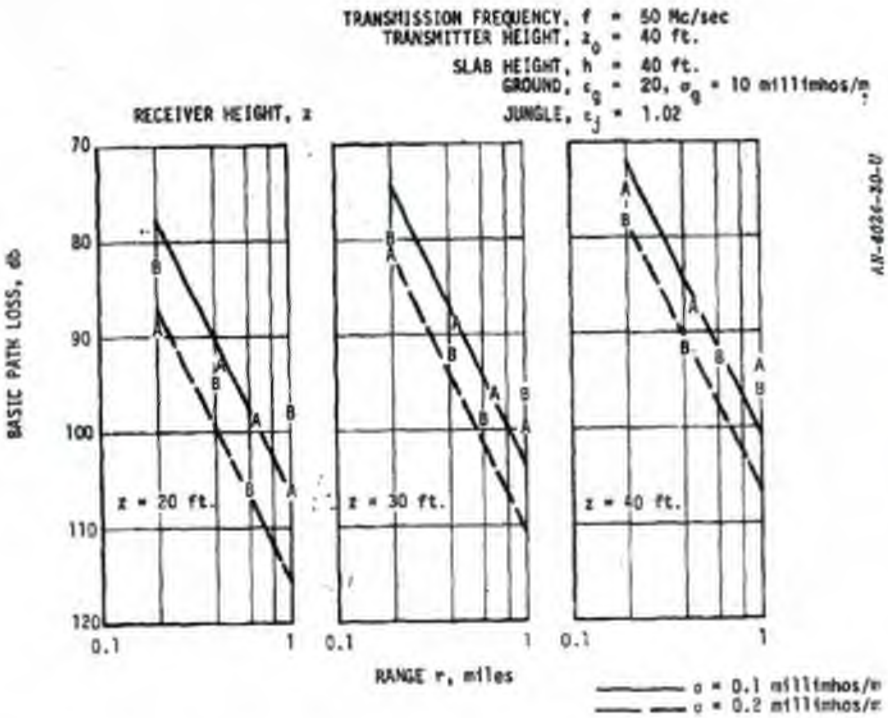

FIGURE 10. COMPARISON OF PREDICTED AND MEASURED PATH LOSS, f = 50 Mc/sec, z_0 = 40 ft

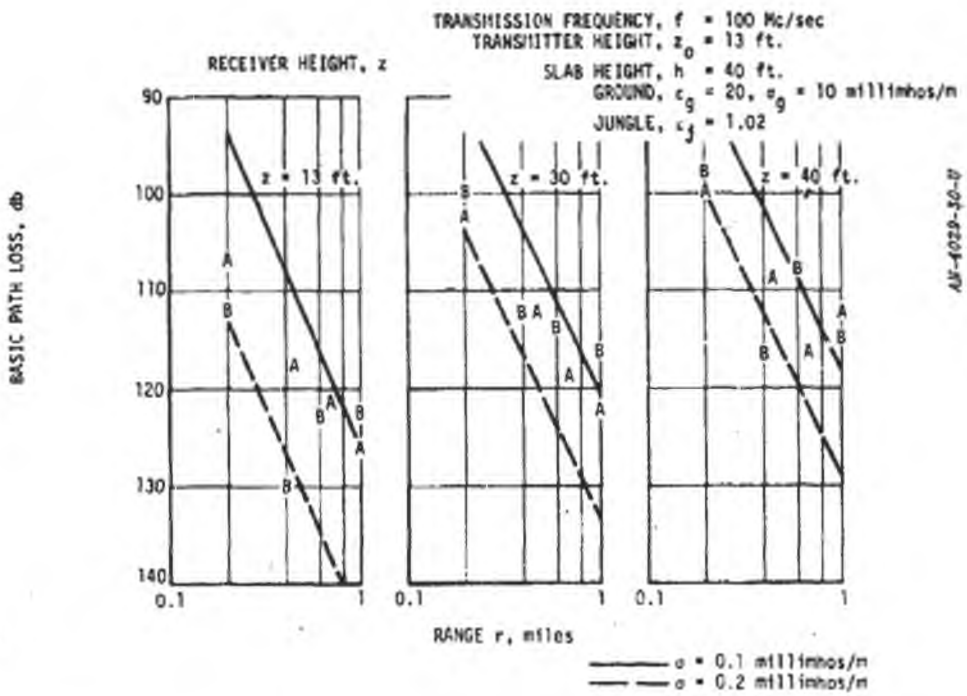

FIGURE 11. COMPARISON OF PREDICTED AND MEASURED PATH LOSS, f = 100 Mc/sec, z_o = 13 ft

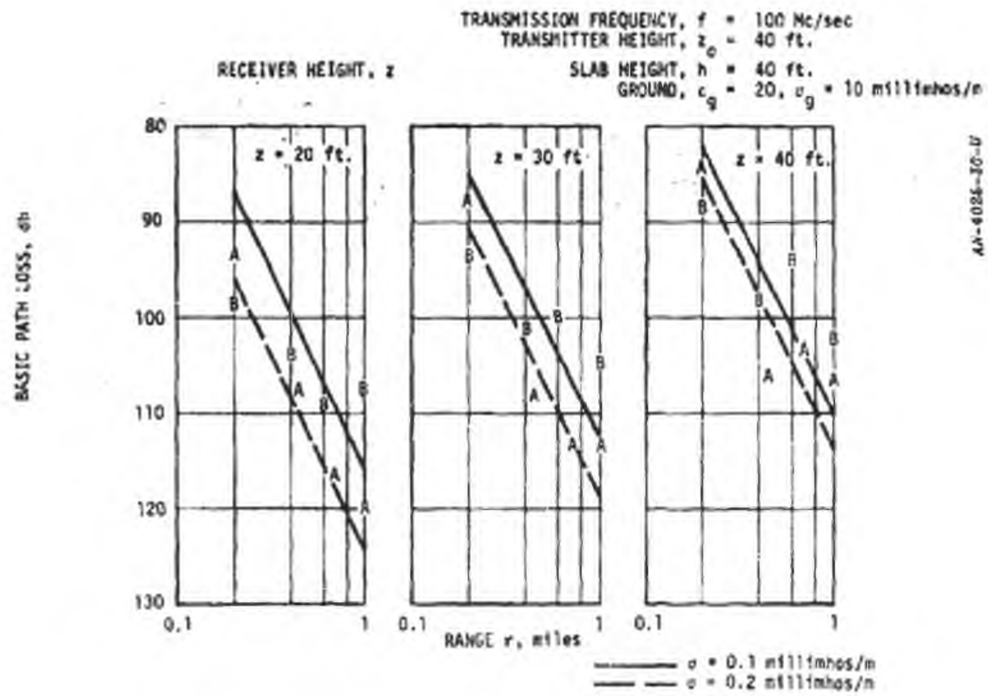

FIGURE 12. COMPARISON OF PREDICTED AND MEASURED PATH LOSS, f = 100 Mc/sec, z_o = 40 ft

[redacted]

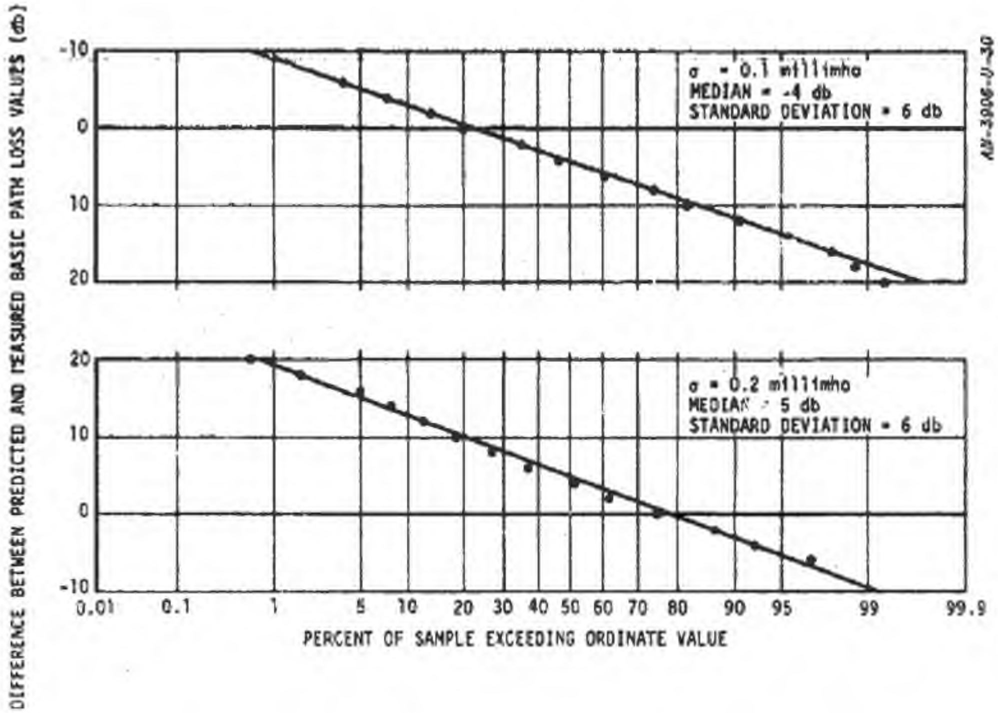

FIGURE 13. DISTRIBUTIONS OF DIFFERENCES BETWEEN PREDICTED AND MEASURED PATH LOSS

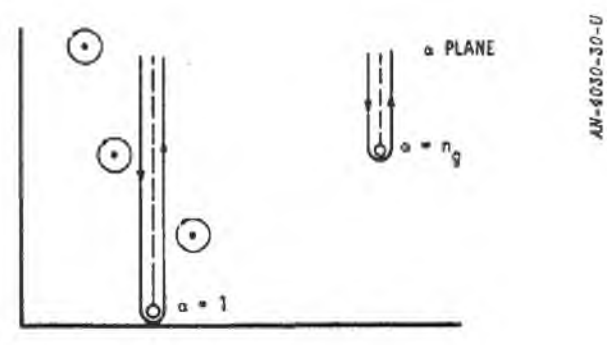

FIGURE 14. CONTOURS IN THE COMPLEX α-PLANE

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11. SUPPLEMENTARY NOTES Part 2, 4613-137-X(2), contains papers not available to foreign nationals.	12. SPONSORING MILITARY ACTIVITY Advanced Research Projects Agency, Department of Defense, Washington, D. C.

13. ABSTRACT

CIRADS Proceedings, Volume I, comprises papers presented at or prepared for the first meeting of the Counterinsurgency Research and Development Symposia, held at Arlington, Virginia, on 14, 15, and 16 June 1966, under the sponsorship of the Advanced Research Projects Agency of the Department of Defense, Project AGILE. Papers prepared for but not presented at the meeting are included. (U)

The purpose of the meeting was to provide a forum for the exchange of technical information in the area of counterinsurgency research and development. The subject matter ranges from the technology of reconnaissance and weapons through tactical and strategic analyses to research in the biomedical and social sciences. (U)

Part 1 contains papers classified through Secret. All classified papers in Part 1 have been approved for release to ABC (Australian-British-Canadian) Nationals cooperating with the United States under the TTCP Subgroup R-Counterinsurgency Programs. (U)

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Reconnaissance						
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March 1967

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SUBJECT: Downgrading of an Individual Paper in these Proceedings

Report No. 4613-137-X(1)
"CIRADS Proceedings (U)"
Volume I, Part 1
AD 376 000
SECRET

Meeting of 14, 15, 16 June 1966
Arlington, Virginia

The classification of "Introductory Remarks," by Dr. Charles M. Herzfeld, Director, Advanced Research Projects Agency, Washington, D. C., pp. 1-4, is hereby changed from CONFIDENTIAL to UNCLASSIFIED.

Authority: Director
Advanced Research Projects Agency
Washington, D. C.

Date of Action: 27 February 1967

(b)(6) [redacted]

Security Officer

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DOD 5200.1-R, DEC 78

REVIEW ON 26 SEP 85

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CIRADS

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PROCEEDINGS (U)

Volume I

Part 2

DDC
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14, 15, 16 June 1966
Arlington, Virginia

Published by
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CIRADS PROCEEDINGS (U)

VOLUME I, Part 2

Meeting of 14, 15, and 16 June 1966
ARLINGTON, VIRGINIA

PROJECT AGILE

Sponsored by
ADVANCED RESEARCH PROJECTS AGENCY

Published by
Infrared Physics Laboratory
WILLOW RUN LABORATORIES
THE UNIVERSITY OF MICHIGAN
under CONTRACT SD-91
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PREFACE
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CIRADS (Counterinsurgency Research and Development Symposia) were organized to provide a forum for the exchange of technical information in the area of counterinsurgency research and development. The operational activities undertaken by the Department of Defense to provide overseas internal defense assistance to the developing nations are broad indeed; these include civic action, psychological operations, paramilitary and military training, provision of military equipment, and actual participation in anti-guerrilla warfare. The scope of supporting research and development is as broad as these operations. Therefore, CIRADS all concerned with subject matter ranging from the technology of reconnaissance and weapons through tactical and strategic analyses to research in the biomedical and social sciences.

The last five years have seen an enormous growth of research and development effort in these many areas. This growth has been spurred largely by the growing war in Viet Nam and by an increasing awareness of such problems elsewhere in the world. The Department of Defense research and development during this period has concentrated on highly specialized items designed for use in Viet Nam as well as on efforts with more general application. These efforts are now sufficiently developed to permit them to be defined as integrated research and development activities including many technical disciplines, with a focus on the overseas internal defense problem. The purpose of CIRADS is to help provide this focus.

The CIRADS Proceedings is the written record of the papers presented at the meetings, and of other papers accepted for publication only rather than for an oral presentation. The publication is handled for ARPA by BAMIRAC (Ballistic Missile Radiation Analysis Center), a facility of the Infrared Physics Laboratory, Willow Run Laboratories, Institute of Science and Technology, at The University of Michigan. BAMIRAC is supported by ARPA under Contract SD-91.

This first volume of the CIRADS Proceedings comprises papers that were presented at or prepared for the first meeting. The meeting was held at the Institute for Defense Analyses, Arlington, Virginia, on 14, 15, and 16 June 1966. The program for the meeting is reproduced in Part 1; last-minute changes are noted there.

Part 2 contains papers classified through Secret and not releasable to foreign nationals. Part 1 contains all other papers classified through Secret.

ABSTRACT
Unclassified

CIRADS Proceedings, Volume I, comprises papers presented at or prepared for the first meeting of the Counterinsurgency Research and Development Symposia, held at Arlington, Virginia, on 14, 15, and 16 June 1966, under the sponsorship of the Advanced Research Projects Agency of the Department of Defense, Project AGILE. Papers prepared for but not presented at the meeting are included.

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CONTENTS*
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CIRADS PROCEEDINGS (U)

VOLUME I, Part 2

LIEUTENANT COLONEL DAN ANDERSON, JR.

Lieutenant Colonel Anderson was born in Pennsylvania in 1920, and grew up in New Jersey. He is a graduate of Haddonfield Memorial High School, Aviation Cadet School at Yale University, and the University of Maryland (BS, major in political science and military history). He learned flying and aerial photography while he was quite young.

During the early part of World War II he flew mapping cover of defense installations in Ohio and Indiana and also worked as a "Tech Rep" for Fairchild Camera Corporation. By January 1943, he had been reappointed to Aviation Cadets, whence he graduated as a Photo Officer at Yale University in November 1943. After a tour of duty as an instructor at Cadet School, he was assigned to a P-38 Reconnaissance Squadron at Will Rogers Field, Oklahoma, and shortly went with the squadron to the CBI Theater. At the end of the war he was in the Philippines as the Executive Officer of a squadron mapping the Far East. Subsequent assignments sent him to Langley Field, Virginia; St. Louis, Missouri; England; Omaha, Nebraska; and the Pentagon, where at present he is assigned as an R&D Staff Officer and Special Assistant to the Assistant for Reconnaissance, Deputy Chief of Staff, Research and Development. He is married, and lives in McLean, Virginia.

AERIAL RECONNAISSANCE IN VIET NAM (U)
[redacted]

This Paper Is Not Releasable to Foreign Nationals

D. Anderson, Jr., Lt Colonel, USAF

Office Assistant for Reconnaissance
Deputy Chief of Staff, Research and Development
Headquarters USAF

ABSTRACT
(Unclassified)

This paper presents a brief summary of the evolution of aerial reconnaissance. These evolutionary changes are compared to the methods in present use to accomplish reconnaissance in a counter-insurgency environment in Viet Nam.

Traditionally, reconnaissance has been the eyes of the commander, and his means of "seeing over the hill." Today, in Southeast Asia, reconnaissance is performing the same identical function -- in a different environment and a different level of conflict.

To define these differences in the present reconnaissance role in SEA, it might be wise to step back, for a few moments, and take a look at the historical evolution of reconnaissance.

The first reconnaissance may have been accomplished by the cave man when he climbed a tree to see just where the "other tribe" was, and what they were up to. The next evolutionary milestone was probably the introduction of the horse-weapons-system into battle. This gave the commander more freedom to roam over a wider area. Cavalry was frequently spoken of as a reconnaissance screen. The high point of this type of reconnaissance was probably reached in the Civil War. However, the tendency of both the Union and Southern Commanders was to use their cavalry as a raiding force, rather than in its traditional reconnaissance role. This may have had a major influence on the outcome of several of the battles by denying the respective commanders vital intelligence.

It was at the time of the Civil War, too, that man finally "got off the ground" to perform reconnaissance. "Ballooning" had emerged as a major sport just prior to this time. As soon as the war broke out, several aeronauts volunteered their services to President Lincoln. One of the first balloons to be used in a major battle was flown in the vicinity of Old Dominion Road, near McLean, Virginia, by John Wise of Pennsylvania. Two forms of balloon reconnaissance (or perhaps more properly, observation) were tried. The one by a John La Mountain in July of 1861 used free balloons to overfly the enemy's territory -- an early form of strategic reconnaissance; the other, more widely used technique, flew the balloon from a fixed position. Both methods were reasonably successful. While many sketches were made from the balloons and telegraphic communications were maintained with the ground, there is no evidence of any photographs being taken.

Balloons more or less died out after this war -- this is the earliest historical example of the discarding of our reconnaissance capability between wars. But sure enough, with the outbreak of the Spanish-American War, balloon reconnaissance was immediately called for. By this time, ballooning was in the hands of the Signal Corps and, through heroic efforts, a balloon and a hydrogen generator were brought from Florida to Santa Cruz. It was used for an observation mission on the day following its arrival, and disclosed an alternate path used by the expeditionary force to get to the enemy trenches.

By World War I, the aeroplane had arrived on the scene. In the European conflict, prior to the U.S. participation, early tactics for the use of the aeroplane were evolved primarily by the French. Lt Moore-Brabazon of England developed their first air cameras, as a result of his survey of French methods. The United States, having invented the aeroplane, fell far behind in aviation, and at the time of our declaration of war, had on hand only 30 officers, 119 enlisted men and 51 aeroplanes, of which only four aircraft were described by "Col" Hap Arnold as serviceable. Be that as it may, the immediate use foreseen for the aeroplane at that time was reconnaissance. For this purpose, the two-place DH-4 Observation/Bombing Plane and the Liberty engine, were the major American contributions to the air war. However, as important as the airplane was to become, balloons were still given equal priority and by the end of the war 23 balloon reconnaissance squadrons were in active service as compared to 28 airplane reconnaissance squadrons (out of a total of 45 airplane squadrons) on 13 November 1918.

What then were the tactics evolved for both the balloon and airplane reconnaissance/observation squadrons? First, the balloon observers learned to sit and look. Soon the observer also learned the art of change detection -- to watch for an increase in troops or of truck traffic, or a new milk cow in the barn in the area in front of him. Any significant change was sure to bring down artillery fire -- except for the cow.

The aeroplane observer learned to take pictures (the balloon observer generally did not). Soon the commander had a mosaic of the entire area in front of him. He also learned to do "contact patrol" consisting of visual observations and telegraphing his report to the ground. He further learned to direct artillery fire, using a "clock" code to transmit his corrections. This was considered tactical reconnaissance in direct support of the Army. If he was sent 50 miles behind the front lines to photograph installations, he was performing strategic reconnaissance.

These concepts for reconnaissance/observation stayed with the Air Corps up through the early days of WW II. The major change in concepts came with the addition of a few long range bombers which were provided with a photographic capability. However, the added reconnaissance "flight" was primarily for "seaward" reconnaissance. In any event, right up to the time of North Africa in World War II, direct support of the Army was still conceived to be by observation methods. This direct support observation was still thought to be best accomplished by the use of slow aeroplanes of the O-52, O-46 and O-47. Each observation aircraft carried an observer of World War I vintage with a camera, a radio and his eyeballs.

By late 1939, the British had found the fallacy of such a doctrine. On the first day of the war, a Blenheim bomber was launched to Kiel to photograph the German fleet and was promptly shot down. This was a policy the Germans followed, almost without failure, as long as the Blenheim was used. The Royal Air Force was quick to admit the error of their ways, and among other steps, soon allocated a portion of their new Spitfire fleet to the job of high altitude reconnaissance. They soon learned their new trade well. At high altitudes, to get a readable image, they needed long focal length cameras. They also learned to keep cameras out the intense cold, and the reconnaissance pilot learned precise navigation. But in learning this trade, dividends were returned. They were out of the range of the hostile ground fire and they did return with vital intelligence — the real role of the reconnaissance aircraft. They also learned that the intelligence available in a single photograph was not something that could be "picked off" by any "warm body" — but instead required a skilled specialist. To this end they enlisted the aid of their compatriots, the photogrammetrists, or map makers, who had already developed such skills to a fine art in converting photographic detail to map-topographic detail.

These were but a few of the experiences turned over to the U. S. forces by the RAF when Pearl Harbor was hit on 7 December 1941. Soon, the U. S. had converted 100 P-38's to hi-altitude, multi-camera photo reconnaissance vehicles. Quickly, the slow and vulnerable observation aircraft were retired from the scene. They were replaced by the P-40, and later the P-51, as a tactical reconnaissance airplane, with a single man crew. These "tac-recce" squadrons still accomplished visual observation, and used two cameras, an oblique and a vertical, to obtain photographic confirmation of what they saw and reported.

Much of the world to which the U. S. was not committed was both unknown (as to its target content) and unmapped. Thus, long range bombers were converted for extreme range, or strategic, reconnaissance, to bring home mapping photography for the preparation of route maps and target materials. The final evolution of this phase came with the conversion of B-29's to F-13's to find the targets for this new (and, at that time, secret) fleet of intercontinental bombers.

By the end of the war, a fleet of 1,117 reconnaissance aircraft had been built to provide complete visual, photographic and long range flexibility. They could fly far, they could fly high or low. They could "dice" the beaches as they did for Normandy, or reach the Yokota Steel Works from India, as they did in preparation for the first B-29 raid. The P-38's also had some considerable success in finding Japanese soldiers filling the tree covered passes at Buna in preparation for an invasion of Port Moresby.

At the end of this conflict, the U. S. reconnaissance capability was quickly demobilized as was nearly everything else. The P-38 and P-51 were scrapped and, in a relatively short time, replaced with the new RF-80 jet airplane. This airplane was available in a few squadrons for the Korean "police action." Now, new techniques were to be developed. Photography had to be obtained from extremely high speed aircraft flying both high and low. The older generation of cameras no longer met the need. The technique of "motion-compensation" to compensate for the forward velocity of a high speed aircraft during the fractional moment the camera shutter was open was perfected. In Korea, a "new"and common method of logistics was soon found to be the "A" frame. Supplies were back-packed in -- but movement was confined to the night. Thus, nite photography was rekindled. Not only were the flash bombs of WW II reissued, but the newer "Cartridge System" was developed and operationally employed to give a multiple exposure night capability.

In addition, and of necessity, one other form of visual reconnaissance was perfected, the so-called "Mosquito-fleet." These were the T-6 trainer airplanes used by the forward air controllers. These were used to supplement the visual observation capabilities of the few remaining RF-51 tactical reconnaissance squadrons. The primary mission of the Mosquitoes was that of marking targets and assessing the results of fighter-bomber strikes. However, each aircraft, working in 2½ hour shifts, from 30 minutes before daybreak until they were unable to distinguish objects in the darkness. They performed continuous visual reconnaissance of possible enemy targets along the front lines. This was accomplished either on their own initiative, or as requested by a division tactical air control party (TACP). Thus, in the Korean War, it was the little "mosquito fleet" that followed in the footsteps of their forerunners, the P-51's of WW II, the O-52's of the in between years, and the DH-4 of WW I, in providing direct reconnaissance support. This technique for support of the field Army is still in extensive use in Viet Nam today.

Reconnaissance of the Korean time period still remained photographic and visual -- with an incessant problem, that of obtaining night BDA and night line-of-communications photography. Processing of films, their interpretation and the provision of area cover for the Army, and target folder materials for air strikes, remained the function of two Reconnaissance Technical Squadrons.

Following the Korean War, tactical air doctrine was, to a degree, de-emphasized in favor of strategic reconnaissance — although a major "in-being" fleet of tactical aircraft was maintained in readiness. In the strategic area, the techniques of "Pioneer" reconnaissance, and hi-altitude targeting and surveillance was perfected. There were the days of the "big birds." First, there were the RB-29's and 50's and later, the RB-36, with their concept of a multi-camera, long focal length capability, for high-altitude intelligence. It was in these days that the first really new technique of surveillance of large areas from maximum high altitudes was perfected. These techniques and lessons were apparently adopted for U-2 operations. It was also the development of such capabilities that led President Eisenhower to advocate the principle of "Open-Skys" at the Geneva Conference of July 21, 1955.

There have followed, in periodic cycles in the ensuing years, a series of small but increasingly vital "reconnaissance wars," such as Lebanon, the Suez, the Congo, Cuba, and the Dominican Republic. But essentially, the reconnaissance capabilities remained static with the main change taking place in the airframe.

In the meantime, the laboratories of industry and the Services had, at first tenuously, then in a bold dash, been experimenting with other portions of the electromagnetic spectrum. They looked at both sides of the narrow visual region. By the early 60's, extensive experiments had been conducted with side looking radar, both coherent and non-coherent, electronic intelligence or ELINT, and on the other side, thermal infra-red had also been thoroughly explored.

By the time of the Cuban missile crisis in the fall of 1962, there had come to be a broad and general appreciation of the necessity of aerial or overhead reconnaissance, as it was now sometimes defined, to differentiate it from ground reconnaissance, in the making of National decisions and policy. As announced by the late President Kennedy, it was the techniques of high altitude surveillance, using the U-2, that uncovered and recorded the initial construction activities essential for the installation of IRBM's. However, once their existence had been revealed, it was extremely low altitude reconnaissance that was used to record the current status of the various sites and determine if, in effect, "the plug" had yet been attached.

At this time, new reconnaissance systems were in the making. The impact of exploding laboratory technology and the necessity for above average quality photography at extreme low altitude dash modes, came together in the design of the RF-4C airplane. To solve the problems of low altitudes and high speeds, and still to provide sufficient lateral coverage for a minimum of sorties, the so-called "panoramic" camera was brought quickly to fruition. This technique used a moving optical system to "paint" large scale images on film. The technical complexities of infrared thermal detection were also solved sufficiently to build operational sets. Side looking coherent radar was installed to provide the long-sought all-weather capability -- so the Battle of the Bulge could no longer catch us "with our eyes down." This was the new era of the "multi-sensor reconnaissance" aircraft.

This then was the fabric on which modern reconnaissance was built, as the United States made the decision to provide military assistance to the Republic of South Vietnam -- in a level of conflict labeled counterinsurgency or "COIN" warfare. These were the evolutionary advances of the techniques of reconnaissance — still following its basic tenet of being the eyes of the commander and allowing him to "look over the hill."

Now, after nearly three years of operations in this type of an environment, it is timely to assess the capabilities of these modern reconnaissance systems to operate in such an environment and determine what, if any, changes must be made for the future. This latter point may be crucial if, indeed, the communist block continues to spread the tenets of communism through the exploitation of "local" wars of revolution within the Asian land mass.

I have recently returned from a forty-five day temporary tour of duty in Viet Nam and Southeast Asia. I make no pretense of being an export on these operations after such a short period of time. However, I do believe it is possible to make a few tentative judgments by comparison with our past experiences. This I will attempt to do.

First, let us define the physical environment. First and foremost — we have, indeed, worked in this type of weather and feature environment before. We flew extensive reconnaissance missions throughout the South Pacific island campaign and in India and Burma throughout World War II. The topography of Vietnam is not greatly different than those areas. To a large degree, the technical problems of high altitude surveillance and low level photography have been resolved. The techniques for the use of IR thermal reconnaissance have been steadily improved and represent the one major advancement in reconnaissance at the present moment. However, considerable information is yet to be learned of all of its benefits. Momentarily, the benefits of side looking radar in this type of an environment are not fully apparent. Primarily, I believe that we are learning its present limitations. It may be determined in time, for example, that non-coherent radar, with a strong emphasis on the MTI mode, (and possibly its transmissability) are best for low level reconnaissance and that coherent radar is more advantageous for the high altitude surveillance mission.

The principal points of similarity between this and previous "reconnaissance wars," are: the need for night reconnaissance -- especially of the lines of communications; the need to provide area (mosaic) cover for the planning of new ground operations; and the need to search out the elements of "targetable systems." By the latter I mean the radars, the food storage depots, the things, that if destroyed simultaneously and in totality, inhibit the enemy's ability to perform effectively. As noted in the Air Force Study of World War II Operations, "the selection of objectives, the grouping of zones and determining the order in which they are to be destroyed, is the most difficulty and delicate task in aerial warfare, constituting what may be defined as aerial strategy."

These, then, are some of the general similarities of war in a counterinsurgency environment and those under other higher levels of conflict. To sum up, we have noted that weather environments of the type encountered in Vietnam have been met before, that the topography has been encountered before, and that many of the reconnaissance missions are identical -- at all levels of conflict (short of nuclear wars).

The differences, then, are generally in the methods we have found useful to reconnoiter what are essentially termed "guerrilla actions." Battles in this level of conflict are not formal military confrontations of regimental or divisional units. The battles fought, so far, have often been in the nature of "Indian fort" wars. Plei-Mei was a typical example. In the landings and the sweeps from coastal points, there is a similarity to former Pacific operations, but there's still a difference. The enemy is not uniformed. At times, his fire must be drawn to identify him. Therefore, reconnaissance for order of battle is often next to impossible.

There are seldom classic FEBA's (forward edge of the battle) established. The Army's exploitation of the tactic of vertical envelopment, by helicopter airlift, indicates the negation of this type of battle. Under these conditions, reconnaissance does not stay out in front of advancing troops to identify the enfilade positions or danger spots.

For counterinsurgency actions, reconnaissance has proven as useful as ever for air actions against line of communications -- the classic interdiction problem — and in providing area cover for planning any ground action, whether it be a forward move from in-place or an envelopment miles away. But reconnaissance must also become more subtle in some ways. To cope with this, a number of changes in reconnaissance techniques have been, and others will be, made. While photography will still be the major source of what President Kennedy, in his Cuban missile speech, called Hard Intelligence, other forms of reconnaissance must also be used. For example, D/F cuts of the radio nets required for command and control are effective activity locators. Infra-red is telling where the nightly cook fires are located. ELINT can reveal the network of the air defense systems. We shall also soon add camouflage detection color films to our reconnaissance bag of tricks, since there is still the old jungle problem of telling where they have hidden their trucks under cut branches.

While I noted a short time ago that we are now in an era which we have termed the multi-sensor era, I think the better description of the requirement for counterinsurgency is "flexible-reconnaissance."

Perhaps if I explain a typical problem area in this type of warfare, I will make this point clear. For many years, the Viet Cong have been digging holes and tunnels in the ground. These people are natural born moles. Their tunnels date back to their conflict with the French. The tunnels have become extensive, and are used for the storage of food, the command and control elements, munitions, and the training of people. It is around these holes that people will accumulate. But remember, there is no fixed battle area, and these soldiers do not wear uniforms. When out in the open, they could be a farmer planting rice, or they could be a Viet Cong. However, if you can find the accumulated holes in the ground, the B-52 raids can do an effective job of breaking them up and destroying their food and munitions.

Normally, the answer to this would be to fly low so as to get a good scale -- say 1:2,000. Remember further that these tunnel entrances are very small sites blended into the ground. However, ground fire has, in many areas, made low altitude flying an untenable zone. If you move up in altitude to maintain the same scale, you add focal length. This, in turn, may bring the camera within the hyper-focal distance limitations thereby causing a slight out of focus condition. It could also make the field of view unacceptably small. This sort of problem is what I mean by more subtle and more flexible capabilities. You must have the ability to deal with the unusual, the farmer/soldier, the caves, backpacked supplies, trucks which move only at night, and trucks hidden under false houses with the connecting roads hidden under cut branches.

So far we have only talked of the problems and methods of collecting reconnaissance in a counterinsurgency environment. Now, let us turn our attention to the problems of the Photo Interpreter. In peacetime, the photo interpreter is inclined to be the forgotten individual. As previously recounted, the British found (and still consider) him to be a pretty important asset. The American view has, at various times, been inclined to be that expressed by an Army Training Reg 210-10 dated 4 January 1926, which said of him in part: "An aerial photograph is, in effect, a graphical report of an airplane reconnaissance. . . All officers should be able to read these photographic reports. No more special training or skill is required to use an airplane photograph intelligently than is necessary to use a topographic map." The PI sections of World War II were large, extensive and modeled on the RAF pattern. The RAF established Ports sections, Airfield sections, etc. The value of this was clearly demonstrated by the methods that were used to find and follow the development of the Buzz Bomb and the V-2 Rocket, resulting in Operation Crowbow and the Penemunde Raid. After WW II, and before Korea, much of this activity was dropped. What, in peacetime, would a PI - PI? I clearly recall, however, the Monday following the invasion of the 38th Parallel, the call came to photostat all reserve PI records for immediate recall! We have, of recent years, learned these lessons and have kept on hand a force of PI's, though still not in sufficient quantity. The photo interpreter is the middle link of the three-link chain of reconnaissance. Reconnaissance collects, the PI converts the film to useful information, while the third link, the D/I staff which includes intelligence analysts converts the information to targets.

What then are the problems of the photo interpreter in a COIN environment? First of all, much of the interpretation is classic location of the line-of-communications, water watch, and those things the fathers of some of the present PI's have done before in the Pacific. The problem is that he must dig these things out from the constant mass of foliage spread over much of the country. The next thing is, he does no classic strategic interpretation. There are few large cities outside of Saigon and Hanoi. There is little airfield "watch." His concern is with people and isolated areas. People who carry things -- guns or supplies on their backs -- and small convoys of trucks coming down the isolated roads with their cargos covered with branches to conceal their contents from his eyes. What he is eternally trying to solve is - How did that truck get down that far on the road when the bridges are down in between? Where can they have a new by-pass now? For this, he is using his eyeballs in an over-extended position, and must have the help of reasonably high acuity camera systems. The people are small, the holes in the ground are small, and natural camouflage is all on the side of the enemy. It is obviously easy to hide considerable small arms firepower, including machine guns, in the grass and underbrush that may surround a helicopter landing area. These become not only difficult, but next to impossible, to find by any conventional methods.

Fortunately, we learned sometime ago of the increase in information content obtainable from a positive film transparency as compared to that that can be gained from a reflective print. Nowadays, you find much of Air Force interpretation being done on light tables. This allows film to be looked at in bulk — by the roll rather than the individual print. We have thus been able to become somewhat more sophisticated in our means of looking at reconnaissance as a result of this print-to-positive-film changeover. We can now use fairly high power "zoom" optical microscopes look at small segments of the film. We can use rear projection viewers to get up to a 20X look at the whole frame -- particularly valuable, for example, when looking for the juts of land which might lead to an underriver bridge, a ferry or a ford. All of this magnification is helpful, but there are still times when the PI needs his "old friends," the stereo pair, to see the third dimension.

At present, this means slowing down his timeliness by sending back to the lab for pair of prints or films — or more often, I'm afraid — forget it! The time has come, I believe, when enough evidence is available to say that present diazo compounds have both sufficient grey scale and resolution, to make them adequate for a large majority of tactical interpretation. By this means, we can give the PI a small self-operated ultraviolet printer-processor with which he can make his own "on-line" disposable stereo pairs. In this way, we will get more stereo looks, at a cheaper cost, and on a more timely basis than with many of the elaborate eye-base wrap-around tables we have tried with little success thus far.

In selecting the PI's tools, despite the difficulties I have outlined to you, I hope you will note that I am advocating good tools and simple operations. Light tables, zoom microscopes, rear projection viewers, "Black-light" printers, a PI kit of hand tools and that's about it. However, I hasten to note that perhaps as we work more with IR, Radar and possibly Laser, some additional tools may possibly become necessary. But for the present, these would appear to suffice.

There is one more trend that for any type of interpretation appears at the moment to be of major importance -- that is, the use of the computer in direct support of the interpreter. To see the importance of this -- the first step into semi-automated data processing -- let us assume a move into Country "X". When we move into any new country, we know something about it. We will have to some degree a "data base." The countryside will have been gone over by someone, and PI reports made of the obvious fixed installations -- bridges, towns, etc. Let us assume that, at start, a base of 600 known obvious items exist. As we move in military forces, the base increases as a result of reconnaissance and as new fixed items are found. As the enemy extends his operations, he brings in more equipment, more items are reported, and as more use is made of the various topographic features by the enemy, for fords as an example, the base continues to swell. In time, a number of things happen. The PI builds up a larger quantity of reports he should refer to. Any neighboring friendly force reconnaissance will also be providing reports and sending them to him. He soon becomes submerged in his files of reports and comparative films. However, if he is conscientious, he should and will attempt to consult them.

Soon, more of his time is spent looking up files than at photographs. One of the main things he is interested in is change. What did it look like before? We have machine formatted our PI reports into what we call the Immediate Photo Interpretation Report (IPIR). Much of reconnaissance is flown to produce these reports. However, if the Navy, yesterday, covered an anti-aircraft site and reported it as "still under construction" -- and it still is -- there is no need for him to spend further PI time on it. He need only say "no change." The storage, sorting, and printout of such reports is an ideal computer use. The computer can summarize, within the area of view of the cameras, and in advance of "PI'ing" (while chemical processing is still taking place) all priority targets and the reports about them. I believe that this technique should be put in active use and taken out of its present experimental phase. Computers are in daily personnel use and handle our supply problem in the field, and should also be used to process our voluminous intelligence data base, both in the field and in our fixed stateside installations.

Now, to the more critical and technically difficult phase of reconnaissance, the so-called real-time reconnaissance. First, though this phrase is used frequently, what do we mean to imply by it? The ideal solution for many tactical situations would be the coupling of the reconnaissance and the strike airplane into a single vehicle. Then, as the pilot observed critical targets, he could hit them. In the daytime in clear weather, the fighter-bomber does just that and has done it well for a long time. We would also like to do this at night, and in bad weather too. This could be accomplished with many categories of targets, if we could illuminate them in a manner that could produce an image on a screen, boost the available night ambient light, or penetrate daylight haze and fog.

Unfortunately, with much of our present technology, the "CRT" screen produces too coarse an image. This means that the targets must be large and/or standing out in the open to be seen. For many of the types of COIN targets I have previously described, results will, therefore, probably be limited by technology for quite a while. In this mode, there is a further practical difficulty too, in that the "second man" is busy navigating at night and in bad weather, and thus doesn't have too much time (and possibly little ability) to be a "PI."

Another alternative is available. But first, when is time important? Primarily for targets that are fleeting or that can be moved in a short time. Fixed installations can be hit, if necessary, the following day. This second alternative could be a flying "PI aircraft," or "hunter" aircraft. It could use several forms of illumination and recorders to find these fleeting targets. The reconnaissance information, as it developed, could be relayed to either orbiting strike aircraft, or "strip-alert" aircraft, as appropriate. However, many problems still exist in this alternative also. The types of sensors amenable to airborne processing, are mostly within the family of "line-scan" sensors. Unfortunately, for every line, there is a space. Thus, image magnification is difficult even if put on rapidly processed silver halide film. If displayed on a light table instead of viewed on a screen, the images for sometime will still tend to be coarse. There are numerous other problems as well. But all must be examined in detail if we are to reduce the reconnaissance time element in dealing with fleeting targets.

The third option, more likely to be satisfactorily solved in the near time period, is the transmission of data. Data can be recorded quickly, processed quickly and -- provided bandwidth requirements are not excessive -- be transmitted to line-of-sight distances. The sensors presently amenable to this are non-coherent radar, IR, TV, Laser and some categories of photography. All can be produced, or reproduced, as a line-scan image on the ground. Overlapping the lines helps to a degree but they still form a line and a space, thus, there is a limit to the finite size of the target for which this is acceptable. However, these sensors do capture an image and will get it to some selected spot in a hurry. Here there can be conventional PI's who can deal with the target data to the degree that the delivered resolution or acuity will allow them. This should improve the timeliness of reconnaissance -- where time is vital, and in dealing with fleeting targets of such size as to make identification positive. For the present, at today's level of technology, it cannot be considered a panacea for all reconnaissance, especially where high acuity is more important than time, and in those target categories where difficulties are being encountered with the use of much higher information content cameras, and fine grain films suitable for microscopic examination.

These three options must be fully explored for counterinsurgency operations, however. For here, people are fleeting, weapons are moving, and logistics carriers are here tonight and on an alternate route tomorrow.

In this paper, I have tried, briefly, to summarize the background of military reconnaissance. From this background, we have then looked at the similarities and the differences of what we call counterinsurgency warfare. I believe we have found many of the classic methods of reconnaissance are still in use and are still sound. They merely need continuing improvement. The differences would appear to lie in the type of warfare and in the enemy we are dealing with — these are problems of Indian-fort battles, moles in the ground and non-uniformed irregulars. For this, a flexible and a fairly sophisticated reconnaissance collection capability must be used. We use our firepower best when we develop the components of the enemy's capabilities into targetable systems. The objects forming these components are both difficult to find and difficult to keep track of in this counterinsurgency environment. Computerized data files in the field should help in this area.

The smallness of many targets such as, bands of people carrying food, a few trucks carrying munitions, mobile defensive anti-aircraft weapons are all easily "faded" into the jungle once observed. These targets require the time between "find and strike" to be minimized. There are, at the least, three options for performing "near-real-time" reconnaissance. Their advantages and disadvantages must be weighed to ensure that proper development emphasis is put on those techniques most likely to succeed in the near term.

I will close by summarizing where I feel that we stand concerning our Air Force reconnaissance capabilities in Viet Nam. But first, let us look at some film production figures. In January of this year, 736,000 feet of original film was processed; in February it was 938,000; in April nearly 1,000,000 feet. This incidently resulted in duplication amounts of 1,664,000 in January and 2 542,000 feet of film in April.

Now as to the components of the reconnaissance systems, I will try and give this in terms of a report card.

Aircraft - B+

The new RF-4C system is doing an excellent job although mainly confined to the night mode at present for which it was brought to Viet Nam.

Camera Systems - B

Higher acuity is needed for the COIN environment.

Infra-red - C

An outstanding example of swift introduction of new technology. Imppovement in resolution and in interpreter training is needed then the grade could be "A."

I am downgrading radar at the moment, primarily because of scale — the present 1:390,000 scale is too small! Technically it works as well as intended, but we have not yet learned to get much in the way of significant military information from the records. However, this will come, and the Viet Nam environment will certainly help to speed its arrival.

So much for collection systems; now let us look at processing:

Chemical Processing - B

As I have indicated, reconnaissance is big business in the Pacific. 2,500,000 feet of dupe film in March is big by any standard. Our problems lie in our limited capabilities to process film rapidly to an adequate photographic quality and in the quantities in which it is collected duplicate it in the quantities required by other intelligence agencies.

Information Processing - C+

The other phase of processing that needs improvement is the reduction of imagery from all sensor systems to useful intelligence. This, as indicated earlier, is the place where computer technology may be of considerable assistance. It at present can rate a "C" only because of the hard work of many people. It is a thought provoking area -- but whatever is done, it must be done in as simple a form as possible consistent with field operations. There is one constant refrain one hears in Viet Nam today: "Keep it simple, stupid." The techniques that may work well in an adequately staffed permanent industrial laboratory, may not be supportable in field operations. Maintenance may be difficult and the training required exhorbitant under a policy of annual rotation of personnel. Of one thing I am sure though, as long as there are wars, the commanders will still need reconnaissance to "look over the hill" for him.

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SECURING A PETROLEUM COMPLEX AGAINST THE THREAT OF INSURGENT SABOTAGE: A SYSTEMS APPROACH (U)

[redacted]

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ABSTRACT

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A meaningful criterion for assessing the criticality of (or necessity for protecting) individual petroleum facilities has been established, and most of the analytic techniques necessary for their application have been developed. A procedure has been formulated which uses this criterion for evaluating and choosing among available measures to enhance system security. The procedure has been applied to a large US-owned system in Latin America, with some interesting and usable results.

1. INTRODUCTION

Defense Research Corporation began studying insurgency in Latin America in January 1964. One of the tasks undertaken was that of determining the vulnerability to sabotage of major industrial installations in Venezuela, and of comparing the effectiveness and costs for schemes which could protect these installations from insurgent sabotage activity.

As part of this effort, considerable attention was given to understanding the nature of the insurgent threat in Venezuela. This included a historical review of insurgent activities in Venezuela in general, and of insurgent activity directed against the facilities of the Venezuelan petroleum industry in particular. The data available included captured insurgent documents and descriptions of insurgent sabotage devices. As of October 1964:

1) There was considerable evidence to indicate that an insurgent command structure was operative in Venezuela and that the Caracas FALN headquarters, in particular, had secured a high degree of centralized control over insurgent activities in various parts of the country.

2) Insurgent planning, weaponry, and tactics, from a military standpoint, seemed to be growing increasingly sophisticated.

3) The Venezuelan petroleum industry in particular seemed to constitute an accessible set of physical targets whereby the presumed insurgent objectives of psychological harassment and economic disruption could easily be realized.

These observations led to the conclusion that the petroleum complex in Venezuela ranks high on the insurgent priority list of industrial targets. Indeed, it appeared reasonable to expect that future levels of violence against petroleum installations could be even more disruptive and costly to the industry than those previously experienced.

Even though, since that time (late 1964) the anticipated threat has not in fact developed, the petroleum system(s) remains vulnerable to serious disruption. Since then, in fact, other petroleum systems (Libya, Iran, Oman) have been sabotaged. Thus the need for a general understanding of the phenomenon remains. Furthermore, application of system analysis to this problem may illuminate the study of other vulnerable operations (e.g., railroads, communication systems, and water transportation).

An attempt was therefore made to describe the industry's position vis-a-vis a possible escalation in insurgent hostilities and, more important, to suggest how this position might be improved. The purpose of this paper is to describe the analytic concepts that have evolved from this effort, and also, to present a specific analysis that was conducted within this conceptual framework.

2. THE SYSTEMS APPROACH

2.1 THE PROBLEM OF PETROLEUM INDUSTRY SECURITY

A large oil-producing complex, such as that in Venezuela, may be spread over immense territory, much of it difficult to maintain under surveillance. Individual facilities are therefore exposed to sabotage with little effort required of the saboteurs. Since oil-producing systems are usually very flexible and redundant, sporadic attacks on less important elements of the system may not seriously inconvenience the producer. But more frequent attacks, in conjunction with more sophisticated techniques and operational planning, can effect a great deal of economic damage, if that becomes the insurgent aim.

Since the producer/distributor is most interested in meeting his market on a timely and least-cost basis, he responds by protecting key, hard-to-replace facilities, enhancing his recovery capability, and accepting the remaining sabotage as an incremental operating cost. His effort is to insure efficient recovery so that the system can be returned to operating order as rapidly and cheaply as possible.

On the other hand, since the future threat is difficult to predict and the interaction between sabotage damage and system operations is a complex one, the specific measure taken may be inadequate or wrong. For example, having taken inadequate steps to protect noncritical elements of his system, he may discover that repeated, timed attacks on them can be damaging indeed. Conversely, having provided protection, but no replacement for critical elements, he may be unpleasantly surprised by a high-risk major insurgent attack.

In summary, the petroleum industry security problem presently is one of allocating limited resources in the face of a poorly defined threat--determining criteria by which to recommend the best expenditures when the insurgent intention may be largely determined by qualitative values.

2.2 THE APPROACH

Given constrained protective resources, and many facilities to be protected, an immediate question is, "Which facilities should be protected first?" Another way of phrasing this is, "What is the relative importance of continued normal operation for each facility?" Since the benefits derived from company operation are primarily economic, the value placed on continued normal operation should be economic also.

The basic hypothesis in this study was as follows: The criticality of a facility can be best measured by the integrated loss of profit which would result from that facility's destruction.

In this approach to measuring criticality, the specific value derived for a facility, in general, is not the same under all conditions. It varies with both (a) the assumed operational conditions at the time of postulated destruction and (b) the amount of down-time associated with the destroyed facility. In turn, operational conditions change with whatever other insurgent sabotage may occur before and after the incident. Expected down-time depends on available spares, repair crews, etc.

The procedure developed to use this criterion pertains to the system of a single operator within the industry. It can be simply described as follows (see Table I):

1) System Simulation - The first step is to devise an analytic method (or model) which (1) describes the net effect of each individual facility in the system on current company operations, and (2) describes the company's current capability for recovering from possible damage to each individual facility.

2) Loss Equations - Sabotage damage to the system results in some combinations of equipment repair and replacement costs, storage oil destroyed, and oil not delivered on demand. An analysis of the company's normal fiscal operations (including tax and franchise obligations) results in an algebraic loss equation which, when applied to any of these oil and cost quantities, results in an assessment of insurgent-caused loss of profit.

3) Threat Postulations - Under this step, a series of incidents against the system are postulated in the light of estimated insurgent objectives, known insurgent capabilities, and whatever sabotage history may exist.

4) Loss Assessment (#1) - Each incident of a threat postulation results in hypothetical damage to a portion of the system. For each threat series, the aggregated system damages can be put into the system simulation model, resulting in a description of net effects on system operations. The loss equations can then be applied to yield an estimate of expected dollar losses in each case.

A difficult problem to be met here is that of the relationship between threat postulation (in terms of numbers of men, timing, and ordnance) and resultant system damage (in terms of how much of the particular facility's capacity is rendered inoperative). In what has been done thus far, resultant damage has been specified rather than derived, but analysis is required which describes mathematically the cause and effect relationships of the attack-damage situation.

5) Postulation of Alternative Security Measures - As a result of steps 1 through 4, the possible economic consequences of the expected threats are explicitly defined. The next question is, "How should the system react in order to minimize expected loss of profit?"

In this, the security function can select from among five basic strategies. These are:

a) "hardening" of company facilities - including concrete reinforcement, water moats, earth covers, etc.,

b) "active" defense of company installations - including armed security guards, pursuit squads, and military ordnance,

c) "passive" defense of company installations - including all intrusion detection and intrusion prevention equipment,

d) increasing the company's ability to recover once damage has been inflicted - including revised sparing and repair procedures, oil-borrowing arrangements with other companies, and possible contingency sales agreements, and

e) expansion of company distribution facilities to provide more alternative routes by which oil can be delivered to the customer.

Any possible combination of these strategies then becomes a security alternative. For each alternative it is necessary to know:

a) The total cost to acquire and operate the security alternative--if this is greater than some predetermined security budget, the alternative is excluded from further consideration;

b) The changes in expected damage specifications (under the original threat postulations) which result from having the security alternative; and/or

c) The changes in system recovery capability which result from having the security alternative.

Again, a relationship which still requires considerable analysis is that of 2).

6) Loss Assessment (#2) - In this step, expected losses are computed for each of the original threat series postulations arrayed against each of the security alternatives. The method used is that of step 4, and the same comments apply.

7) Computation of Reduction of Loss of Profit - For each threat postulation and each security alternative, the difference between expected loss of profit to the system without the alternative and expected loss of profit to the system with the alternative is a measure of the alternative's effectiveness (or value) in providing system security.

8) Cost Effectiveness Comparisons - If the preceding steps are carried out for several different budgetary levels, the results can be graphed as shown in Fig. 1.

There are as many loss reduction values for each security alternative as there are separate postulations. If recommendations of the form, "If you expect this, then you should do this" are sufficient for the person who is to use these recommendations, then the analysis need be carried no further. The procedure outlined to this point provides such information.

It may be, however, that the beneficiary of this analysis is unable to decide on such a basis. If so, the multiple loss reduction values for each security alternative could be combined into one value simply by taking an average which is weighted, say, to reflect the relative likelihood of each threat postulation. Even if such weightings cannot be derived, the information developed in this procedure can still be used to formulate a security posture which is reasonably efficient in all contingencies.

3. EXAMPLE ANALYSIS

Having described in some detail the methods of approach, let us now turn to a specific example wherein some of these techniques were utilized.

The petroleum-producing system considered was the BCF (Bolivar Coastal Fields) operation of the Creole Petroleum Corporation in Venezuela (see Fig. 2). Production from this system is approximately one-half of total BCF production and about 40% of the Venezuelan total. The physical facilities operated there by Creole include over 1,000 miles of pipeline and more than 2,000 wells, and represent a total capital investment of somewhere between $1 and $2 billion. Creole is a U.S.-owned company, the parent company being Standard Oil of New Jersey.

The economic effects of insurgent attack were analyzed in this case from the standpoints of both Creole and the Venezuelan government. The latter question was of interest because the Venezuelan petroleum industry is responsible for almost 1/2 of all government revenue, with Creole the major contributor. Thus Creole losses directly affect government income and hence the state of the Venezuelan economy.

Referring again to Table I, the steps accomplished in this particular analysis were:

1) System Simulation
2) Loss Equations
3) Threat Postulation
4) Loss Assessment

Due to time and resource constraints, the remaining parts of the general approach were not undertaken. Even so, it was still possible to generate some interesting and useful results.

3.1 SYSTEM SIMULATION

Creole BCF operations were simulated by the schematic shown in Fig. 3. This gives the assumed normal average flow rates through all production elements which contribute (control the contribution of) at least 50 thousand barrels of oil per day (50 MBOPD) of Creole BCF production.*

In the simulation, there are two outout points to the Creole BCF operation. These are La Salina, from which only crude oil is shipped (685 MBOPD average), and Amuay, from which both crude (100 MBOPD average) and refined products (410 MBOPD average) are exported. Assuming no existing production or demand surpluses, average market demands at the BCF output points (when expressed as daily averages) are equal to these delivery amounts. Rather than attempting to account for day-to-day fluctuations in market demand, this study assumed that demand for Creole crude oil at each output point could be approximated by the average daily crude production rate at that point.

The question of demand for Creole refined products was somewhat more complex. In order to reconcile the seasonal demand (high in winter, low in spring) on fuel oil** and other products with the economic desirability of constant production rates at the refinery, it is necessary for Creole to maintain approximately 20 million barrels of post-refinery (or products) storage capacity at

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* The 50 MBOPD criterion was established by Creole through earlier studies of its own. It was accepted here because data pertaining to most elements of less capacity were unavailable.

** Fuel oil deliveries to the United States constitute some 70% of Creole's annual refined product sales.

Amuay. In October of a given year, the Amuay pit storage facility is full to its 20 million barrel capacity. From 1 October to 1 April, products are taken from this storage to supplement normal refinery production and then, from 1 April to 1 October, excess refinery production (due to reduced products demand) is used to replace storage inventory. In the simulation model, two constant demand functions were used to approximate this situation, one for each six-month period.

As was mentioned, insurgent attacks postulated against Creole for use in the model were to be described in terms of resultant element(s) destroyed. When a delivery element was destroyed, the simulation assumed that Creole would immediately utilize some combination of two possible recovery measures. These were:

1) Partial recovery of element contribution through emergency or temporary repairs at the element, and

2) Partial recovery of element contribution by rerouting through alternative elements or by utilizing available production and storage surpluses.

The downtime/loss characteristics of each element of the system were described by a graph such as that shown in Fig. 4.

Many other assumptions were invoked in constructing the simulation model, but further detail is not warranted here. For a more complete listing, the reader is referred to Ref. 1.

3.2 LOSS EQUATIONS

In developing the equations of dollar loss, the following argument was essentially the one adopted.

A gross realized revenue value can be attached to each barrel of crude oil produced for delivery and sale by Creole. This value varies with grade, whether or not the crude is processed (refined to products), current market prices, and the customer to which the oil is sold. Similarly, dollar value can also be attached to any quantity of Creole reserve storage oil. Essentially, this value is equivalent to the per-unit-quantity incremental operating cost for oil extraction and gathering.

Incremental operating cost is the sum of three costs. The first two are (a) the cost of labor and utilities for extraction and gathering, and (b) the cost of actual equipment depreciation. The third and largest cost is the royalty or extraction tax which Creole must pay to the Venezuelan government for every barrel of crude extracted. The amount of this tax varies with grade and ranges from 17% to 24% of expected gross revenue realization.

Subtracting these incremental operating costs from the gross realized revenues results in a reasonable measure of incremental Creole gross profits.

The oil industry in Venezuela is subject to a tax on its gross taxable income which is paid in three phases: the flat Schedular tax (2-1/2%), the progressive Complementary tax (up to 45%), and the Additional tax (50% of all oil company income after taxes which exceeds the government's total taxes derived from the oil company). Creole is in the top bracket of the complementary tax schedule, and hence the Venezuelan government receives approximately 48% (45 + 2.5) of the Creole gross profit.

With respect to implied equipment repair and replacement costs, it has been current Creole practice to include all damage costs due to sabotage as part of normal Creole operating costs. Since operating costs are deductible, the Venezuelan government is, in effect, absorbing 48% of these damage costs. Thus, repair cost implied by destruction of any Creole element is shared on a 52% - 48% basis between Creole and the Venezuelan Government.

When the particular revenue and cost data were manipulated according to this argument, the following loss equations resulted:

$$\text{Creole Loss} = \left[\sum_i \left(C_{Di}N_{Di} + C_{Si}N_{Si} \right) \right] + K\,C_R \text{ , and}$$

$$\text{Government Loss} = \left[\sum_i \left(\bar{C}_{Di}N_{Di} - \bar{C}_{Si}N_{Si} \right) \right] + (1-K)\,C_R .$$

Where — N_{Di} = the total quantity of ith grade oil not delivered on demand, in MBO.

N_{Si} = the total quantity of ith grade oil destroyed in storage, in MBO.

C_{Di} = Creole loss of profits per MBO of ith grade oil not delivered, in $ thousand.

$\bar{C}_{Di}$ = Government loss of profits per MBO of ith grade oil not delivered, in $ thousand.

C_{Si} = Creole loss of profits per MBO of ith grade oil destroyed, in $ thousand.

$\bar{C}_{Si}$ = Government loss of profits per MBO of ith grade oil destroyed, in $ thousand.

C_R = the total implied element repair and replacement cost, in $ thousand.

K = the percentage of equipment losses borne by Creole through existing tax structure (K = .52).

3.3 THREAT POSTULATIONS

Six independent attack-series were postulated against the Creole BCF operation.

Attack-series number one is a recapitulation of all successful insurgent activity against Creole's BCF installations which occurred from December 1961 to December 1963. This first attack-series was included primarily to provide a partial test of the loss assessment model (by comparing available independent estimates of actual loss with that computed by the model).

Both the successful and unsuccessful attacks of the 1961 to 1963 time period are included in the second postulation, but with an assumption of 100% success for the latter. This series was selected because it provides some insight into what might have happened, as opposed to what did happen.

The third postulation represents insurgent activity which is at once intensive (considerable damage inflicted in a short time) and random (little account given to economic criticality in the choice of Creole targets). It was included as a possible "next-step" increase in insurgent activity.

Postulation number four is even more intensive* than number three. In this case, target selection is no longer random--all activity occurs against just two pipeline elements of the BCF operation. The motiviation assumed here is disruption of Creole operations, but without regard to actually maximizing economic loss. This fourth series was intended to represent a severe escalation from the present level of pipeline attacks and, concomitant to this, an increase in required insurgent resources.

The fifth and sixth postulations were developed as alternative means to the same end; viz, maximum economic disruption of the Creole Petroleum Corporation and all revenues the existing Venezuelan government derives therefrom. The first alternative (number five) represents an exhaustive approach, using a carefully prepared target list, phased over 260 days. The second (number six) is a violent, one-shot attack, involving no local guerrilla resources, but also one which is far less effective in realizing the overall objective.

Table II shows several incidents from one of the attack series. T_o is the time of initial attack.

3.4 LOSS ASSESSMENT

Calculation of Creole and government losses was facilitated by constructing, for each threat postulation, a table such as shown in Table III. The quantities in each of the last three columns were then aggregated and the respective totals substituted into the loss equations. The results were exhibited in both tabular and graphic form. (See Table IV and Fig. 5.)

3.5 RESULTS AND CONCLUSIONS FROM THE ANALYSIS

In the main, this analysis substantiated what had already seemed intuitive , obvious. That is, elements which control large circulations of oil to the system delivery points are generally elements of appreciable economic criticality. This conclusion, however, was necessarily qualified by the state of the remaining system at the time of element disruption. As an example, it was found that:

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* In terms of incident frequency and coordination, although total losses are much less than in attack-series number three.

1) A single disruption of either, or both, of the Ule-Amuay pipelines is <u>not</u> critical if storage inventories at Amuay are at normal levels and if La Salina is delivering normally. If Amuay storage is intact but La Salina deliveries are disrupted, then a single break in Ule-Amuay flow is still noncritical, but the number of successive breaks which can be tolerated is considerably reduced. If no supplemental storage is available at Amuay, then even a single pipeline break is hyper-critical. The same conclusions hold generally for the Ule pump stations.

2) The loss assessment exercises also revealed system elements which were not so obvious in their criticality. The most striking example of this is the 1200 MB crude inventory at Amuay refinery. Postulations 3 through 5, in particular, showed that the disposition of this inventory is a most crucial factor in the system's ability to supplement capacity reductions in the Ule-Amuay pipeline flow.

3) But perhaps the most startling result to come out of this analysis was recognition of the fact that destruction of stored inventory oil can yield <u>increased</u> revenue to the Venezuelan government. This arises because when the destroyed oil is replaced, the original extraction tax on it is repeated and hence the government receives more than it would have had the oil not been destroyed. This conclusion became more significant when considering the possible existence of some militant faction which seeks to damage U.S. interests, but not to discomfit the Venezuelan Government. Surprisingly, the industry itself was not aware of this situation until our study results were presented.

4. CONCLUDING REMARKS

Let us recapitulate the main substance of this paper.

A meaningful criterion for assessing the criticality of individual petroleum facilities has been established, and most of the analytic techniques necessary for its application have been developed. A procedure has been formulated which uses this criterion for evaluating and choosing among available measures to enhance system security.

The real value of this whole procedure to the petroleum industry rests on two essential elements. These are:

1) the feasibility of threat postulation within realistic boundaries

2) the feasibility of quantifying the relationships between threat configuration, assumed security measures, and resultant system damage.

If these problems can be overcome, then what is suggested here should yield satisfactory results for individual, as well as for country-wide cases.

REFERENCES

1. [redacted] A Model for Assessing the Economic Consequences of Insurgent Activity Against the BCF Operations of the Creole Petroleum Corporation (U), Defense Research Corporation IMR-132, October 1964 (CONFIDENTIAL).

2. [redacted] Insurgent Activity Against a Petroleum Producing System: Postulation and Damage Assessment (U), Defense Research Corporation IMR-177, December 1964 (CONFIDENTIAL).

TABLE 1

A SYSTEMS APPROACH TO INDUSTRIAL SECURITY

Step 1 - System Simulation

Step 2 - Loss Equations

Step 3 - Threat Postulations

Step 4 - Loss Assessment (1st Iteration)

Step 5 - Alternative Security Measures

Step 6 - Loss Assessment (2nd Iteration)

Step 7 - Computation of Reduction of Loss of Profit

Step 8 - Cost Effectiveness Comparisons

TABLE 2

INCIDENTS IN AN ATTACK SERIES
(from Threat Postulation #1)

T_0 + 40: Ule-Amuay pipeline #1, km 4.5, is damaged by explosives. No fire develops. A section of the pipeline has to be replaced, requiring a temporary shut-off.

T_0 + 135: Ule-Amuay pipeline #1, km 116.5, is damaged by explosives. No fire develops. A section of the pipeline has to be replaced, requiring a temporary shut-off.

T_0 + 136: Ule-Amuay pipeline #2, km 216.0, is damaged by explosives. No fire develops. A section of the pipeline has to be replaced, requiring a temporary shut-off.

T_0 + 200: Maracaibo Division office building is damaged by explosives. (no critical areas involved). Damages estimated at $3,200.

T_0 + 310: Electric substations HTSS 13, 31, 32, and 37 are partially damaged by explosives and fire. Substation HTSS 37 is shut off temporarily.

T_0 + 315: Caracas Division office building is machine-gunned from an automobile traveling on the freeway. Damages (not critical are estimated at $1,500.

TABLE 3

LOSS ASSESSMENT TABLE

(For Threat Postulation #1.)
(Only Part of the Series is Shown.)

TIME	LOST [illegible]	[illegible]	NO. OF [illegible]	TOTAL	SUPPLEMENT BY SYSTEM [illegible]	[illegible]	[illegible]	[illegible]	SUPPLEMENT BY STORAGE [illegible] (1000)	[illegible] LO (1000)	[illegible]	[illegible]	TOTAL REPAIR COST [illegible]
T_0	Avg												[illegible]
$T_1 = 3$	5%												10
	.3	B-C	1	10	75 at LO	10	1	10			0		10
$T_2 = 3$	40	B-F	1	40			1		40 X		0		
to	40	AB-C	1	40	95 at LO	40	1	40				0	
$T_2 = 40$	120	AB-F	1	120			1		120 AB (replaced by T_3=40)			0	
	.20	B-C	1	20	25 at LO	20	1	20			8		[illegible]
$T_3 = 40$	30	B-F	1	30			1		30 X		0		
to	40	AB-C	1	40	75 at LO	30	1	30	10 AB			0	
$T_3 = 120$	160	AB-F	1	160			1		160 AB (replaced by T_4=120)			0	
	.30	B-C	1	30	25 at LO	30	1	30			0		10
$T_4 = 120$	30	B-F	1	30			1		30 X		0		
to	40	AB-C	1	40	75 at LO	30	1	30	10 AB			0	
$T_4 = 130$	160	AB-F	1	160			1		160 AB (replaced by T_5=[illegible])			0	
	.10	B-C	1	10	25 at LO	10	1	10			0		10
$T_5 = 130$	40	B-F	1	40			1		40 X		0		
to	40	AB-C	1	40	45 at LO	40	1	40				0	
$T_5 = 200$	120	AB-F	1	120			1		120 AB (replaced by T_6=200)			0	
$T_6 = 200$	90												5
$T_7 = 310$													
to	30	AB-C	20	600	75 at remaining LO	30	20	600			0		250
$T_7 = 550$													
$T_8 = 310$	4%												Avg
	.20	B-C	3	60	25 at LO	20	3	60			0		50
	30	B-F	3	120					120 X		0		
$T_8 = 440$	40	AB-C	3	120	25 at LO	40	3	120	90 AB			0	
to	160	AB-F	3	480					480 AB			0	
$T_9 = 471$	10	B-C	2	20	25 at LO	10	2	20			0		
	40	B-F	2	80					80 X		0		
	40	AB-C	2	80					80 AB			0	
	120	AB-F	2	240					240 AB (replaced by T_{10}=471)			0	

TABLE 4

CUMULATIVE LOSSES FROM ATTACK-SERIES #1

	Cumulative Losses, in $ thousands[A]	
Time	Creole	Venezuelan Government
T_0	30	30
T_0 + 1	35	35
T_0 + 2	40	40
T_0 + 40	45	45
T_0 + 135	50	50
T_0 + 136	55	55
T_0 + 200	60	55
T_0 + 310	235	230
T_0 + 448	260	255
T_0 + 472	270	265
T_0 + 475	720	715
T_0 + 586	730	725
T_0 + 609	740	735
T_0 + 658	755	750
T_0 + 732	765	760

Notes:

(A) Creole losses are rounded up to the nearest $5,000.
Venzuelan losses are rounded down to the nearest $5,000.

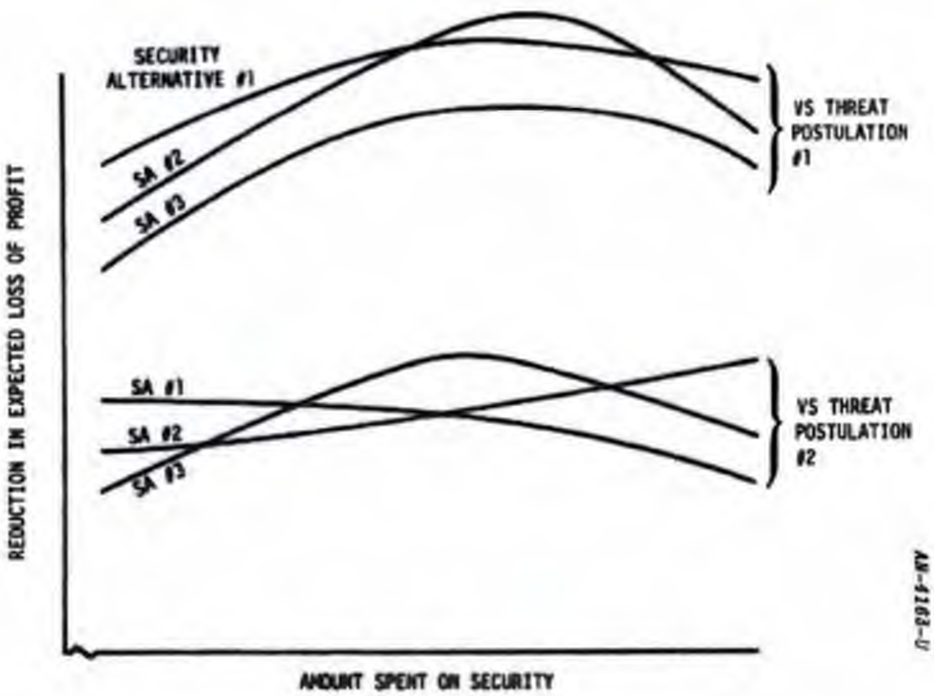

FIGURE 1. COST EFFECTIVENESS COMPARISONS

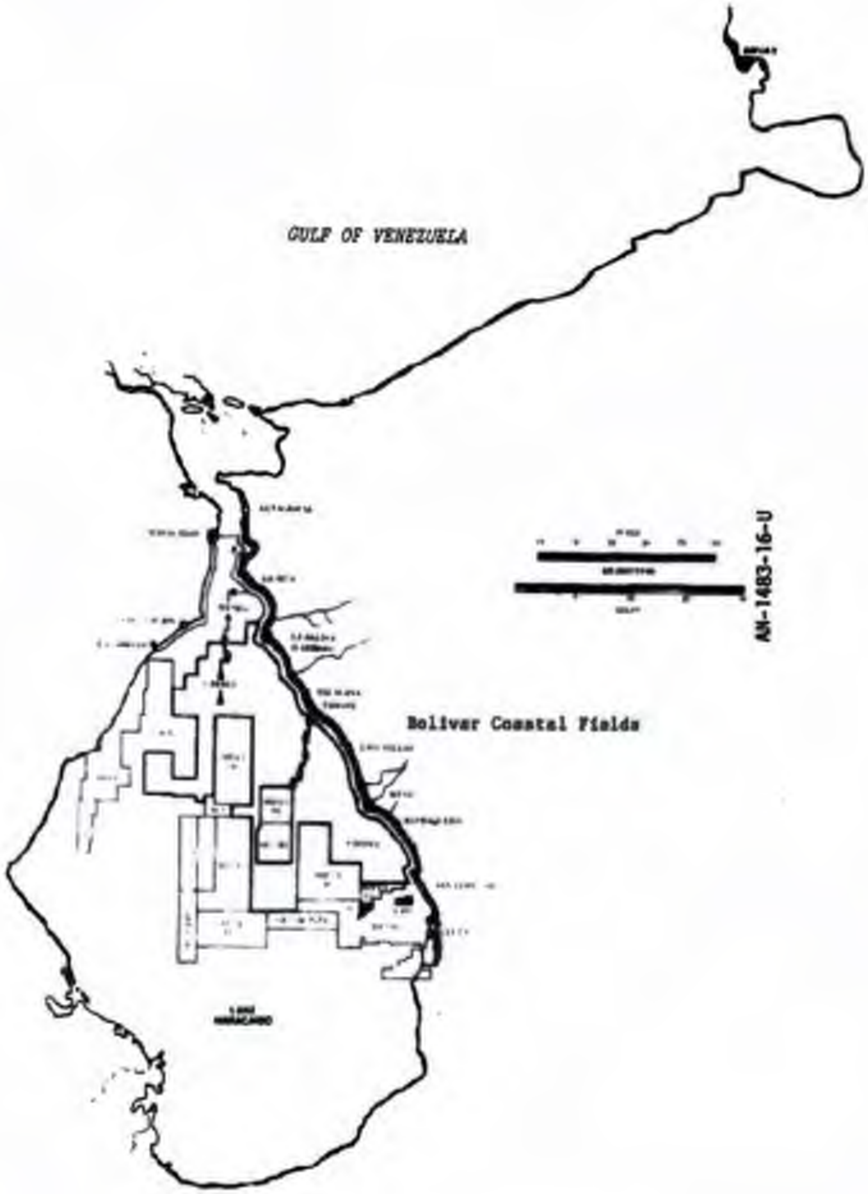

FIGURE 2. LAKE MARACAIBO CONCESSIONS MAP

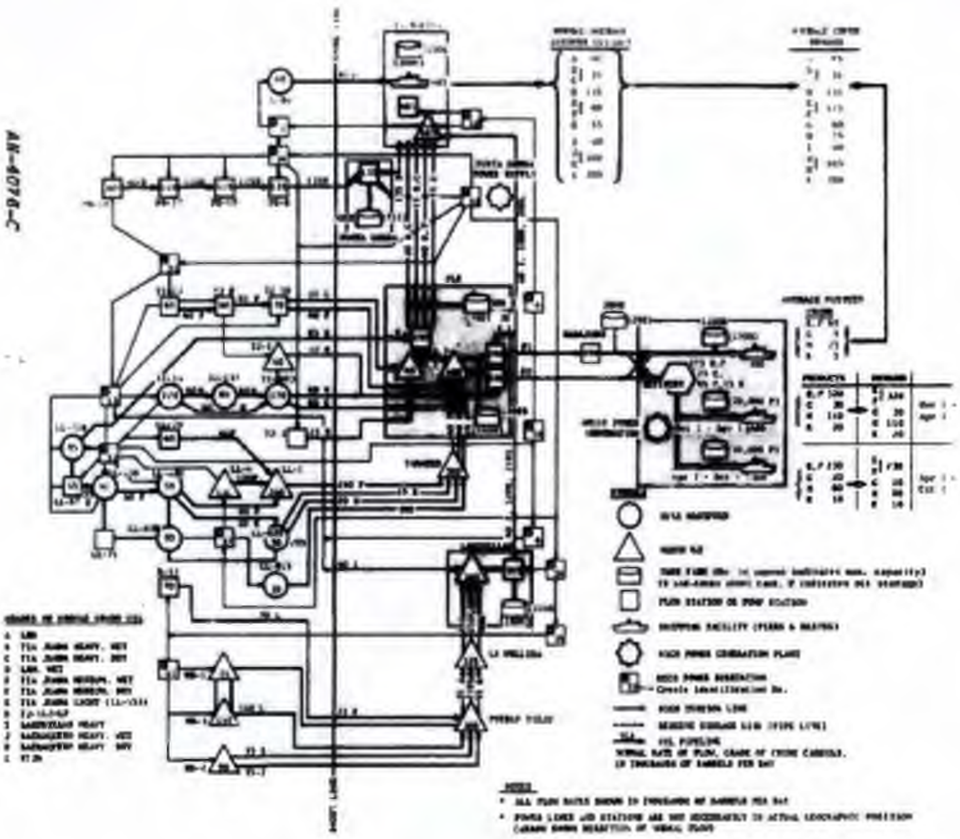

FIGURE 3.

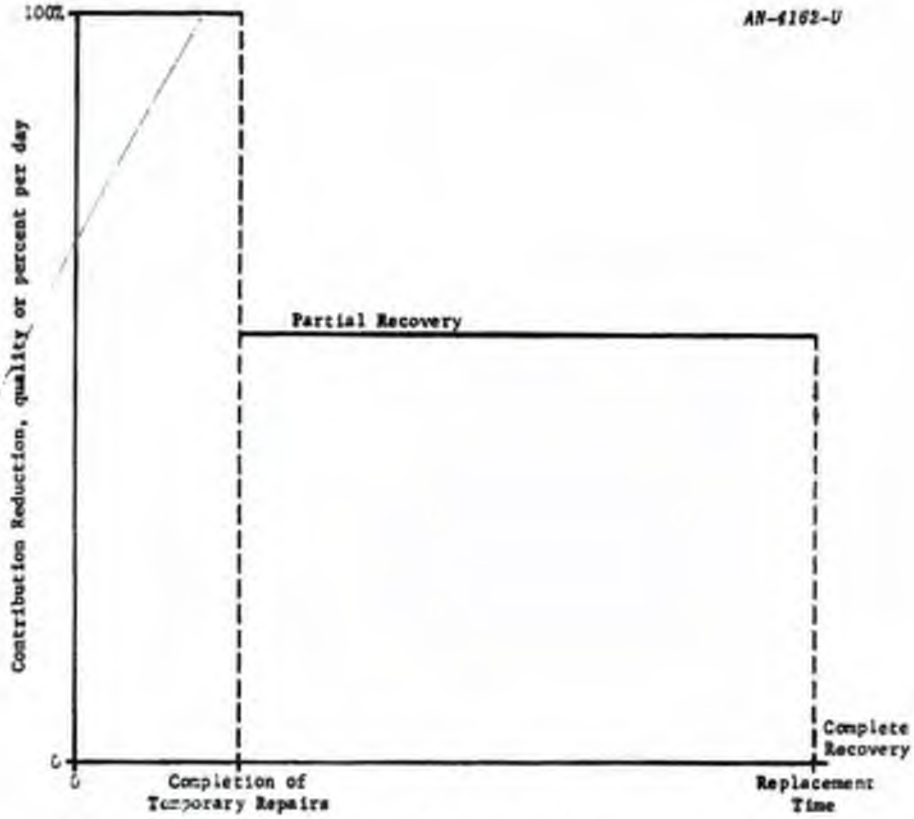

FIGURE 4.

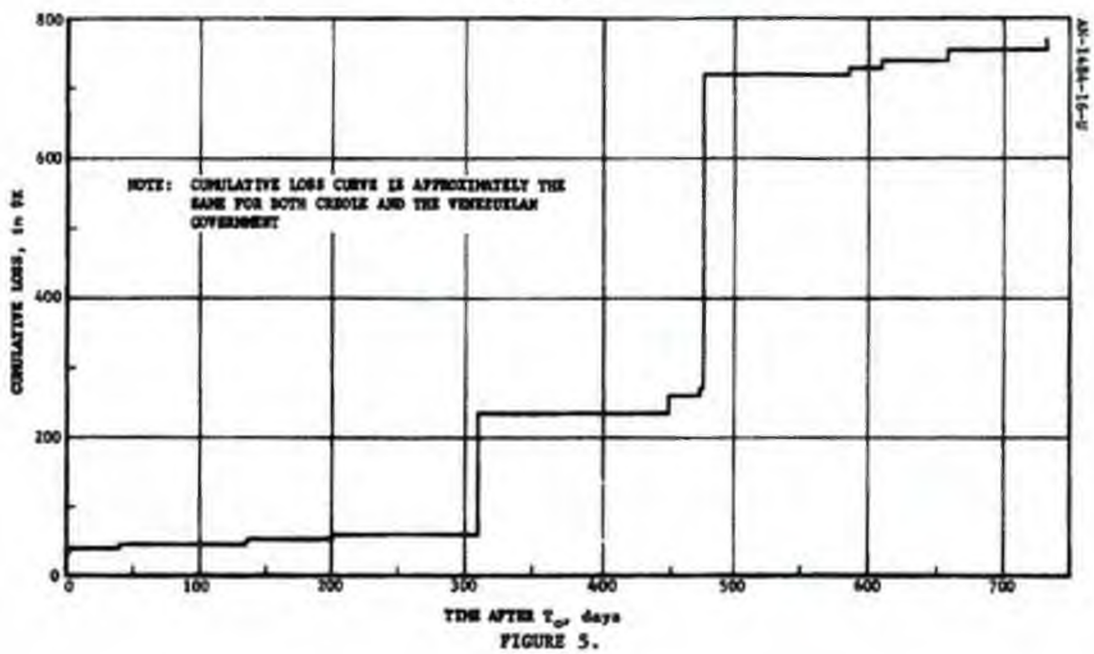

FIGURE 5.

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INSURGENCY IN THE CONGO (U)

~~(Confidential)~~

This Paper is Not Releasable to Foreign Nationals

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ABSTRACT
(Unclassified)

The continuing insurgency in the Democratic Republic of the Congo (DRC) is reviewed. Even under Belgian rule, the Congo had never been completely free of insurgency and banditry. Sporadic uprisings, rooted in tribal antipathies, occurred frequently, but recent outbreaks have also been characterized by racial hatred, intervention by outside forces, and overt and covert encouragement of "wars of national liberation."

The most recent large rebellion began in 1964. This paper traces the military campaign that led to the rebel defeat, and discusses a number of significant problems that need solution by the R&D community. Since the Congo insurgency has some major differences from more familiar ones, the problems posed need to be studied carefully.

INTRODUCTION

Insurgency and its cure is a favorite topic for all kinds of people today, ranging from scientists and engineers through political pundits to United States Senators. There is a large war going on in Viet Nam, and it began as an insurgency. As a result, we tend to equate all insurgency with South Viet Nam. Yet, even in neighboring Laos, Cambodia, and Thailand things are quite different.

A few case histories are part of the lore of insurgency specialists - Greece, Kenya, Algeria, Philippines, Malaya, and Viet Nam. However, there are nearly two dozen going on now, all different and all complex. Some of these are under control, in the sense that the established government is not in imminent danger. Others are clearly just starting, have little or no outside support, and may or may not grow in the future. Finally, some are merely organized banditry, perhaps getting a modest amount of support from trouble makers and exporters of revolution.

The Joint Chiefs of Staff list three countries where the danger from insurgency is high, where the situation is critical to United States interests: Viet Nam, Laos, and the Congo. This paper deals with the last of these. First, because it's in the geographical area of the world assigned to CINCSTRIKE/USCINCMEAFSA; second, because it is critical; and third, because it is different in many ways from the "well known" insurgencies and worth a hard look.

INDEPENDENCE COMES

The Democratic Republic of the Congo was the Belgian Congo. It achieved independence hastily in June of 1960. Until 1958, the Belgian Congo was supposed to be a model colony. Soon after General De Gaulle's 1958 Brazzaville promise of freedom to French colonies in Africa, agitation for independence grew. Rioting and overt "freedom" movements began in early 1959. The Belgians had planned to retain control of the Congo at least until 1970, but by late 1959 they decided to get out and get out fast - in June 1960.

On independence, a Congolese government was formed, with Joseph Kasavubu as President. The Prime Minister of this government was Patrice Lumumba. These two men headed factions which held very different views of the proper form of central government. Lumumba believed in a strong central government, a one party state, guided democracy, and so on, modeled after Ghana. Kasavubu's faction favored a federation of the old Congolese provinces, with a weak central government.

A few days after independence, the Congolese Army (the ANC) mutinied. All Belgian officers were dismissed and two sergeants major of the old Force Publique were named Chief of Staff and Commandant.

During the Army mutiny, rioting and instability erupted throughout the Congo. Literally hundreds of thousands of natives marched on the cities, expecting the millennium to have arrived with freedom. The combination of a mutinous army, rioting mobs in the cities, and political conflict led to a rapid breakdown of order. The United Nations was asked for and agreed to help in restoring internal stability in the Congo. A UN peace-keeping force was sent, and technical agreements were negotiated between the UN and the new government.

The conflict between the Federalists and the Centralists in the government led to unilateral secession of some provinces from the Congo. Moise Tshombe proclaimed an independent Katanga, and Albert Kalonji followed suit in Kasai Province. The UN peace-keeping force did not immediately intervene in the secession of the two states. Tshombe, however, asked the Belgians to return and help restore order in Katanga. He set up a Katanga Gendarmerie - officered by white mercenaries. Katanga, maintaining its own army and having "neocolonialist" ties, enraged the black African countries in the UN. The Soviet bloc, the United Arab Republic, and the radical Africans persuaded the UN to try to restore Katanga and Kasai Provinces to the central government by military force.

ANC Chief of Staff Joseph Mobutu had moved into a position of central power. He used the ANC to depose Lumumba and proclaim a new democratic government. He also closed the Soviet embassy at this time.

Patrice Lumumba, the deposed premier, attracted a following not only in the Congo but throughout the radical black African states and even in the West. Lumumba's deposition, arrest, transport to Katanga, and subsequent execution created one of the great martyrs of the Congolese independence movement.

Lumumba's followers withdrew to Stanleyville and formed a new government headed by Antoine Gizenga. This rump go[illegible]ment asked for and received diplomatic recognition from a number of the black African countries. However, it was unable to control the large northeastern part of the Congo and eventually fell apart. The legitimate Congolese government in Leopoldville, with Cyrille Adoula as Prime Minister, managed to retain a weak hold on the country.

The UN campaign to overthrow Tshombe in Katanga was difficult. The gendarmerie and mercenaries gave the UN force some very hard fights. During one of the cease-fires, the Secretary General of the UN, Dag Hammarskjold, was killed in an airplane crash while attempting to fly into Katanga to negotiate with Tshombe.

In 1962 and 63, the Katanga secession movement petered out and Tshombe left the country for exile. In early 1963, the weak central government of the Congo was in nominal control. The Katanga secession movement had been crushed, its leaders in exile or imprisoned. The Stanleyville group, with a tenuous claim on legitimacy, had collapsed and its leaders were in exile. With leaders and movements in exile, not a day went by but that some coup, counter coup, rebellion, or grand re-entry to the country was rumored.

The bitterness in the UN over the entire Congo peace-keeping effort has continued to this day. The Soviet Union and France have never paid their assessments for the costs. The continuing maintenance of some 20,000 troops in the Congo, plus the large economic and technical assistance programs, were bankrupting the UN. A decision was made for an orderly withdrawal of UN military forces by 30 June 1964. This, of course, became a signal for all the plotters to reintensify their efforts in anticipation. By the time the UN forces had withdrawn, rebellion flared anew in several parts of the Congo.

REBELLION BEGINS

In late 1963 and early 1964, Pierre Mulele returned to the Congo from the Congo Republic in Brazzaville. Mulele was another dissident plotter who had gone into voluntary exile. He made a few trips to Moscow and Peiping, and picked up the usual books on guerrilla warfare. Mulele gathered around him the dissident young tribesmen in Kwilu Province. These "jeunesse" were mostly adolescent boys aged 12 to 20. The jeunesse, armed at first with crude weapons, began a reign of terror. Kwilu rapidly fell to the jeunesse.

The eastern region of the Congo along Lake Tanganyika has always been the scene of tribal warfare. Tribes in this area hate all authority, no matter who tries to exercise it. Gbenye and Soumialot, two of Lumumba's followers, exploited these tribal hatreds and started a rebellion against the Congolese government in the Albertville region. The pattern was much the same as in Kwilu. The rebels approached a town, the ANC went out to meet them, fired several volleys into the woods, and ran away. The rebels took over the town, set up a revolutionary government, and began executing intellectuals. An intellectual in this part of the Congo was anyone who had completed the sixth grade.

In the spring of 1964 still another tribal rebellion broke out in Kivu Province. This ranged along the Congo-Burundi border from Uvira north almost to Bukavu, the capital of Kivu. Fortunately, the Kivu rebellion bumped into a solid Congolese Army unit, led by Lt. Colonel Leonard Mulamba. He rallied the ANC and defeated the rebel attack against Bukavu. Because there were richer pickings elsewhere, the rebels broke off their attack on Bukavu and moved west and south.

The early phase of the Congo rebellion was probably not a "nationalist uprising" or any externally directed struggle against the government. It was a tribal rebellion that drew its strength from the disappointed and discontented followers of Patrice Lumumba. Nevertheless, by the time the UN withdrew, the apparatus of a so-called "people's uprising" was put together. Gaston Soumialot had set up shop in Burundi. He arranged outside support for the rebel movement in the eastern Congo. There is ample evidence of financial support by the Chicoms and the UAR in these early stages. Soumialot moved to Albertville when that city was taken. A crude campaign of terror, formation of people's cooperatives, and all the buzz words of Marxism gave the rebellion the appearance of a socialist revolution. These trappings, however, followed rather than led the initial rebellion.

GEOGRAPHY AND ENVIRONMENT

Map 1 shows the geographic and transportation features of the Congo. Most of the country is tropical rain forest. In the south, rain forest gives way to a savannah and to highlands in the Katanga region. The northeastern region is high prarie, a few thousand feet above sea level. Along Lake Tanganyika, the terrain is rugged and mountainous, ranging from 5,000 to 10,000 feet.

The Katanga region is enormously rich in mineral resources, particularly copper and uranium. Kasai Province is one of the world's largest producers of industrial diamonds. Gold and silver mines are scattered through the south and the northeast. Mineral and agricultural exports provide a large source of foreign exchange.

The major cities grew up as transportation hubs or near mineral wealth. Transportation in the Congo depends on a combination of rivers, railroads, and highways. The Congo River is navigable from Leopoldville to Stanleyville. A rail line connects the port of Matadi with Leopoldville. At Stanleyville, Stanley Falls block navigation, and there is a rail by-pass for approximately 50 miles to Ponthierville. South of here the river is known as the Lualaba River, and is navigable to Kindu in Maniema Province. The major transportation south of Kindu is rail. Albertville, on Lake Tanganyika, presents an opening to East Africa. Kigoma, in Tanzania, is at one end of a railroad line that runs across Tanzania to Dar es Salaam.

A railroad runs from the Katanga mining region through Elizabethville and up to Kamina. From Kamina one branch of the railroad runs north and slightly east to Kindu, with a spur going over to Albertville. Another branch from Kamina runs on up through Kasai Province and the diamond mines. Another rail line runs from Elisabethville west through Angola to the Atlantic. This is the world's last remaining wood burning railroad. It is slow, but it hauls out Katangan copper.

These cities control the routes of transportation - road, rail, or air - and are the key to control of the Congo. This, of course, is why the fall of Albertville was so important. A rebel drive west from Albertville could seize the railroad running from Kamina to Kindu and cut off Katanga from the rest of the Congo.

GROWTH OF THE REBELLION

To review the military situation at the time the UN withdrew, Map 2 shows the Mulele revolution in Kwilu Province and the two separate areas of rebel activity in the Eastern Congo. At this time the rebels in the Eastern Congo had built up a governmental structure and settled down to an occupation.

Rebel military tactics depended on drugs, witchcraft, and a poor opponent. There is ample evidence that the rebels entered battle under the influence of a brew of boiled hemp leaves and corn alcohol. The narcotic and alcohol produced an ecstacy and frenzy in the rebels without degrading their physical capabilities. In addition, the rebels' witchcraft and charms inspired them. They firmly believed that bullets from the white man's weapons would not harm them - would in fact turn to water. In this they were aided by the inability of the Congolese Army to maintain fire discipline and to aim at targets. Generally, the ANC fired wildly into the air over the heads of the rebels before running away. The combination of witchcraft and drugs, along with tribal atavism and a lust for killing, made the Simba a formidable opponent for the Congolese Army.

In July 1964 roving bands of rebels ranged through large areas of the east, reaching as far west as Kamina and Luluabourg (Map 3). While these bands roamed the countryside, they made no attempt to occupy towns or consolidate their gains. Occasionally they ran into small units of the ANC that did not run, and then the Simbas did. The two pockets of rebellion in the Eastern Congo linked up and moved westward. In the space of about five weeks, the rebels had widened their activities to the area shown on the map.

In Leopoldville Premier Adoula's government began to panic. Widespread rebel activity and the failure of the ANC to check the rebels led to Adoula's dismissal and the return of Moise

Tshombe from exile. He sought US and Belgian help in stamping out the rebellion. The US Military Mission to the Congo, working along with Belgian advisors to the ANC, began to bring in material and supplies needed for restoration of law and order in the rebel held areas. The failure of the ANC to withstand rebel attacks led Premier Tshombe to contact Michael Hoare, a South African who had served in the Katanga Gendarmerie. Hoare was commissioned a Major and empowered to raise a band of mercenaries. Ads soon appeared in South African newspapers, offering "good pay to any fit young man looking for employment with a difference."

Stanleyville fell to the rebels in early August. This shocked the Congolese government and the free world. Stanleyville was garrisoned with a large force of supposedly well trained ANC and police. The rebel advance caused panic in the ANC. Some deserted to the rebel cause; others ran for their lives.

By now Leopoldville was in an uproar. Rumors of surrender or coups were widespread. If there was to be any hope of stopping the Simbas, redeployment of existing Congolese forces and the mercenary bands would be needed. The logistics situation was frightful. An appeal to the United States led to the procurement of several hundred trucks for surface transport. Further, our Military Mission and the United States Ambassador asked for transport aircraft to help the ANC.

CINCSTRIKE/USCINCMEAFSA assembled a small Joint Task Force headquarters called JTF Leo. This twelve man command-control group, in turn, was assigned a force of four C-130 aircraft, crews, and maintenance support. A rifle platoon from the 82nd Airborne Division was also assigned to provide local security at N'djili Airport and to "ride shotgun." (The rifle platoon from the 82nd Airborne was later relieved by a platoon from the 2nd Infantry Division.)

The arrival of JTF Leo had a spectacular effect in Leopoldville. The C-130s arrived and the paratroopers unloaded along with the airmen and their gear. This stopped all the rumors of impending doom in the city. The overnight change was nearly unbelievable. If any single event ever confirmed the validity of the "show of force" concept, it was the arrival of JTF Leo in the Congo.

Hoare's mercenaries began to arrive in the Congo on 23 August 1964. It became apparent that tactical air support would be required by the ANC and mercenaries. Accordingly, T-28s and B-26s were provided by the US. Pilots and maintenance personnel were hired by the

Congolese government. The pilots turned out to be Cuban refugees who had participated in the Bay of Pigs action.

While Hoare was organizing his mercenaries into the 5th Commando, the rebels were busy in Stanleyville looking for new worlds to conquer. Their attention again turned to Bukavu. An attack was mounted - this time better planned and better armed than the previous attempt. While a few US and Belgian observers got into Bukavu, the defense again depended on ANC Colonel Leonard Mulamba.

By the time of the second Bukavu campaign, the rebellion in North Katanga had petered out. The tribal dissidents began to lose interest, and the occupation forces drifted out of Albertville. The ANC and Katanga Gendarmerie quickly re-entered the city. This provided a base for air operations and made some air support available for the defense of Bukavu. Aircraft operating from Albertville had to fly out approximately 250 kilometers to cover Bukavu. The importance of a good combat radius in a counterinsurgency airplane becomes apparent here.

The rebel attack on Bukavu succeeded in taking about one-third of the city. At this point the Congolese checked the advance and hurled the rebels back. The rebels, retreating rapidly from the city, returned to Stanleyville with stories of ten thousand American soldiers and thousands of American airplanes attacking them. Despite the failure in Bukavu, rebel activity spread through the Northeast Congo all the way to the border, and a rebel spearhead moved down the Congo River toward Coquilhatville.

Map 4 shows what was really the high water mark of the rebel campaign on 11 September 1964. While gaining a large amount of territory, and, in fact, controlling about one-third of the Congo, the rebels had been driven out of or had abandoned the southeastern section entirely.

Hoare dispatched 40 mercenaries to reinforce the garrison at Coquilhatville. The first mercenary action at Lisala was brutal - the Simbas believed in their magic against white man's bullets. Twelve mercenaries armed only with light automatic weapons attacked 400 rebels dug in with heavy machine guns and recoilless rifles. Before the fight was over at least 160 rebels were dead, and the rest headed for the bush. One mercenary received a superficial wound. From this time on, the rebels were on the defensive. The Lisala fight was the turning point.

COUNTERATTACK

The pattern established at Lisala continued throughout the next several months. Small detachments of mercenaries - ten, twenty, or thirty - would spearhead the attack, followed up by perhaps a company size unit of the ANC. The mercenaries fought well, but cautiously. They refused to attack unless they had air cover, so the campaign had to be built around the combat radius of the T-28 and available airfields. Although the river and rail network in the Congo is the major line of communication, airfields turned out to be the strategic prizes.

Hoare's mercenaries and the ANC moved to Lisala and Boende from Coquilhatville, then to Ikela and Bumba. A force was also moved to Bukavu. The main counterattack proceeded along the railroad from Kamina to Kongolo, and eventually to Kindu.

As this military campaign began, Stanleyville became the focus of world attention. The rebels had seized about two thousand non-Congolese in the Northeastern Congo. These included missionaries, settlers, business men, and diplomatic personnel. Some 1600 were held around Stanleyville. From the day Stanleyville was occupied, the rebels threatened these hostages with a variety of atrocities. Rescue operations were contemplated, and some planning began as early as mid-August to retrieve the captured personnel. As rebel fortunes declined, the threat of a massacre increased. Negotiations were tried through the Red Cross, the United Nations, and some of the black African states. None succeeded.

When Hoare began rolling, tensions increased further. Time and again, as the mercenaries neared a town, the rebels executed whatever hostages they held. These executions were of the most brutal kind. People were hacked apart and disemboweled while still alive, burned, strangled, or shot. Recognizing that the hostages might be killed before Stanleyville could be secured, the United States and Belgian governments worked out a plan for rescue of the hostages in Stanleyville.

A force of 545 Belgian paratroops was airlifted by US C-130 aircraft to Ascension Island in the Atlantic. From there, on order the force would be airlifted to Kamina Air Base and staged from there for parachute assault on Stanleyville. The force closed Ascension Island on 18 November 1964.

To try and save the hostages known to be held in Kindu, Hoare made certain his attack proceeded with surprise a.-d great speed. As a result, he was able to rescue all 125 non-Congolese hostages in Kindu. He then began to prepare for the move north to Stanleyville. There never was any question that 200 mercenaries, backed up by 400 ANC and supported by T-28s, B-26s, and T-6s, would be able to take Stanleyville. The only question was whether the hostages would survive until Hoare could reach the city. Hoare had to regroup and await resupply at Kindu, about 200 miles from Stanleyville. Once he moved out, the risk to the hostages in Stanleyville mounted so rapidly that the paratroops were deployed from Ascension Island to Kamina on 21 November.

The Belgian paratroop force arrived in the early morning of 22 November 1964. The C-130 aircraft used to deploy these forces were augmented at Kamina by the four C-130s normally assigned to JTF Leo. Even though the paratroopers had been moved to Kamina, the Dragon Operation had not yet been given a go by all parties concerned.

On the night of 23-24 November 1964, the order was given to execute Operation Dragon Rouge. This was to be a parachute assault on the Stanleyville airport. At approximately first light, five C-130 aircraft dropped a total of 320 Belgian paratroopers. Within thirty minutes the assault force had secured the airport and cleared the runways of obstacles placed there by the Simbas. Additional C-130s then landed with 225 more troopers and vehicles and supplies. As the force was assembling to move into town, a telephone call was received at the control tower, reporting that the hostages had been taken to the square in downtown Stanleyville and were to be executed. The Belgians moved out at once, and succeeded in fighting their way to downtown Stanleyville. When the rescue force was approximately one block away, the Simbas opened fire on the assembled hostages. The victims scattered into the surrounding houses and yards. As the Belgians came near, the Simbas broke off to escape. However, they had killed 21 of the hostages and others were seriously wounded. The Belgians evacuated the wounded and the surviving hostages to the C-130s, and recovered the bodies of those who had been murdered.

Hostages were flown out to Leopoldville that same day. There the international community provided shelter and medical care. By 25 November, 919 refugees of many nationalities had been evacuated from Stanleyville, and 21 bodies had been removed.

By the end of 25 November, Hoare's column, advancing from the south, had entered Stanleyville and linked up with the paratroopers. Reports reaching Leopoldville indicated that a large number of hostages were held in Paulis, some 250 miles northeast of Stanleyville. The Belgian and United States Governments decided on a second rescue operation, called Dragon Noir. The

C-130s that had returned to Leopoldville were flown back to Stanleyville the night of 25 November and loaded for the assault. On the morning of 26 November, 256 Belgian paratroopers were dropped on the Paulis airfield, beginning at first light. Troops secured the airfield, and additional C-130s landed with equipment and personnel. In Paulis, the Belgians found it necessary to send wide-ranging patrols up to 25 miles outside the city limits to rescue many small groups of hostages that had been dispersed through the countryside by the Simbas. A total of 376 refugees were evacuated from Paulis. The Belgians held Paulis until 27 November. At that time, all possible hostages having been rescued, they conducted a tactical withdrawal under fire. The Simbas attacked the airfield, and the last C-130s taking off required air cover from the B-26s of the Congolese Air Force. A number of hits were taken by the C-130s, although no major damage was incurred.

Additional rescue operations were considered, but not conducted. World opinion and outcry reached a high pitch after the first two rescues. A political decision was made to terminate the Dragon Operation. The Belgian Parachute Battalion was redeployed to Kamina Airbase on the 27th, and departed on November 29th for Ascension Island, returning to Brussels on December 1, 1964. The Belgians suffered two KIA (one each at Stanleyville and Paulis) and two WIA.

JTF Leo retained six aircraft to assist in resupply and rehabilitation in Stanleyville and to help evacuate additional hostages freed by Hoare and the ANC. Despite all the hullabaloo of world opinion, and to some extent opinion in the United States, we should remember that 1295 persons - who most surely would have been murdered - were saved in the Dragon Operations. Over 2000 were ultimately rescued.

Map 5 shows the situation on 18 November, just before the Dragon Operation. Hoare's column is driving north from Kindu to Stanleyville, and another column is driving east from Lisala and Bumba. Finally, a small force is moving north along the Uganda border. After seizing Stanleyville, Hoare's mercenaries were withdrawn and the city was garrisoned by the ANC plus some Katanga Gendarmerie. Hoare needed time to regroup his forces.

CLEARING THE NORTHEAST

The next step was clearing the northeast border. The Congolese rebels were receiving significant quantities of weapons and supplies from the UAR, Algeria, Ghana, and perhaps the Soviet Union and certainly the Chicoms. Soviet-made aircraft were observed transiting Khartoum on their way to the Southern Sudan. Equipment unloaded here was then convoyed by road across the Congo border.

The government of Uganda gave the rebels complete support. Uganda was both a safe haven and a source of supply. Furthermore, Uganda put heavy pressure on Rwanda to stop assisting the legal government of the Congo. Rwandan activities were significant, particularly in the defense of Bukavu. The Bukavu airport is in fact located across the border in Rwanda, and this is where the C-130s supplying Bukavu landed.

Most Chicom assistance came through Tanzania and Burundi. The Chicom embassy in Bujumbura became a major source of funds. The main supply route led through Tanzania via railroad to Kigoma on Lake Tanganyika, and then by boat across the lake to a rebel stronghold near Fizi.

While Hoare was regrouping, another mercenary force, the 6th Commando - made up mostly of "French speaking" (as opposed to "English speaking") mercenaries, was sent to Stanleyville. The 6th Commando undertook a road march from Stanleyville to Paulis. Paulis had been temporarily seized in the Dragon Noir Operation, but had been abandoned before the ANC could get there. The convoy was ambushed regularly and effectively by the rebel forces all the way to Paulis. For the first time, we began to see signs of improved military know-how on the part of the rebels. The ambushes along the road were well planned, well supported, and quite often involved elaborate pits - or elephant traps - dug in the road to stop the vehicles.

Eventually the 6th Commando managed to get through to Paulis, but with fairly heavy losses. Even in May 1966, the Stanleyville-Paulis road was not open for travel.

Hoare's Northeastern Campaign, mounted in the spring of 1965, looked at the outset to be a long, bloody fight. It turned out to be a triumphal march through the countryside. Hoare moved with incredible speed for some 500 miles from the Bukavu and Goma area up the Uganda border to Lake Albert. Since it was thought that the rebels would strongly resist in the Bunia area, Hoare obtained some boats and sent a part of his force along Lake Albert to the rear of the rebels. This amphibious assault, covered by air, in conjunction with a frontal attack, broke the back of the rebel resistance in the Bunia area. Hundreds of rebels fled across the Uganda, Sudan, and Central African Republic borders. For practical purposes, the rebellion was broken in the northeast in the space of a few weeks.

Again, the tactics were the same. A detachment of Hoare's mercenaries led off, followed by ANC troops. The mercenaries did the bulk of the fighting, with the ANC providing rear area security, follow up, and occupation forces. To protect his lines of supply, Hoare - now promoted to Lieutenant Colonel - garrisoned the little towns with 20 or 30 ANC and 1 or 2 mercenaries.

In a sense this was, by modern military standards, a crude campaign. World War II vintage airplanes, boats propelled by outboard motors, and armored cars were the main items of military equipment. Nevertheless, this was successful in the Congo - so successful, in fact, that armored cars and air cover became an essential ingredient of any mercenary campaign. The ANC seems to concur in this view, since they are pressing hard now to build their forces around this concept.

REHABILITATION

As a long term solution to the internal security problem, the ANC had to be rebuilt from scratch. This was recognized by all concerned, including the Congolese Government. A training camp was set up at Kitona (near Matadi), with the objective of turning out well trained battalions of the ANC. This training camp was to be run by Belgians. A tripartite logistics group was established to coordinate US, Belgian, and Congolese efforts. There are only a handful of competent Congolese officers of field grade, and the company grade officers are generally poor. Our hope is that the Kitona training will develop good NCOs and junior officers.

In September of 1965, the rebellion in the northeast had been crushed. Roving gangs of bandits still operate in some parts of the countryside. They have, however, little or no popular support and really represent a return to tribal warfare. The Kwilu rebellion was dying of its own accord, and the only significant area of rebel activity remained in the Fizi-Baraka area. This, you will recall, is where the whole thing started. The tribal revolt there has roots going back many generations. It promised to be a tough nut to crack.

Externally, the African states gave up on the rebels. The Sudan cut off external support for the Congolese rebels. Sudanese dissidents were ambushing many of the convoys to obtain their own military supplies. Furthermore, Hoare's mercenaries followed the Simbas in hot pursuit across the border to knock off the rebel camps. This led the Sudanese to relocate the rebels from the immediate border area.

Uganda has also had second thoughts about support of the rebel movement, and has at least closed the border to overt support. The King of Burundi took control of the government and threw out the Chicoms. The major external problem for the Congo in the fall of 1965 was Tanzania.

The Tanzania supply route led to a nice little naval problem. Supplies unloaded at Kigoma were transshipped to Fizi by boat across Lake Tanganyika. The Congolese have a small, fresh water navy to patrol this part of the border. We, in fact, provided them with some boats through the Military Assistance Program to do just this. Several hot little naval engagements have been fought by boats armed with .50 caliber machine guns, mortars, and 75 mm recoilless rifles. B-26s and T-28s, based in Albertville, have been used for surveillance and interdiction of the sea routes with some success.

Internally, the Congo is recovering from the revolution. The economy, which should have been wrecked by five years of disorder, has shown remarkable resiliency. The execution of the so-called intellectuals by the rebels wiped out most of the infrastructure in at least one-third of the country, but things are going much better than anyone had expected. Foreign aid and technical assistance, not only by the US and the UN but by other powers, particularly the Belgians, will be needed to help restore the economy and administration of the Congo.

In the spring of 1965, after the successful campaign in the northeast, the transportation routes began to reopen. The last rebel pockets were eliminated along the Congo River, and barge traffic could be resumed. The need for air transport was diminishing. Air Congo and the Congolese Air Force had the capacity to handle the little air cargo that was needed.

We decided that JTF Leo should be terminated. A gradual phase down, starting in early 1965, brought the number of C-130s to four, then three, then two. By June it was clear that JTF Leo could be withdrawn without hurting the military situation. Bulk cargo that had to be moved by air could be handled by Congolese resources. To provide for movement of outsize cargo in emergencies, we arranged to assign a C-123 to the U. S. Military Mission in the Congo. When this aircraft arrived, JTF Leo returned home.

During its one year in the Congo, JTF Leo moved 10,899 tons of equipment and supplies, and carried 36,664 passengers. This was done with an average of three C-130s and about 125 personnel. JTF Leo demonstrated that a well planned and executed operation of great military and political significance can be run economically with a small force.

FIGHTING IN THE EAST

During the months between the Northeast Campaign and October 1965, Hoare had to completely rebuild his mercenary force. Although he rarely had more than 600 mercenaries in the country at any one time, a total of about 2000 served in the Congo. The mercenaries were a pretty scurvy lot by all accounts. Nevertheless, they fought well. Of the 2000, approximately 100 were killed in action and perhaps three to four times that many were wounded. Considering that the "mercs" were doing this for money and not for glory, they exposed themselves to a fairly high risk.

The continuing infiltration from Tanzania resulted in an improvement in rebel weapons and training. T-28s operating in the area began to receive ground fire from automatic weapons. They never encountered this in the earlier stages of the campaign. At least one Cuban advisor was killed and his body recovered by the ANC. Papers found on him indicated that some number between 10 and 50 Cuban guerrilla experts entered the Eastern Congo.

Hoare's campaign plan to clean out Fizi-Baraka was fairly simple (Map 6), but again made use of his limited resources effectively. One column was sent north from Albertville as a blocking force. Meanwhile ANC forces based in Albertville were used to clear the eastern shore of Lake Tanganyika. Hoare put about 200 of his men in boats, proceeded north on Lake Tanganyika, and landed to the rear of Baraka. He then advanced on Baraka, seized the town after a hard fight, and moved on through the town. He ran into strong opposition in the mountains leading to Fizi and halted.

The rebels used mortars and recoilless rifles in Baraka. More important, the rebels for the first time showed excellent fire discipline. All this was continued evidence of the role of the Cuban advisors. When Hoare moved an additional 200 men from the blocking force back to Albertville and up Lake Tanganyika by boat, the landing ran into severe opposition. The rebels set up a beachhead defense with mortars and recoilless rifles. The boats had to stand off shore for the day before they could land. Air strikes finally reduced the rebel defenses. After redeploying, Hoare marched on Fizi with his reinforced unit of approximately 350 mercenaries and a following force of 150 ANC. The rebels fled to the woods and hills, and Fizi fell.

POLITICS AS USUAL

With Hoare's success at cleaning up the Fizi-Baraka area, the spotlight shifted from military operations to political machinations in Leopoldville. President Kasavubu got into a political hassle with Premiere Tshombe. After several maneuvers, Kasavubu declared that Tshombe was out of office until a new parliament could elect a premiere. During Hoare's campaign in the Fizi-Baraka area, elections had taken place in the other provinces of the Congo. In late November of 1965, while the turmoil of politics in Leopoldville reached its peak, General Mobutu, the Commander in Chief of the ANC, seized power and declared himself President of the country. He appointed Colonel Mulamba, the hero of the Bukavu defense, as Prime Minister. Ex-President Kasavubu was promised a senator's seat for life, but stripped of his presidential office. President Mobutu and Prime Minister Mulamba put together a new coalition government and announced that they intended to run the country for five years before holding elections. Mobutu started a campaign of honesty in government and directed that everyone roll up his sleeves and get to work. One result of this is that it is now fashionable to wear rolled sleeves in Leopoldville.

With cessation of major rebel activities in sight, Mobutu and Hoare began to have disagreements on the proper role of the mercenaries. As a result, Hoare and his "English speaking" mercenaries left the Congo when their contracts expired. With Hoare gone, the operations in the Lake Tanganyika area became the responsibility of Ops Sud, the ANC Command in Albertville. Some of Hoare's mercenaries are still fighting in this region, and there are numerous small actions taking place throughout the rugged mountain terrain.

The infiltration route across Lake Tanganyika has been closed off by the efforts of the lake force. Attempts by Ops Sud to clear the western shore of Lake Tanganyika have not been entirely successful. Nevertheless, rebel control in the area is diminishing steadily. The Ubwari Peninsula, located to the south of Fizi, is a rebel stronghold. Periodically Ops Sud sends units through the peninsula to sweep out rebels. Again, the rugged terrain makes it impossible to clear and hold this area indefinitely. Rebel activities in the Lake Tanganyika region are diminishing, although there are an estimated 6000 well armed but poorly organized Simbas in this area. The remaining activities have shifted north to the Rusizi Plain, lying on the Burundi border.

In the Northeast another mercenary force, this time made up of "Spanish speaking" mercenaries, has been employed. The rebels, by now reduced almost to banditry, are being pursued and systematically broken up. From time to time forces of several hundred to a thousand rebels have offered to surrender. They are being resettled and rehabilitated by the central government.

The countryside around Stanleyville still contains some rebel bands. The key rail link between Stanleyville and Ponthierville to the south was opened only in early May of 1966, when the ANC and mercenaries retook the area around Ponthierville. The 6th Commando, fighting to the northeast of Stanleyville, has reopened the road from Stanleyville to Bafwasende and Nia Nia. Mopping up actions will probably continue here for several months, if not years.

CONCLUSIONS

This tale of the insurgency and its suppression in the Democratic Republic of the Congo leads to several conclusions. In fighting a war against rebels who control a large portion of the country - and particularly in the case of the Congo where they had controlled it for only a brief period - stabilization of the military situation is essential.

The Congolese needed military help desperately in 1964. The U. S. Military Mission to the Congo, COMISH, had the difficult job that always seems to go with helping a country toward stability. Basic needs for equipment, supplies, and training have to be identified. Host governments are sensitive, sometimes not very capable, lack money, and have insatiable appetites for prestige hardware. With a modest staff - less than 50 - and a limited budget, COMISH did a wonderful job of helping the ANC to help itself. As the Congolese Army is retrained and equipped, COMISH continues to show how the U. S. can achieve its goals effectively and economically.

Airpower played an absolutely vital role in the Congo. JTF Leo gave the ANC and the government of the Congo the ability to redeploy forces rapidly and to resupply them without reference to surface communications. As noted above, JTF Leo moved 10,899 tons of supplies and 26,664 persons with three C-130s in one year. This strategic mobility contributed to the rapid defeat of the rebels once the tide had been turned. The tremendous tactical success of a rather small number of antiquated aircraft, the T-6s, T-28s, and B-26s, was startling. Here again a small number of these aircraft, introduced early enough, played a major role in suppressing the insurgency.

Native troops in many emerging countries do not have competent leadership. For years the colonial powers refused to train native senior military personnel. A very few Congolese officers of outstanding ability have developed into competent leaders. The majority, however, are unfit for their jobs. You cannot train colonels and generals overnight. This means that leaders have to be provided. Whether mercenaries is the nice way of doing it is beside the point. They were available in this case, and the decision was made by Premier Tshombe. In fact, the U. S. Government opposed this. History probably will show that Tshombe was a realist, that mercenaries were the only solution at the time.

Although the rebel campaign moved rapidly in July and August of 1964, they were beaten by the superior strategic and tactical mobility of the ANC and mercenaries. This was truly a war in which mobility outmaneuvered firepower. The rebels were better armed, but proved to be less mobile than the mercenaries. A lot of caution should be taken before generalizing this experience. The Congo situation was peculiar, with the rebels believing in magic and lacking much fire discipline. In some cases air strikes simply terrorized the rebels, causing large concentrations to vanish into the woods.

An interesting problem for all of us to ponder is political restrictions on weapons. Our State Department refused to allow export of bombs or napalm to the Congolese Air Force. The T-28s and B-26s were limited solely to machine guns and 2.75 inch rockets for armament. So here is a situation where there are not only constraints on the types of aircraft employed - because jets were never allowed in the Congo - but also on the ordnance that could be used by these aircraft. These political limitations on weapons will probably be present, and in fact may be desirable, in many future insurgencies. Thus, the R&D community needs to take such possibilities into account when planning and developing equipment.

Several other interesting problems emerged in these campaigns. Wheeled armored vehicles were extraordinarily useful in the Congo. This was a war of movement, and, although strategic movement depended on the existence of airfields, tactical movement was on the surface. In the jungle environment of most of the Congo, with poor roads - but nevertheless roads - the armored car proved its worth. There is a growing feeling that armored cars, as opposed to tanks, may be extremely valuable for handling stability type operations.

The air war forces a look at requirements for counterinsurgency aircraft. Quite often air cover had to be flown from bases 200 miles away. No jet aircraft were allowed in country. As noted, the aircraft could carry machine guns and rockets, and nothing else. Furthermore, there were requirements for cargo hauling and reconnaissance.

Just speculating idly on aircraft characteristics, I wonder how the AC-47 ("Puff the Magic Dragon") would have done against the Simbas. Certainly it has the range and time on station, and it has machine guns. The effect of 12,000 rounds per minute on the primative Congolese rebel mind might have led him to quit then and there. If not, the killing power would have finished things quickly. The DC-3 is also useful for cargo hauling, and has been adapted for recce operations. It might be ironic if the old "Gooney Bird" turned out to be the prototype of a modern counterinsurgency aircraft. After all, counterinsurgency aircraft are not expected to stay and fight for air superiority. They are assumed to operate in a condition where there is no air opposition.

Next, the problem of opening up the river from Leopoldville to Stanleyville raises again the question of riverine warfare. Nobody has done much more than talk about it, draft up a few manuals, and perhaps speculate on what might be done in the Mekong delta. In the Congo the problem is vital. One barge a month from Leopoldville to Stanleyville can haul more cargo than three C-130s working at maximum effort for the same month. Furthermore, a barge can haul things that are inconvenient or impossible for the C-130. How do we patrol a river? What tactics do we use? How do we screen and defend a barge convoy? What clearing activities are needed?

The ambushes of the 6th Commando during the move from Stanleyville to Paulis raise again the old question of how to detect and counter ambushes. At one point someone speculated about a drone vehicle that could run ahead of the convoy on the road. Unfortunately, at the desired 30 miles per hour convoy speed, the drone gets to be a pretty difficult technical feat. Someone suggested infrared detectors from aircraft. But of course this would require that there be no jungle cover over the roads. Sound military tactics - the use of scouts and flank security forces - seem to be overlooked in all this. The mercenaries used reconnaissance by fire effectively. Maybe the measure of effectiveness for ambush detection devices is to compare them to the performance of well trained patrols using sound tactics.

Finally, the border surveillance and control problem reappears here. In this case it has a different twist. It involves infiltration by water across Lake Tanganyika. This ought to be grist for the mill of an operations researcher who knows something about search theory. Questions of what kinds of boats and what kinds of sensors can be answered after we understand the basic problem of border control on the lakes.

This paper attempted a brief review of the insurgency in the Democratic Republic of the Congo. The insurgency in the Congo is not over, and it probably won't be over for 20 years - perhaps not even 100 years. It has been suppressed, however, and most of the country is back to whatever passes for normalcy in that part of the world. If we want to talk about complete victory - having a country with economic standards of, say, the less advanced countries of Western Europe, a democratic form of government, a reasonably good fighting force - then we should not consider the Congo a victory. Far from it - we haven't begun to scratch the surface. But in June of 1964 the Congo was coming apart at the seams. When the UN pulled out, most of the country was in a nervous state - if not panic - and in two months one-third of the country was under rebel control. Prompt action by the US Government, the Government of Belgium, and by the Congolese Government itself restored a measure of stability to an otherwise desperate situation. As things go in primative Africa, this may be what passes for a successful counter-insurgency effort.


DEMOCRATIC REPUBLIC
OF THE CONGO
ANGOLA


REPUBLIC OF THE CONGO
17 JULY 1964
CENTRAL AFRICAN REPUBLIC
SUDAN
HAUT CONGO
CUVETTE CENTRALE
GABON
SANKURU
KIVU
Rebellion
NORTH KATANGA
Rebellion
TANGANYIKA
MULELE
Rebellion
FORCE OF TSHOMBE'S
GENDARMES
ANGOLA
NORTHERN RHODESIA


DEMOCRATIC REPUBLIC OF THE CONGO
7 AUGUST 1964
CENTRAL AFRICAN REPUBLIC
UGANDA
CUVETTE-CENTRALE
GABON
MULELE
Rebellion
NORD-KATANGA
TANGANYIKA
ANGOLA
NORTHERN RHODESIA


DEMOCRATIC
REPUBLIC
OF THE CONGO
11 SEPTEMBER 1964
CENTRAL AFRICAN REPUBLIC
SUDAN
UGANDA
CUVETTE CENTRALE
GABON
MAINDOMBE
KWILU
LOMAMI
TANGANYIKA
KWANGO
NORD-KATANGA
LUALABA
KATANGA ORIENTAL
ANGOLA

ZAMBIA
ANGOLA
TANZANIA
UGANDA
SUDAN
CENTRAL AFRICAN REPUBLIC
DEMOCRATIC REPUBLIC OF THE CONGO
18 NOVEMBER 1964


Stanleyville
Boende
Lubutu
Opala
Ikela
Monkoto
Rutshuru
OCRATIC REPUBLIC
Lomela
Bukavu
Shabunda
OF THE CONGO
Kindu
Kibombo
Port-Francqui
Kasongo
Fizi
Kigoma
Uvinza
Kaliua
Tabora
Kongolo
Luluabourg
Kabalo
Tshikapa
Kabinda
Mpanda
Portugalia
Kabongo
Beni

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(b)(6) [redacted]

CONCEPTUAL ANALYSIS OF THE MALAYAN COUNTERINSURGENCY (U)

~~SECRET — NOFORN~~ (Except ABC)

(b)(6) [redacted]

Historical Evaluation and Research Organization
Washington, D. C.

ABSTRACT

[redacted]

When Communist guerrilla warfare began in Malaya in 1948, the defending military found that the tactics and doctrine for jungle war that it had developed in World War II were adequate to prevent escalation to large-scale operations. However, victory proved to depend upon the evolution and conscious application of certain concepts that ultimately involved all agencies of government. Of these concepts, the most important was the resettlement of Chinese squatters and estate labor so that soldiers and police could then attack the lines of communication from the guerrillas to their civilian sympathizers. The situation thus created permitted successful application of other concepts, most notably in intelligence and food control.

CONCEPTUAL ANALYSIS OF THE MALAYAN COUNTERINSURGENCY (U)

Within the CIRADS limits of time and space, this paper attempts to analyze the conduct of the Malayan counterinsurgency campaign, 1948-1960, in terms of the concepts which governed that conduct, or which are suggested by the operations themselves. The nature of the available sources, primarily, the records of the British War Office, and the writer's own capabilities require focussing on the roles of the several Commonwealth forces; only so much of the Communist guerrilla concepts are presented as to help in understanding their opponents'. The discussion of the British concepts (if so for brevity they may be called) will try to outline their origins, evolution, implementation, and utility. Then, the paper will try to conceptualize the operational factors in the counterinsurgent effort.

The relevance of these ideas to any given situation is best determined by those familiar with that situation. With but two exceptions, the paper does not attempt to offer any general propositions.

Background

Terrain

The Malayan peninsula, where these operations were conducted, is roughly elliptical, about 400-miles long, and 200 across at the widest point. The Thai border to the north runs through heavy forest; the Government forces did not try to cordon or fence it. In the period 1948-1960, Malaya was about 80% jungle and 17% rubber plantation. The backbone of the Malayan peninsula is a mountain range. The often mountainous jungle area was the critical terrain feature for whoever controled the jungle controled Malaya. No place of importance in Malaya was more than a few hours' walk from it.

Racial composition

In 1948 there were present 2.4 million Malays, and 1.9 million Chinese. The Malays were an easy-going, uncommercial people. They are Muslims. of a fighting stock, and within the memory of men still living every adult Malay went armed. In 1948 they were a largely rural, aristocratic society, whose elite were accepted leaders and showed both a flair and an interest in politics and administration.

The 1.9 million Chinese were unassimilated politically and socially, though so successful economically as to rouse Malay fear and prejudice. Language was a major problem in that very few of the government's administrators, police, and soldiers spoke Chinese. Before World War II this great community had been largely self-governing through family, clan, and secret society, and the leadership of its great merchants. Then, during World War II some 500,000 Chinese, suffering the hunger and oppression that had followed on Japanese conquest of Malaya, had become squatters along the jungle fringe. They gardened in truck farms and they were outside the structure of civil administration, notably, outside the range of police activity.

Government

The Federation of Malaya was a federation of nine semi-sovereign states and two colonies. The Malay states' relation to the Crown was set by treaty, not by statute. One of the ideas underlying the Federation's organization and operation was that Malaya emphatically belonged to the Malays. Consequently, land title was largely restricted to them, and 80% of the lower civil service posts in the central government were reserved for them. The state posts were Malay.

The higher ranks of the Federation civil service, the elite Malayan Civil Service, numbered about 300, of whom 15% were Malay. First class university honors were a pre-requisite for appointment. The middle grades of the Federation service were about 60% British. Observers thought this civil service, in 1948, too small for its tasks, with many departments seriously undermanned.

In this government, the British could advise. but since it was a Federal government. with limited powers, and since the states were Malay, they could not order. The British advisers to the several states were just that. For example, after taking up his post in 1948 a British adviser in the first several months received but one correspondence folder. He had not yet won the confidence of the officials of the state he was advising. Also relevant is the British practice of "seconding," so that a British subject seconded to a Malay state or working for the Federation did not feel that his first obligation was to Whitehall nor did he have secret links to the Colonial Office. He served Malaya.

In short, in 1948 this Federation Government seemed so undermanned as to be handicapped, had limited powers, and seemed slow to react.

Army

When the campaign began in June 1948, Malaya and Singapore between them mustered 12,687 troops in the combat arms, and 16,999 service troops.

These troops had one great asset, recent successful combat experience in the jungle against an Asian enemy. Only three years before the British Army had contributed the major combat effort toward defeating the Japanese in Burma. As a result, the local garrison had doctrine, tactics, and equipment adapted to jungle warfare; its battalions could live, move, and fight effectively in the jungle. About 50% of its officers and non-commissioned officers had served in Burma.

The foundation of this combat effectiveness in jungle war was air supply, that is, routine use of aircraft for supply in the combat zone. So supplied, the British combat units were not road-bound, nor trailbound (indeed, in fighting guerrillas they habitually moved off-trail and off-road) while the probability of ambush was sharply reduced.

The six British, three Gurkha, and two Malay battalions present in June 1948 differed sharply in combat efficiency and jungleworthiness. They were in process of forming 17 Gurkha Division, and some were training battalions. However, doctrine and training methods were in hand and in a few months all were combat-ready.

RAF

The RAF was fresh from having supported the British Army in Burma. As a result, air-ground cooperation was understood and thoroughly practiced. The squadron each of transports and fighters were adequate for the early days; indeed, only one transport squadron was ever in Malaya.

Police

The police were a weak spot in 1948. They were 2,000 understrength, with a total of 10,000. Of them, 24 inspectors, and 204 rank and file were Chinese. Had a Chinese wanted to inform on the guerrillas, he would have been hard put to find a policeman he could talk to. Moreover, the Japanese occupation had injured the police. In 1948, the process of retraining and rebuilding was under way but only that. The operational strain on the police from current conditions in Malaya may be judged by the fact that there was as much crime in one month in 1948 as in an entire pre-war year.

The Communist Guerrillas

Strength

At peak strength, in the latter months of 1948, there were about 12,000 uniformed, armed Communist guerrillas in the field; the documents and interrogations yielded by the mass surrenders of 1957-1958 have shown common and smaller estimates to be seriously in error.

Organization

For this paper's scope and purpose, the two most significant organizational groupings were the full-time fighting guerrillas (Malayan Races Liberation Army) and their logistical support, that is, their base among the people (Min Chong Yuen Tong). This latter divided functionally into elements who were combat/service elements operating a few miles to either side of the jungle's edge, and sympathizers among the people.

In racial composition, the guerrilla organization was 95% Chinese; their support came from within the Chinese community.

Command and control was decentralized with organizations operating under broad directives. Coordination was obtained by having the leader at the lower level a member of the higher level's committee, and by foot couriers.

Arms

Initially, the guerrillas probably had enough infantry weapons to arm the equivalent of three World War II infantry regiments—had they been allowed to mass. Arms were largely British in origin; ammunition was to be replenished by capture.

Doctrine

The basic concept was that guerrilla war unfolded in three phases: (1) Gaining control of selected areas by terror, force, persuasion; (2) turning these areas into bases in which organized military units would form; (3) uniting bases and units to support large-scale operations.

However, the Malayan guerrillas gave the impression of taking with the utmost seriousness the maxim that they should flee from the strong and attack the weak. Consequently, a stubborn defense or a spirited attack, in either case regardless of numerical odds, would almost always lead the guerrillas to abandon an operation.

The use of terror was a problem to the Malayan guerrilla. He feared that terror directed against the Chinese community might alienate the very people whose support he sought, whom he claimed to champion. Terror directed against the Malay would almost certainly result in immediate savage reprisals by Malay countryfolk against the nearest Chinese villagers, upon whom the guerrilla depended for support; experiments with terror against the Malay forcefully underlined this. Observers came to feel that the Communist guerrilla never solved the problem. Without terror he could not compel support; with it, he alienated enough to downgrade the resultant exacted support.

Appreciation of the British, and of Their Strategic Problem

Having witnessed the Japanese defeat the British in 1941-1942, largely by their being able to operate in the jungle as the British then could not, the guerrillas took it as given that the British could not operate in the jungle. Moreover, in many of the squatter areas the Communists were the local administration. Here they would get food, information, and recruits. As the Communists looked about them in 1948 they considered that given the operational potentials of the jungle-squatter area combination and the assumed inability of the British to operate in the jungle they were probably almost at Phase II of guerrilla war.

Sketch of Events

The Calcutta Conference of March 1948 probably signalled wide-spread insurrections in Southeast Asia, including Malaya. The Malayan Communist leadership understood these were the beginning of World War III.

In May and June 1948 there were a number of murders and atrocities directed at planters, officials, British businessmen. They were of no military consequence. Outgated public opinion forced the Federation to declare a state of emergency, which gave it sweeping powers to arrest, search, and detain, and to alert the military and direct it to support the civil power.

The Communists then decided to mobilize their guerrilla forces.

The troops in Malaya now proceeded to demonstrate that by jungle sweeps they could fragment the guerrillas and keep them from massing. The guerrillas could and did mobilize 12,000 but could not use them militarily. Through 1948 and all of 1949 the Communists showed they could only attack non-military targets and commit acts of terror. They had not expected this, morale suffered, and surrenders were rising through 1949.

In early 1950, the British Government recognized Red China. In consequence, surrenders stopped and guerrilla incidents rose 160% from December 1949 to June 1950. This was an intolerable level. To give a new approach, Lt. Gen. Sir Harold Briggs was sent to Malaya (legally, as a civilian). Malay opinion would now accept putting the 500,000 Chinese squatters plus estate workers and tin miners into villages and the framework of administration, so Briggs was able to do this. He also integrated police, military, and civil command elements at all levels of government. These two together are loosely called the Briggs Plan.

Briggs' powers were limited and the machine he set up did not work at full efficiency. This was dramatically evidenced when in October 1951 the guerrillas assassinated the High Commissioner of Malaya. As a result, all civil and military powers were put in the hands of one man, who was further armed with the promise of independence. This was General Sir Gerald W. R. Templer. Templer made the Briggs Plan work, and from then on it was a slow steady mop-up, climaxed by the mass surrenders of 1957-1958. After them, the formal end of the state of Emergency in 1960 was anti-climactic.

British Operational Concepts

One Constant

Through the 12 years of the Emergency, one concept was applied without change. This was that the military were acting in aid of the civil power.

Administratively, this meant that the ultimate conduct of the Emergency rested in civil hands. That from 1951 to 1960 the Directors of Operations were soldiers is an interesting exception to the fact that at all other levels of direction in this same period the orders were issued by civilians. In the earlier period 1948-1950 all directing authority was civil. In the earliest days the Commissioner of Police was seen as giving an undefined guidance to the counterinsurgent effort.

Legally, this concept meant there was no martial law, no courts martial. Captured guerrillas had all the legal rights of an arrested citizen. None was punished without full trial, and none was tortured for whatever reason. In practice, there were very few trials. The aim of government was to win rather than to punish. Therefore, the guerrilla who decided to become as it were the state's witness partook of the advantages of that familiar position; the threat of trial and almost sure conviction was the stick, and generous rewards the carrot.

Government could also detain without trial, and could search and arrest without warrant. Detention was applied with vigor, and seems to have been effective in sorely handicapping the guerrilla supply organization—and in offering the chance to win over its members thus made accessible.

Concepts in the first years of the Emergency

To agree that the military would act in support of the civil did not tell responsible officials how that support was to be given or directed. In practice, initially the counterinsurgent effort was a cooperative one between the several agencies of government, proceeding on the basis of consensus. No one man, no one agency, could order. The Commissioner of Police had had long experience in Palestine. He ran his own department and he gave suggestions to the others but his power went no farther. The Chief Secretary was told to coordinate. In practice, this meant that at long intervals he presided over ad hoc gatherings of senior officials to discuss the Emergency.

At the operational level, police and military knew and fully accepted that they were to cooperate. The difficulties lay in defining cooperation, in defining the respective functions of military and police. The military gathered intelligence, and the police operated jungle squads modelled on platoons of infantry. When jungle sweeps were conducted, the responsible commander might or might not decide to bring the police into the operation.

In the realm of local politics, the several Malay States objected to resettling the Chinese squatters. The need for this was seen from the beginning, but consent and action could not be obtained.

In short, the counterinsurgent effort in the early days, 1948-1950, lacked coherence. Both concepts and organization that could focus and direct the effort toward its goals were lacking.

Military thinking, 1948-1950

Acting in support of the civil, and by 31 March 1950 built up to 18,523 in the combat arms and 13,674 service troops in Malaya and Singapore, the army was the principal counterinsurgent agent. Looking at and deploring the conduct of antiguerrilla operations in China, Greece, and North Vietnam it resolved not to let itself be broken into penny packets and tied down into point defense. Instead, it resolved to use mass and mobility, exploit its ability to fight, to move and to live anywhere in the jungle and use its strength on jungle sweeps and large-scale screening operations. Point defense was left to the rapidly-expanding police, who were sheltered as it were by the way the army's jungle sweeps fragmented guerrilla formations. Under all operational circumstances, passive defense was avoided by the army and by larger police formations. To patrol by day and to ambush by night was the practice.

The RAF entered into the above by its provision of air supply in all weathers and to all points. Interestingly, both army and guerrillas agreed and stressing the absolutely fundamental nature of air supply. Point and area targets were bombed either on information or on speculation. The scale was so small, 331 tons of bombs the first two and one-half years, that its lack of effect on the campaign does not surprise while the possible effect of a large effort is unknown.

Results of the above

The army's jungle sweeps and support of screening operations served (1) to prevent the guerrillas' massing into formed units, and (2) greatly to handicap their supply service, the Min Yuen. The guerrillas could not enter Phase II and could only operate in Phase I. At this level, the guerrillas did maintain an unacceptable incidence of terror.

As a by-product of its jungle sweeps, the army steadily improved its skills in field craft, jungle navigation, and the miner tactics of jungle war. Professionally, it was a more effective combat instrument in 1950 than in 1948. Growing professional criticism of the large jungle operation as a futile blow in the air did not appreciate its functional importance in fragmenting the guerrillas and preventing their massing. However, because the jungle sweeps had done that, and because the soldiers were far more effective in the jungle than ever before, the circumstances had been created to permit introducing and applying new concepts that for the first time imposed a coherent pattern and gave effective organization to the counterinsurgent effort.

The Briggs Plan

A week after he arrived in Malaya, Lt. Gen. Sir Harold Briggs issued his basic paper. In it were the concepts later to be known as the Briggs Plan. The central concept of the plan was to force the guerrilla to fight on ground of the government forces' choice. This would seize the initiative from the guerrilla. To do this, Briggs rearranged the battlefield on which actions were taking place. When he arrived, Chinese Communist guerrillas had the run of squatter areas inhabited by half a million Chinese who were outside law and public administration. Army and police had been sorely handicapped on that battlefield so Briggs had it rearranged.

Briggs rearranged the battlefield by two acts: The first was to resettle the squatters into viable, policeable, fenced villages (fenced, not fortified). Traffic in and out of these villages could be controlled. In so doing, Briggs appreciated that food was the weak spot of the Malayan guerrilla. He could go for weeks without shooting a bullet but he had to eat. Therefore resettlement forced him to set up an LOC to the villages and make the operation of that LOC a primary concern. The operation and the protection of this LOC and its associated supply organizations was expected to and did absorb an ever greater part of the guerrillas' manpower. The functioning of the LOC was expected to and did offer intelligence targets and ambush targets to the police and the soldiers. The army was reployed accordingly so that it could maintain an appropriate level of manpower in the jungle fringe, that is, between the people and the guerrillas.

As regards conscripting the Chinese into the Home Guard, Briggs argued, and correctly, that the Chinese villager would cooperate if outer circumstances made it appear that he was forced to. It should also be noted that food searches at the village gate gave the villager a perfect excuse to withhold or to reduce support. Under the new regime, not even members of a Chinese villager's family would know if he had passed information or fired an accurate shot.

It should be emphasized that the Briggs Plan was intended to and ultimately did force the guerrillas to reduce what they called military operations almost to the pro forma level, as all their energy and imagination had to center on one thing, food-gathering.

With resettlement and a Chinese home guard Briggs introduced a new scheme of command and control, conceptually independent of both the above. At each level of government, from the capital at Kuala Lumpur down to each of the 71 administrative districts into which Malaya was divided, Briggs set up a war executive committee. The key word here is executive. Each committee commanded the counterinsurgent effort in its area by issuing orders to the military, police, and civil agencies in that area. The senior civilian was chairman. Representatives of each agency concerned attended meetings. To make this exercise of command administratively possible, each committee ran a combined operations and intelligence section.

The Briggs Plan Appraised

Briggs put his plans into effect as Director of Operations, but the powers he was given were not adequate to the post. The role of the police was critical, yet he could not order the correction of any deficiency he found in them, or with any other agency. If a member of a war executive committee disliked an order as it affected his agency, he could appeal. Therefore, the machine did not work at full efficiency even though it must be noted that with the implementing of the Plan guerrilla incidents began to fall.

Moreover, the available records suggest that he did not see or did not have power to develop an important implication of his work. That is, the Briggs Plan in action greatly simplified the intelligence problem by (1) simplifying the problem of identifying members of the guerrilla organization, and (2) forcing the guerrillas into repetitive, highly organized activities, e.g., the food lift. The opportunities that Briggs had created had to be exploited. His successor, now Field Marshal Sir Gerald Templer, K. G., held views that suited the occasion.

The Governing British Concepts Fully Developed

In Templer's thinking, food was the basic weak spot of the guerrilla anywhere in the world. The Briggs Plan was obviously taking care of that so Templer then moved on to what he saw as the next priority in counterinsurgent concepts. These were two things that he bracketed in his thinking and in his conduct of operations, and which he compared to the right and left fists of the boxer, intelligence (broadly defined) and information, i.e., a public information program to, in the slogan he launched, win the hearts and minds of the people.

Under Templer, intelligence became the responsibility of the police, and of the police alone. The military would certainly gather combat information, but its processing into intelligence was the task of the Police Special Branch. The days of divided responsibility and effort were ended, and, the police received the means to do their new job.

In the conduct of military operations, the penetration of the guerrilla command organization was now set as the objective. This might never appear in the field orders, and the military might chafe at the demands placed on them by Special Branch, or the restrictions, but this fundamental objective never changed in the course of the Emergency. The philosophic implications are interesting. The aim of war has been defined as to impose one's will on that of the enemy. His will does not exist in vacuo, nor is it disembodied; it is the will of a group of men. If, then, Special Branch could turn a Communist commander and make him an agent of Special Branch, the task of overcoming the will of the guerrilla enemy was proportionately easier. In the event, Special Branch were able to penetrate the Central Committee of the Malayan Communist Party, that is, the guerrilla high command.

To win the hearts and minds of the people, Templer and his successors created a machine that could saturate the communications media. The theme it broadcast was that of an independent, prosperous, multi-racial Greater Malaysia. The theme received daily demonstration by deeds which ranged from civic action to Malayan independence; we need not dwell on them here. Here one need only note the demonstrated efficiency of Templer's two concepts, summed here as intelligence and information.

Two Operational Concepts

For the day to day conduct of operations, 1953 saw the invention of the food denial operation, which became the most effective government had. Food denial meant the rationing and control of the stockage, sale, and movement of food, including the mass cooking of rice, in an area of a size, and so patrolled and ambushed, that porters could not bring in rations from outside. Thus, the area for Operation Bonanza was 400 square miles, and it took about 20 government personnel for each operational guerrilla. Here one must note that the guerrilla had been forced to operate in scattered small parties and that by 1953 there were an estimated 4373 armed guerrillas at large in Malaya, exclusive of their support organizations. When a food denial operation began, the local guerrillas would lie low and live off their stocks for three to four months. Then, they had to begin taking increasingly desperate chances, and the kills and surrenders would begin. In 12 to 15 months, the numbers and identity of kills and captures, and the end of guerrilla incidents would suggest that there were in fact no more guerrillas in the target area.

In June 1953, probably by the Resident Commissioner in Malacca, it was suggested that if in a given area there were no guerrilla incidents for a length of time that all restrictions on the people, such as curfew and food control, be lifted, subject to later good behavior. The area would be called "white." If the people of an area wanted restrictions lifted they could aid greatly to that end. The "white area" thus was a reward for good behavior and the hope of receiving it in incentive to cooperate with the police. In no sense was one declared as a challenge to the guerrilla.

The General Working of Operational Factors

The above has presented in simplified form the conditions in Malaya and the concepts applied there. Examining the course of events and the conduct of operations suggests that the operational factors in the Malayan counterinsurgent effort were: Army operations, resettlement and food control, police intelligence, public information, and the unique system of command and control.

The foundation of the counterinsurgent effort in Malaya was success in jungle war, combat effectiveness in the jungle. Without it, the whole counterinsurgent effort would have been swept away as was that of the French in Viet Nam. These "early successes in jungle war made resettlement and food control possible. This in turn yielded profitable targets for the army and for police intelligence. Reassured by them, the populace increased its support, which resulted in more and better intelligence. To make these varied activities mutually supporting required their careful, continuing integration, which the command and control system provided."*

Two General Observations

From the above, and from the nature of guerrilla war in general, two observations suggest themselves. The first is that under all circumstances food is a weak spot for the guerrilla and so action aimed against it is worthwhile. The second is that intelligence is a police function. The intelligence sections of military units are so small, the units themselves move so frequently, that they cannot develop the mass of detailed local knowledge needed to deal with guerrillas who shelter in and are from the local people.

*Riley Sunderland, Army Operations in Malaya, 1947-1960 (U). RM-4170-ISA, page 6 (SECRET).

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MONITORING THE PHYSICAL STATUS OF GUARDS

BY MEANS OF BIOSIGNAL TELEMETRY (U)
(Unclassified For Official Use Only)
This Paper is Not Releasable to Foreign Nationals

(b)(6) [redacted]

The RAND Corporation
Santa Monica, California

ABSTRACT
(Unclassified For Official Use Only)

In protecting a given installation, guards are commonly deployed within the area containing the installation as well as at posts and beats along the area's perimeter.

The measures taken to protect against intrusion into an area will vary with its importance, size and location. These measures might include a variation in the number of guards and their location, a voice communication system between the guards and the area's headquarters, as well as monitoring the first team of guards by a second team. The last two measures, whether or not they are periodic, leave time intervals in which a guard may be physically overcome and the area penetrated.

To minimize such incursions -- which could mean a surprise attack on the unsuspecting installation -- a specialized communication system continuously informing the area's headquarters of the physical condition of each guard is suggested. With this system, such physiological indicators as heart beat, brain activity and certain muscle potential will be transmitted from the guards to headquarters indicating whether any guard is dead, injured or unconscious. A supplementary means, by covert voluntary action, to signal capture is discussed. This information could serve as a warning system which would alert the entire base as well as initiate remedial action.

This paper discusses the various physiological indicators that might be transmitted and monitored. The measurement and telemetry of heart rate has become a fairly standard practice, so that this subsystem is easily adapted for use in this system. Telemetry of electroencephalic signals may introduce some problems because any movement of the electrodes tends to distort the signal. Methods to avoid this problem are presented. Telemetry of muscle action potential would require some training of the guard, as well as pretesting of the biosignal telemetry system to avoid using it on an individual incapable of controlling his actions under stress conditions.

Apart from perimeter defense, point defense and monitoring men stationed at posts away from their command area, there may be additional applications of the system in individuals whose physical monitoring is desirable.

I. INTRODUCTION

In guarding a vital installation, it is common practice to monitor the guards deployed in and around the area containing the installation to insure that they remain alert and intact. The monitoring methods commonly used are periodic communication by voice or radio between the area's headquarters and the guards and/or their monitoring by a second team of guards.

These methods are essentially periodic in time and geographic location, thereby leaving intervals of time in which guards can be overcome and the area penetrated without headquarters being immediately warned of the intrusion.

To minimize the probability of such a penetration, a system employing a continuous check on the physical status of all guards would be desirable.

This Memorandum suggests a practical and inexpensive system that could meet this requirement. In this system the physical status of the guard force would be monitored by observing directly the physiological signals which indicate heart function (electrocardiac signal), or brain organic function (electroencephalic signal), or certain muscle activity (muscle potential and muscle movement) of each guard. These signals, continuously monitored from each guard, would inform headquarters instantaneously if any guard is dead or unconscious and quickly if any guard is seriously injured.

Only modified versions of the aforementioned physiological signals are considered for telemetry from the guards to their headquarters. Unlike the involved multiple-electrode system required for medical analysis, only a few electrodes are used here, since only gross physiological indicators are needed to indicate the physical well-being of the guards.

Monitoring heart patients and astronauts by means of electrocardiac telemetry is an established technique; experiments with telemetry of brainwaves (radio-electroencephalography) and muscle potential (radio-myography) have also been made. Thus, both experience and equipment are available for this newly suggested application. The sensing and consequent transmission of these signals is entirely involuntary, requiring no overt attention or action on the part of the guard.

A commonly considered continuous monitoring system is the "dead-man switch" alarm system. There are many varieties of this unsophisticated system, characterized by simplicity of design and operation, and these no doubt have their place in the defense system. However, the information given by the alarm is limited, by comparison to the physiological signal report, and in some instances the switch may cause the guard's attention to be diverted from his duties. The "dead-man switch" is more susceptible to false alarm, more vulnerable to enemy capture and ruse than the physiological system, and may provide an opportunity for a malingering guard to "outwit" the system by improper use.

The suggested system is relatively sophisticated but requires very little training of the guard and only a minimum of physical discomfort to him. It appears to be fairly straightforward and practical. Once developed and available for use, it might be used in rather routine circumstances in preference to current practices just because it is easier and cheaper.

In the sections to follow, the physiological signal telemetry is described; the three physiological signals, commonly referred to as biological signals or simply biosignals, and their relative importance in this system are described. Their abnormal and normal ranges and the possible problem areas of each are also indicated. The practical aspects of the system such as the size and weight of the portable equipment, possible discomforts to men using the equipment, and training are discussed for each of the biosignals considered for telemetry.

Although this paper considers primarily perimeter defense applications, there are additional applications in industrial security where monitoring organic failure of guards is an important consideration.

II. BIOSIGNAL RADIO TELEMETRY SYSTEM

Each of the guards deployed in defense of an area will carry portable telemetry equipment. This equipment will consist of electrodes connecting the emitted biosignal first to a preamplifier, then to a transmitter and finally to an antenna. The modulated biosignals will be transmitted to monitoring receivers at the area's headquarters. If several separate but closely situated areas are being guarded, a relay station in each area could retransmit the received signals to a single control station accommodating the entire region.

It should be noted that although direct radio signal propagation from the guard's antenna to headquarters' antenna is implied in this system, it is not intended to restrict communication only to a direct radio link. In fact, because of terrain and radio noise, it may be better to use radio transmission for a short distance to a relay terminal (properly tamper proof and alarmed) which is connected to headquarters by wire. Also in cases where guards are deployed close to a metallic fence which encloses the installation, coupling to the fence which then serves as a wire to headquarters is a possibility.

Although a number of modulation techniques may be employed in transmitting the biosignals, a basic frequency-modulation design is suggested here. It is a proven technique in the field of medical radio-telemetry, and a number of off-the-shelf designs and equipments are available.

Each guard would be assigned a separate channel of bandwidth sufficient to accommodate the modulated baseband of the conditioned electrocardiac, electroencephalic and muscle-action signals for transmission purposes. A baseband of 500 cps per guard will be more than adequate to sense with fidelity the biosignals considered for telemetry.

Subcarriers derived from the basic carrier, say in the VHF band, of the portable transmitter will be modulated by the biosignal to be monitored. The portable transmitter may be a separate telemetry transmitter or, if guards already use a walkie-talkie system, that transmitter may be modified so that the sensed biosignals may be transmitted by it as well.

At headquarters, separate receivers, each tuned to a different guard, will perform the monitoring function. In each receiver locally generated subcarriers will be mixed with the incoming signals and separate i-f filters will isolate the three different biosignals into appropriate subchannels. A detector following each of the i-f filters will extract the waveform of the biosignal.

Each of the biosignal waveforms will enter into a separate subchannel containing a comparison circuit. This circuit will compare the received biosignal with reference signal levels corresponding to the upper and lower bounds of the normal range of amplitude and frequency of the biosignal for that particular guard. Although the majority of guards will fall into the normal range of the biosignal for the adult male population, there may be a few guards for whom special adjustments of the upper and lower bounds in the comparison circuit will have to be made.

The output of the comparison circuit will indicate one of three conditions: normal, abnormal, or borderline. The abnormal reading will be indicated by, say, a red light and the borderline by an amber light; both lights being accompanied by an audible alarm. The lights would be located on a display board, with each guard assigned a specific location on that board. Since each guard's deployment region is known, the display of a colored light would also indicate the location of the problem area. In addition, a control panel can be designed so that by turning a switch, the visual indication of the biosignal of interest could be raised on the panel's oscilloscope. This may be necessary in borderline situations.

III. BIOSIGNALS TO BE MONITORED

The three biosignals considered for telemetry in the perimeter defense warning system are, in their order of importance to the system, modified forms of:

1. Electrocardiac (ECG) signal
2. Electroencephalic (EEG) signal
3. Certain muscle movement or muscle potential signals

ELECTROCARDIAC SIGNAL

Of the three signals, the electrocardiac signal is the most valuable to the operation of the system. It is easiest to sense, and the required hardware for its sensing and telemetry is most readily available. It is considered most valuable because during a physical confrontation between the guard and the intruder, the kind of physical damage most likely to be suffered by the guard, i.e., injury involving loss of blood and/or death, would be clearly indicated by the ECG signal. The amplitude of the ECG signal is generally above the ambient musculature potential and is thus easily detectable. Furthermore, the ECG telemetry techniques have been implemented and associated equipment is currently in use, although now only for heart patients and astronauts.

The electrocardiac signal will unequivocally indicate death or physical injury caused by bullet or knife. Further, it can indirectly indicate a physical struggle, as the gross muscle potential will ride on the PQRST waveform.*

The PQRST waveform, which originates in the sinoauricular nodes, causes depolarization and consequent contraction of the heart musculature. This gives rise to the typical tracing composed of the P-wave auricular depolarization; the QRS complex, ventricular depolarization; and the T-wave repolarization. The PQRST waveform and its repetition rate can be used to obtain a precise measure of the cardiac rate (number of heart beats per second), timing (the relative duration of the various sections comprising the waveform), and rhythm (whether there exist any inversions of the normally positive sections). If the entire PQRST is to be radio-telemetered, the signal characteristics of a channel sufficient to reproduce the waveshape with fidelity are 0.1 to 100 cps with an amplitude dynamic range of 0.05 to 2.0 millivolts (32 db).

As seen from the sketch in Appendix B, the R-pulse can be easily extracted and applied to a pulse-counting circuit whose output modulates a carrier. This results in a narrower band signal than if the entire PQRST waveform was transmitted. Heart rate exceeding 100 beats per minute (tachycardiac condition) and lasting over 90 seconds indicates injury which results in internal or external loss of blood. A heart rate of less than 40 beats per minute (brachycardiac condition) would indicate that the subject's (guard's) physical functions are deteriorating and that he has probably collapsed. Figure 1 is a pictorial representation of the ranges of the cardiac rate.

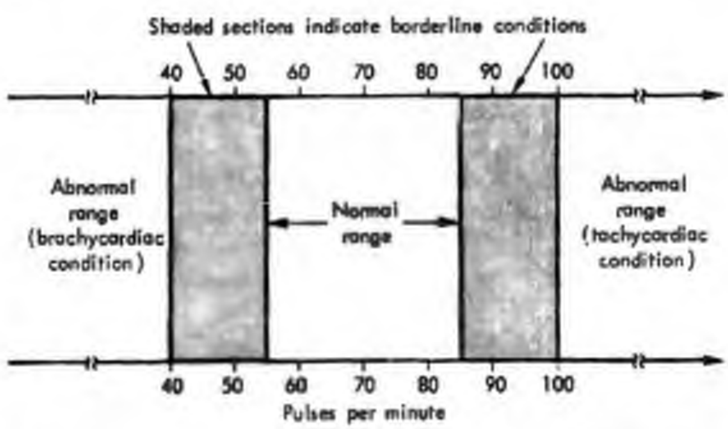

FIGURE 1. RANGES OF CARDIAC PULSE RATE FOR THE ADULT MALE AT REST POSITION**

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*A graphic description of the PQRST waveform is given in Appendix B.

**This figure does not intend to represent any of the idosyncratic features of individuals during and after exercise, when extremely tired, when in shock, etc., but rather to indicate broad regions where the monitor should query the guard.

A pictorial representation of the placement of the electrodes necessary to obtain the modified ECG signal is given in Fig. 2. It is important to note that the multi-electrode connections required in a doctor's office to obtain a complete ECG recording are not necessary, and a simple dual electrode configuration is used to obtain the modified ECG version for telemetry purposes.

The two electrodes shown in Fig. 2 are connected to two ends of the primary of a transformer with its secondary midpoint connected to the ground of the difference amplifier which follows. The transformer is commonly used in this manner to introduce a large rejection ration of in-phase interferences as well as to eliminate the necessity for a third electrode that would, in the absence of the transformer, have to be placed on the chest and connected to the amplifier ground.

Certain precautions are necessary when placing the electrodes (each approximately 1/2" in diameter) on the chest so they will not fall off while the guard is on duty, or cause skin irritation. The following steps are suggested toward meeting these two aims:

1. Cleansing the skin with alcohol in two places on the chest above the heart
2. Placing electrolyte gel on the skin and electrode
3. Placing an adhesive tape collar on the skin surrounding the electrode (this is sometimes referred to as a "band-aid" electrode).

FIGURE 2. PLACEMENT OF ELECTRODES USED TO PICK UP THE HEART SIGNAL FOR TELEMETRY

Depending on the personal preference of the guard, a harness or a pair of straps worn around each shoulder could be used to bind the flat-faced electrodes onto the chest instead of having band-aid type electrodes. A belt-like structure wound around the upper portion of the chest may also be used to hold the electrodes against the skin above the heart. Wearing the belt straps or harness, as well as wearing the band-aid type electrodes, may be uncomfortable in warm weather.

Medical corpsmen should place the electrodes on the chest of the guard. Since part of their training consists of taking electrocardiograph recordings, they should have no difficulty performing their tasks in the field. In certain respects these tasks will be simpler because only two electrodes are used in this system as compared with the multiple-electrode system used to obtain the electrocardiogram.

THE ELECTROENCEPHALIC SIGNAL (EEG)

The telemetry of a modified form of the electroencephalic signal, the α-rhythm, can be used to augment the ECG monitoring. Its purpose is to detect sleep and some injuries that might occur during a guard's physical encounter with the intruder. The type of injury that would be indicated by the EEG and not by the ECG is one producing a comatose condition without involving any loss of blood. Enemy action normally required to produce this condition would be knocking the guard unconscious.

Because of the low level of the EEG signal and its susceptibility to a variety of muscle potential interferences, it is much more difficult to sense than is the ECG signal. Moreover, its sensing may cause some discomfort to the guard, thus making the telemetry of EEG a more complex problem from a practical point of view. It would appear that the decision whether or not to telemeter the EEG would depend on the area's commander, who would take into account the importance of the area to be guarded, the nature of the expected threat, etc.

Table 1 presents a list of α-rhythm amplitudes together with their frequency characteristics for normal, borderline and abnormal cases. The borderline and abnormal readings are obtained from a comatose condition induced by injecting chemicals, breathing certain lethal gases, or by a severe blow on the head.

TABLE 1. RANGES OF α-RHYTHM AMPLITUDE AND FREQUENCY CHARACTERISTICS FOR AN ADULT MALE

Range	Amplitude (microvolts)	Frequency (cycles per second)
Normal	20-100	9-16
Borderline	100-150	6-8
Abnormal	150-300 > 300 < 20(a)	0.5-5 at any frequency 6-8

(a)Reading obtained from a sleeping subject.

In the case of a blow on the head, the immediate electroencephalograph reading will be masked by muscle potential variation to the order of 5 to 25 millivolts and frequency from 5 to 20 cycles per second. When the physical blows cease, the α-rhythm will be characterized by lower than normal amplitude and frequency: frequency of 6 to 8 cps and amplitude less than 20 microvolts. It should be noted that these signal characteristics are also obtained from a sleeping subject.

It is clear from Table 1 that three separate ranges of amplitude and frequency can be obtained from the α-rhythm. The necessary signal processing for the appropriate classification can be accomplished by circuitry included in the guard's equipment. The transmission of only three indications would allow for a narrow-band frequency-shift-keying modulation.

A summary of the essential information relative to the guard's physical condition contained in the biosignals is shown in Table 2.

EEG ELECTRODES, THEIR PLACEMENT AND ELECTRODE LEADS

To obtain the α-rhythm, one electrode will be placed on the upper occipital region and the other on the parietal region--toward the midline, thereby minimizing musculature interference.* The electrodes may be mounted in a band around and across the skull, in the inner headband of the helmet, or pasted onto the head with appropriate tape. The reference or ground electrode may be pasted to the apex of the head, attached to a band around the head or to the inner helmet band for support, or entirely eliminated by using a transformer described previously for the sensing of the ECG signal. If one electrode of each pair used in ECG and EEG is grounded, ground loop problems may result which could probably best be resolved by using an additional (third) chest electrode and/or head electrode as the ground electrode.

TABLE 2. SUMMARY OF PERTINENT INDICATIONS CONTAINED IN ECG AND EEG BIOSIGNALS

Biosignal	Death	INJURY: With Loss of Blood	INJURY: With no Loss of Blood, e.g., Blow on the Head, Coma Produced by Gas	Sleep
Electrocardiac Signal	✓	✓		
Electroencephalic Signal	✓		✓	✓

It is to be noted that the dual electrode configuration used in the telemetry subsystem is considerably simpler than the 11 or more scalp electrodes normally used to obtain a complete electroencephalogram.

Two kinds of electrodes are considered for sensing the frontal to occipital electroencephalic signal. The first, called the capelectrode, is the type commonly used for hospital electroencephalograph recordings. It is a thin, flat circular metallic (silver or lead) electrode about 1/4" in diameter. One electrode is to be placed at the hairline and the other at the back of the head. The area under the frontal electrode should be scrubbed with alcohol or acetone. The area under the occipital electrode should be likewise treated with the additional precaution of spreading the hair away from the area. Electrolyte gel is placed on the area and on the face of the electrode, and the electrode is firmly affixed by either an adhesive tape collar placed around the electrode or by the use of Bentonite paste or Collodian glue.

The second electrode, which has been developed recently and is of a more sophisticated design, has the advantage of being more less susceptible to muscle voltage interference resulting from the motion of the head and other portions of the body. This electrode is composed of a porous silver chloride pellet housed in a small tube, 3/16" long and 1/4" in diameter, filled with electrolyte gel.

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*In addition it may be advantageous to place the miniaturized EEG preamplifier beneath the top of the helmet with special shielding in the helmet and an antenna designed so that the outer portion of the helmet becomes part of the antenna.

The skin area under this electrode and the manner of attaching it to the sensed area is similar to that of the capelectrode, except that a flange is used to support the AgCl electrode. In either case, to prevent the electrodes from falling off, a head band or the cap commonly worn under a helmet should be used.

The leads connecting the electrodes to the preamplifier should be of the low-noise coaxial variety (Microdot wire) rather than of the more commonly used rubber insulated copper wire. The Microdot wire minimizes the tribo-electric effect, the voltage artifact resulting from vibration and mechanical shock which normally interferes with the low-level electroencephalic signal.

PROBLEM AREAS

Although ordinary medical corpsmen who have taken electroencephalograms of patients in hospitals would have no trouble placing the two electrodes while in the field, their main concern would be to insure that these electrodes do not fall off during guard duty and that good electrical contact is made between the skin and the electrode.

Wearing EEG electrodes generally introduces physical annoyance, but this would be reduced as the guards become accustomed to it. Scrubbing or abrading the surface under the electrode may be a bit painful, but it is of short duration. To obtain the best skin contact, the scarification procedure is advised. Here a thin needle is used to perforate the skin to a very low depth (~ 1/16") and the hole is filled with electrolyte gel. This reduces the contact resistance and results in an increase in amplitude of the electroencephalic signal. Because of the pain involved in the perforation, this procedure may not be considered acceptable even though it is beneficial to the EEG signal link.

Ordinary eye blinking may introduce signal interference in the EEG signal. It can be high enough to momentarily block the α-rhythm so that for a short time neither a normal nor abnormal reading would be received at headquarters. However, as the blinking action ceases the α-rhythm could be monitored again. (A consistent eye blink would, of course, have to eliminated from EEG monitoring.) Severe scratching of the scalp, grinding of teeth or careless movement of the helmet which moves the electrodes would produce similar disturbances.

GUARD CAPTURE INDICATION

Although in any encounter, the intruder would probably attempt to physically incapacitate the guard, there is a possibility that the enemy, aware of the guard's ECG and EEG telemetry, would hold up the guard with a gun or knife. This would foil the warning system since the situation would not be disclosed to headquarters either by the heart signal or the brain waves, thereby enabling the enemy to penetrate the unsuspecting area.

As no involuntary physiological function would generate a signal unequivocally indicating capture,* a voluntary physical action must be considered which will emit a particular physiological signal that could be detected at headquarters as the "capture" signal. Furthermore, this action must be such that it will not alert the intruder, while holding up the guard, to the fact that a message is being transmitted. However surreptitious this physical action might be, it must still be performed under the watchful eye of the captor; thus, the element of personal bravery must enter into the "guard-capture" signal link. Therefore, the subsystem could not always be depended

*Although initially the guard would probably be frightened, resulting in a faster than normal heart rate, the tachycardiac condition would fall to a normal count in less than one minute. Since the rapid pulse rate could also be a "startle response" due to a sudden sound or movement in the guard's environment, the short-duration tachycardiac condition is not a reliable capture indicator.

upon to function when the hold-up situation occurs and must be considered as a supplement to the basic involuntary biosignal telemetry system.

Of the variety of voluntary actions that may be considered for producing the desired muscle potential indicating capture (such as repetitive eye blinking, swallowing, finger movements, etc.), the two chosen as most acceptable are the guard holding his breath for a period of time and emitting a soft repetitive throat-clearing sound.

The application of air pressure to the walls of the windpipe, resulting in the sound emission, produces the muscle action potential that can be used as the biosignal indicating capture.

Training of the guards in the emission of a repetitive sequence of throat-clearing sounds would be required so that the resulting muscle potential could be detected with a minimum of equivocation. There are a wide variety of throat or "dime" electrodes which could be hidden below the top level of the shirt collar and affixed to the lower portion of the guard's throat that would sense the induced muscle potential of the larynx. The signal emanating from the larynx would modulate a subcarrier in the channel assigned to the guard. An experimental program will be necessary to aid in the design of a filter to segregate the signal potential indicating a "hold-up" condition from signals resulting from normal speech activity.

A guard capture indication less vulnerable to discovery by the enemy is sensing the lack of expansion or contraction of a guard's chest, accomplished by the guard holding his breath for more than 15 seconds. Sensing voluntary breath stoppage can be readily achieved by placing an elastic band across the upper portion of the guard's chest with an appropriate sensor attached to the band. (For example, the sensor may be comprised of a spring attached to the wiper arm of a potentiometer.) A sensor reflecting no change in length for at least 15 seconds would be sufficient to trigger an alarm tone generator.

As the normal breathing rate for the adult male at rest varies from 14 to 18 expansions and contractions per minute, the period of 15 seconds during which no expansion or contraction takes place is a compromise period, being three and a half times longer than the lowest normal interval, but not long enough to cause physical strain which could be reflected on the guard's face.

A physical examination to determine any breathing difficulties that might prevent a guard from holding his breath for the prescribed time duration will, of course, be necessary to eliminate those individuals from using this biosignal telemetry subsystem.

The elastic band, being close to the ECG electrodes, could also be used as an additional support for the electrodes. Wearing a belt or an elastic band across the upper portion of the chest may be a discomfort to some guards. It certainly appears to be more of an annoyance than the dime electrode placed around the throat. The discomfort could best be determined in field training under warm weather conditions.

The guard capture signaling subsystem, if employed, would also enable the guard to call for aid or otherwise alert headquarters in situations where he is not confronted directly by the intruder but observes at a distance enemy activity prior to penetration.

SIGNAL INDICATION OF UNAUTHORIZED ELECTRODE REMOVAL

After capturing the guard, the enemy might immediately remove the electrodes and place them on the body of one of the intruders, thus conveying to headquarters the impression that all is well. To offset this kind of action, an impedance-change detector could be connected to each pair of electrodes. Thepurpose of this circuit would be to note instantaneous changes of signal source impedance.

The output of the detector circuit exceeding a preset threshold would trigger a tone generator which would in turn produce a narrow-band signal in the guard biosignal channel. The receipt of this tone would indicate to headquarters that tampering with electrodes has taken place and, therefore, biosignals received after the disappearance of the tone must be suspect.

Another use for this circuit might occur when a guard is engaged in a physical battle with an intruder; by removing one of his electrodes, the guard would be able to communicate an alarm condition to headquarters.

IV. FALSE-ALARM CONTINGENCIES*

POSITIVE INDICATION OF A NEGATIVE CONDITION

"False-negative" alarms, abnormal biosignals received by headquarters indicating that a guard is physically hurt, dead or captured when in fact he is well, would be caused primarily by electrodes falling off. The probability of this occurring and causing a false-negative alarm can be minimized by insuring before the guard leaves for duty that the electrodes are securely strapped on with adhesive tapes, etc. As a matter of course, the entire telemetry system on the guard should be checked before he leaves for duty.

False-negative alarm can also be caused by failure of the circuit components used in the equipment. As such, the probability of false-negative alarms can be minimized at the design and building stage of the equipment development.

The false-alarm situation when all equipment is in order and yet no signal is received at headquarters indicated that heavy propagation loss exists in the guard's signal path. Topographical regions may exist around the base from which the transmitted signal would not be of a sufficient level to exceed the receiver threshold. This situation may occur if the guard is deployed in a valley surrounded by high hills or on the opposite side of a hill from the receiver antenna. Knowledge of the topography surrounding the base would aid in determining whether or not there will be propagation problems. A propagation survey of the region before the biosignal telemetry is employed would be of value in minimizing false-alarm situations due to unexpectedly large attenuation losses. In cases where such losses are common, relay stations may be installed on top of a hill or on some other high structure to provide, as necessary and feasible, line-of-sight communication.

A false-negative alarm can also be produced when a guard is startled by a noise or movement. This is due to the fact that a sharp increase in heart rate is a major component of the "startle response." However, the duration of the fast heart rate, for most adult males, is on the order of one minute and very seldom exceeds two minutes before returning to normal. Thus, when a fast heart rate is detected, a timed delay of two minutes would be inserted before a red light appears on the display board at headquarters. Electrocardiac examination with simulated field situations would also be a factor in reducing the false-alarm rate and might reduce the necessary delay period as well.

NEGATIVE INDICATION OF A POSITIVE CONDITION

A negative indication of a positive condition, i.e., a biosignal whose characteristics are within the normal range apparently telemetered from a guard who is in fact dead or injured is a "false-positive" alarm situation. The false-positive alarm, which would result in no help being sent to a guard who is in need, as well as in not providing the area with an alert when it security

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*This section, as well as the entire Memorandum, does not treat electronic warfare situations. There are many applications for the suggested system where jamming, spoofing, repeat-jamming, etc., do not enter, and at this time attention is directed only to those.

is probably being breached, again depends on the failure rate of the components and circuits used. The probability of a false-positive alarm is, however, lessened by the fact that appropriate failures must take place during and after the guard has been physically incapacitated.

The circuit indicating change of impedance which would detect electrode removal would be helpful in minimizing an enemy-induced false-positive alarm situation.

V. CONCLUDING REMARKS

1. With respect to possible technical problems envisaged in the building and operating of the system, none is expected in the telemetry of the heart signal. The measurement and telemetry of heart rate has become standard practice when monitoring astronauts and hospital patients, so that this subsystem is merely adapted for use here.

2. The telemetry of the reduced version of the EEG may introduce some problems because, any movement of the electrodes tends to distort the EEG signal. Often, too, muscular distention of the forehead or any portion of the scalp produces muscle potentials that override the low-level EEG. It is expected, however, that silver-chloride electrodes, the scarification procedure, and very firmly fixed electrodes would tend to minimize common EEG interference. An experimental program intended to determine a possible change in electrode size and a different placement of electrodes along the scalp, as well as a judicious choice of location for the EEG preamplifier, should be helpful in obtaining a signal less susceptible to pick-up of common muscle potentials of ordinary body movement.

3. All guards participating in guard duty employing the biosignal telemetry system must have their electrocardiogram and electroencephalogram taken during normal and hyperphysical activity to determine if any individuals possess abnormal physiological indicators. This examination should result in the elimination of most false-alarm risks.

4. The order of difficulty in implementing the biosignal telemetry system increases from ECG to EEG, while the most common result of a physical confrontation between the guard and an intruder would be indicated by the ECG. That is, killing or wounding the guard with a gun or knife would be indicated unequivocally by the ECG. An enemy may approach from behind and knock the guard unconscious if he is aware that only the ECG monitoring system is employed. With the modified EEG being monitored as well, the enemy, in order to maintain the element of surprise in his penetration attempt, would have to "hold up" the guard without harming him in any physical manner.

5. Whether a soft repetitive throat-clearing sound or the guard holding his breath is used to warn the area's headquarters of capture, the guard should be trained in one of the chosen signal indications. The training would help develop a facility for emitting the repetitive sequence of three or more soft sounds; in the case of the guard holding his breath, the training would be used to eliminate those who are short of breath during stress conditions.*

6. Depending on the various requirements of the area to be guarded, not all of the three biosignals need be monitored. For example, there may be instances where, based on requirements and on the area commander's judgment, only one, say, the electrocardiac signal, need be monitored.

*It is clear that when the enemy learns of this breath-holding technique he may attempt such obvious countermeasures as holding a weapon to the guard's head and warning him to breath normally. This leads of course to the usual tradeoff consideration between desired security level and complexity/cost factors. A hybrid system involving a modified accelerometer subsystem and "deadman" switches as well as additional biosignals could improve the security level, but in many instances the simpler system, say only the cardiac rate signal, may be all that is necessary.

7. If portable radiotelephone (walkie-talkie) equipment is part of the guard's equipment, the transmitter may be modified so as to modulate and transmit the sensed biosignals, thereby saving weight and cost.

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Appendix A

ESTIMATED WEIGHT AND SIZE OF THE GUARD'S EQUIPMENT

The total weight of the portable telemetry equipment to be carried by the guard will be less than three pounds. This weight is composed primarily of batteries. For an assumed radiated power of 5 watts and a system conversion efficiency of 50 percent, a 10-watt supply is required. A standard off-the-shelf battery weighing twenty-three ounces will supply this power for eight hours. For purposes of comfort, the battery, whose size is a bulky 2½" x 1½" x 1½", may be hung from the guard's belt. A less bulky battery package consisting of a long slender container may be designed. This would result in a better weight distribution when worn on the belt. The entire transmitter, approximately ten ounces in weight, will be transistorized using miniature components throughout. Its size will be equal to that of a package of "king-size" cigarettes. The transmitter may be placed in the breast pocket of the uniform.

If protruding antennas are to be considered they may be telescopic in design, a foot or two at its maximum length, and attached to the helmet worn by the guard. If this attachment is not convenient, the antenna may be connected to a shoulder strap. Both antenna configurations have been and are used successfully for personal transmitter units in various military situations.

The EEG preamplifier, whether attached to the inner ceiling of the helmet or placed in a shirt pocket, will not exceed three ounces in weight. This includes the electrodes and electrode leads. An additional ten ounces maximum will include the antenna, chest electrode and leads, throat electrodes and necklace.

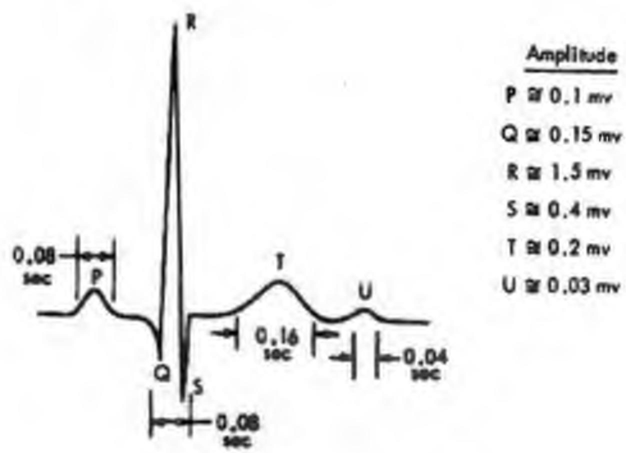
A sketch of the various units of the biosignal telemetry system as worn by the guard is shown in Fig. 3.

FIGURE 3. A GUARD WEARING THE BIOSIGNAL TELEMETRY EQUIPMENT

Appendix B

GRAPHIC DESCRIPTION OF THE PQRST WAVEFORM

A graphic description of the ECG signal, the PQRST waveform, whose characteristics are within the normal range, is given in the sketch below. The waveform is composed of several sections, each preceding an actual muscular contraction. Thus, the P-wave, indicating auricular depolarization lasting from 0.08 to 0.11 seconds, is approximately 0.1 millivolts at its maximum. The QRS complex, representing the ventricular depolarization lasting about 0.08 seconds, is 1.5 millivolts at the peak of the R-pulse. The T-wave, which represents the ventricular repolarization, has a duration of about 0.16 seconds and is approximately 0.2 millivolts at its peak. The U-wave is an "after-potential" wave which follows the T-wave. Its maximum level is 0.03 millivolts and its duration is approximately .04 seconds.



TYPICAL PQRST WAVEFORM OBTAINED FROM THE ECG

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THE VISUAL RECONNAISSANCE PROGRAM

IN SOUTH VIETNAM (U)

~~(CONFIDENTIAL)~~

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The RAND Corporation
Santa Monica, California

ABSTRACT

~~(Confidential)~~

The Visual Reconnaissance (VR) Program in South Vietnam is a combined, but separately administered, effort of the U.S. Army, U.S. Air Force, and Vietnamese Air Force. VR is presently the primary means of detecting and quickly responding to Viet Cong (VC) movement. In addition, VR serves the following important functions: to gather and evaluate "fresh" target information useful to all friendly military and intelligence organization, to detect (and thereby deter) the massing of enemy personnel and the movement of supplies and troops, to provide battle area information to ground commanders, and to demonstrate SVN/US "presence" to the populace and to the VC (perhaps most important in those many areas where friendly forces rarely venture).

The paper qualitatively describes the separate VR programs and quantitatively analyzes both the target sighting results and the flying program for each service. Suggestions to improve the program are offered in the following areas: The need and capability to increase VR, utilization of VR intelligence, hardware aids to VR, nighttime VR, VR aircraft, Vietnamese observers, and topics for future study.

PREFACE

This Report, sponsored by the Advanced Research Projects Agency's AGILE program, documents, analyzes, and suggests improvements in the airborne visual reconnaissance program in South Vietnam. The study was initiated in September 1965 as part of a larger RAND study of Forward Air Control. Field work in South Vietnam was conducted from December 1965 through March 1966.

The visual reconnaissance portion of the study is reported first because the findings have had some, and may have additional, immediate effect upon the visual reconnaissance program in South Vietnam. Field work revealed that the program needed documentation at an early date, lest other demands for Cessna O-1 aircraft resources cause the program to falter.

Informal briefings and suggestions were given to Military Assistance Command-Vietnam (MAC-V) Pacific Air Forces, and 7th Air Force personnel during the course of the field study. At the time of the study team's departure from Vietnam, some of the suggestions in this Report had been adopted by 7th AF and others were being studied.

In part, the study is a field evaluation of a previous RAND study (b)(6) [redacted] Southeast Asia Trip Report, Part II--SIAT: The Single Integrated Attack Team, A Concept for Offensive Military Operations in South Vietnam (U), RM-4400-PR (Confidential). This Memorandum suggested a widespread visual reconnaissance program in South Vietnam, to be closely coordinated with aggressive ground patrols.

SUMMARY AND SUGGESTIONS

This study examines the visual reconnaissance (VR) program as it was constituted in late 1965 and early 1966. The goals, uses, organization, level of effort, results, and productivity of VR are examined. Suggestions for immediate and future program improvements are offered, and problems requiring further study are noted. The Marine airborne observation program and out-country operations are not discussed.

Airborne VR can supplement, but never replace, such standard military reconnaissance collection techniques as vigorous ground patrols, agent reports, and electronic monitoring. However, the limited amount of territory under friendly control at any one time and the acknowledged insufficiency of these more standard techniques in spotting enemy movements have contributed to what the authors feel is a relatively high intelligence productivity from VR: VR is, and likely will continue to be, the primary means of detecting and quickly respon ing to VC movement, even though the probability of detection of movement is quite low. These statements, plus the knowledge that many relatively low-value interdiction (ID) targets are currently being struck in South Vietnam, point toward increasing the level of the VR effort in order to detect additional high-value ID and "movement" targets, thereby further restricting VC operations.

The overall effort has been less coordinated and productive than "VR program" implies. There have been essentially three separate and distinct efforts: USAF, USA, and VNAF. To a very considerable extent, this has been the result of VR being considered, at most, a secondary role for the liaison aircraft. Higher priority roles are airstrike control missions for USAF; artillery adjustment, radio relay, and convoy escort for USA; and airstrike control missions and administration liaison for VNAF. In addition, there has been a paucity of knowledge concerning the utility and effectiveness of the VR effort, due partly to a lack of analysis.

The bulk of the VR effort is conducted by the 362 Cessna O-1 aircraft* which are based in each of South Vietnam's 44 Provinces. These aircraft average slightly less than 2-1/2 flying hours per day; roughly half this time is devoted to VR.

For visual reconnaissance purposes, South Vietnam's 66,000 sq mi have been divided into 214 separate areas, roughly corresponding to the Districts within the Provinces. The VR pilots feel that the average flying time to perform a reasonably complete visual reconnaissance of the area is about 2 hours plus 1/2 hour transit time. The areas are classified as "critical" or "routine," based on their military situation and the productivity of VR in the area. Coverage of "critical" areas (generally coastal and lowland populated areas and border areas) are scheduled roughly once each day; "routine" areas (generally heavy foliaged, mountainous, and low-population density areas) are usually covered twice a week. Currently, an average of 65 percent of the VR areas are being covered daily.

*As of 28 February 1966. The O-1 was formerly designated the L-19 by U.S. Army.

A "significant" VR sighting (significant enough, in the VR pilot's opinion, to be formally reported) occurred roughly once every 4 sorties, or every 6-1/2 flying hours; a significant sighting which involved movement of persons or equipment occurred only one quarter as often. The pilot recommended military action (airstrike, naval gunfire, artillery adjustment, or ground action) against roughly 25 percent of all reported sightings. In some 30 percent of the cases for which the pilot recommended military action, the same pilot, while still airborne, directed the action or helped carry it out. The reporting of significant sightings differed widely among the Corps and services; for example, while the USA and USAF reported many sightings in I Corps, no VNAF or USA IV Corps sightings were reported to 7th AF Headquarters Intelligence, MAC-V or the Combined Intelligence Center-Vietnam (CIC-V).

The most productive hours for VR sightings of enemy movement are established in the study; by far the most productive hours were those in the late afternoon and early evening;* the least productive hours were those during the noon-to-3-p.m. "siesta" period. The aircraft utilization and VR flying hour distribution with time of day were such that productivity was far below its potential; the bulk of the VR activity was concentrated around 9 to 10 a.m. and 2 to 3 p.m., with virtually no dawn or dusk flying.

Flying hours per month per O-1 aircraft range from 35 for VNAF, through 70 for USA, to 95 for USAF; yet such a comparatively simple aircraft should be capable of operating 200 hours per month, even assuming operation solely in daylight. Reasons given by 7th AF** for low utilization rates were lack of pilots and inadequate maintenance capability. It is shown that sufficient O-1 aircraft, qualified pilots, and maintenance capability may be available in the theater to support a doubling of the VR flying program.

The O-1 aircraft has marginal flight performance and has had a rather high loss rate (about one aircraft lost per 4000 flying hours, both combat and operational). On the other hand, the excellent visibility afforded its aircrew, its wide range of radio communications gear, its comparatively low maintenance costs, and its ability to operate out of very short rough airfields, are extremely desirable attributes.

SUGGESTIONS

Increasing the Level of VR Effort

An accurate prediction of the benefits of an increase in VR effort cannot be made. However, our understanding of VC movement requirements, plus the additional intensity and breadth of coverage afforded by a doubling of the VR effort, lead us to suggest that the number of movement sightings would be more than doubled.

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*Very little VR flying was accomplished after sunset or before sunrise. Hence, the productivity of nighttime VR remains to be established.

**Only USAF was queried on maintenance.

The capability to support this doubling of VR flying within the current in-country aircraft, pilot, and maintenance resources is shown in Section VI. Although an immediate increase is both desirable and feasible, a sustained increase would have to be supported by additional equipment and personnel to offset the increased aircraft attrition and for contingency planning needs.

We are not considering at this time alternate uses of increased O-1 flying. Additional support of the out-country ID effort or the application of FAC/VR resources to the South Vietnamese Pacification Program are other potential candidates for increased O-1 flying activity.

Utilization of VR Intelligence

Except for a few outstanding cases, VR in SVN has been a separate effort by each of the services involved, and within each service the VR effort has not been organized and directed to maximize its effectiveness. Maximum VR effectiveness requires a recognized "VR Program."

Although a trial reorganization of all O-1 aircraft and pilot resources is underway in IV Corps, VR is well down on the mission priority list and receives little special recognition other than a desire to make maximum use of existing O-1 resources. It is not suggested that VR be performed with a separate group of resources, but that the overall effort be coordinated and expanded as follows:

- Develop an integrated capability to compile, monitor, and analyze all of the VR intelligence to have detailed knowledge of the current methods of VR operation and actual and likely VC counteractions, so that the VR program can be more adaptive to changed conditions. Specific items requiring continuous monitoring and analysis are movement sightings per VR flying hour, sighting of an unusual amount of VC activity 4 to 15 km ahead of a friendly operation (the so-called "bow-wave" effect), and patterns of VC unit movements in the presence or absence of friendly activity.
- Produce, disseminate, and constantly update a loose-leaf book concerning:
  - a. VC operating procedures, VR countermeasures and ruses
  - b. "Preferred" VR procedures for varying types of terrain, population, military orders of battle, etc.
  - c. Techniques and procedures for VR pilots
- Design and monitor a uniform reporting system.
- Assign intelligence personnel, possibly noncommissioned officers (NCOs) to each VR base location for debriefing and assisting in certain of the VR aids discussed below.

VR Aids

There are several devices which are now available, or should be available in the near future, to aid the VR mission:

- Cameras and Processing Equipment. Some VR pilots are now provided with hand-held cameras, but insufficient attention has been paid to processing and dissemination. If cameras were more widely distributed, if rapid processing were available, and if dissemination procedures were developed, the output would better serve immediate intelligence needs and provide a permanent visual record. A "footlocker" film developing kit available to the proposed Intelligence NCO at Province or Division level would provide a timely and relatively inexpensive means for permanently recording VR intelligence and briefing Army and Air Force personnel.

- o <u>Tape Recorders</u>. A lightweight (2- or 3-lb) portable tape recorder wired into the VR pilot's headset would allow a permanent oral record of significant sightings and other information which is now memorized or written on the windshield or map with a grease pencil. The Intelligence NCO could transcribe the tape, distribute copies and keep files by date, area, and target type.
- o <u>Binoculars</u>. Experiments with binoculars in VR aircraft have so far proven largely unsuccessful because of their bulk and the "jitter" and re-orientation problems. At least one U.S. manufacturer (Bell & Howell) is well along in developing lightweight, hand-held, optically stabilized zoom binoculars. It is suggested that the development progress be monitored for VR pilot use. Higher and hence safer VR aircraft altitudes should be possible using binoculars.

<u>Nighttime VR</u>

At present there are enough well-documented cases of successful VR and airstrike control at night in SVN to indicate that the searching of areas having a high expectancy of VC activity, such as roads and canals, should be standard operating procedure when the moon provides sufficient illumination.

Although the few field tests of night-vision devices (NVD) have been inconclusive, there is great promise in the near future for an improved, stabilized system for use over areas of suspected VC activity. A prototype system could be operational before 1967.* It is suggested that advanced development and field testing of these devices be pursued as a high priority item for VR use.

<u>VR Aircraft</u>

The O-1 is probably the best <u>available</u> aircraft for performing the VR mission. The aircraft offers a unique combination of good viewing for pilot and observer, versatile radio communications, easy maintenance, and takeoff and landing capability on short and rough fields. However, serious performance limitations such as its top speed, rate of climb, and maximum gross weight (which precludes the installation of substantial protective armor), render it vulnerable to ground fire.

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*See RM-4925-ARPA, <u>Airborne Night-Vision Systems for Counterinsurgency</u> (U), [redacted] and [redacted], to be published, Secret.

The performance of the O-1 can be greatly improved at a small cost almost immediately by installing a larger, commercially available engine. The new engine and a few additional modifications can increase the top speed of the O-1 by about 50 percent and can more than double its rate of climb. In addition, it can allow crew and critical engine protective armor to be installed, more smoke rockets to be carried, or the range to be increased. Furthermore, some armament could be installed.

Any follow-on VR aircraft should retain the many good features of the O-1 (low initial cost, good viewing for the aircrew, versatile radio communications, easy field maintenance, and short and rough field operating capability), but have improved performance, some armor protection, a lower noise output, provisions for NVDs, and provision for a minimal armament capability.

Vietnamese Observers

At one time the rules of engagement specified that a Vietnamese observer be in the rear seat of the aircraft on all missions. This is still common practice in a few of the Provinces, but the majority of U.S. VR missions carry only U.S. personnel. We suggest that an effort be made to reactivate the former policy because Vietnamese observers usually have a superior knowledge of:

- peasant living habits and customs
- terrain
- VC operations
- Vietnamese language

The practical problems are the shortage of English-speaking Vietnamese observers and the possible conflicts in authority and responsibility.

Topics for Future Study

- Alternative Uses of O-1 Aircraft Resources. This Report concentrates on the VR program and does not discuss the several other important roles played by the O-1 in Southeast Asia. Two topics which are closely related to SVN VR activities are (1) the ongoing and future role of VR in interdicting out-country Lines of Communication (LOCs), and (2) what VR could do in direct support of the Province Pacification efforts (possibly working closely with Popular Forces/Regional Forces, U.S. AID personnel, District level VN personnel, and the psy-war effort).

- Armament on VR Aircraft. This is a complex question with strong arguments on both sides. Very briefly the arguments are:

Pro-Armament

a. Small, fleeting targets (for which political approval could be granted) are often spotted by VR pilots, yet strike aircraft often cannot arrive in time to attack, or the target is not "worth" a large ordnance expenditure.

b. "Pin by fire" tactics could be employed by VR pilots to keep an enemy unit from moving before strike aircraft or artillery can respond. This tactic is sometimes used by USA "Mohawk" (OV-1) pilots.

c. VR pilots' morale should improve since they could "defend" themselves.

Anti-Armament

a. VR pilots might tend to become "fighter pilots" and hunt mostly for targets they could attack alone (U.S. armed helicopters, when not operating in support of heliborne operations have exhibited this tendency).

b. With armament VR pilots would take more chances and become more vulnerable.

c. An incentive would be provided to circumvent the rules of engagement (which are presently well observed by VR pilots).

The validity of the above statements plus other information should be explored to provide a rational answer to the armament question.

o Effects of VR Aircraft Speed on Sightings and Vulnerability. The affect of speed upon the ability to detect targets and upon VR aircraft vulnerability should be measured by conducting operational tests. There is presently little data on this subject for the current operational environment and procedures.

Many of the suggestions made here have already been fully or partially implemented by 7th AF or MACV as the result of the study team's work.

ACKNOWLEDGMENTS

During their field work in SVN, the members of the study team worked through the VNAF/USAF Tactical Air Control Center (TACC) and collected much of its information through USAF channels. The excellent cooperation of 7th AF and USAR-V was an invaluable aid to the study.

Four principal sources of information were used:

1. Records and reports of USAF 2nd Air Division (2nd AD, now 7th AF), USAR-V, and VNAF.

2. Pilot interviews, including USAF FACs and Air Liaison Officers (ALOs), U.S. Army Forward Air Observers [FO(A)], USAF strike pilots, TACC personnel, and Direct Air Support Center (DASC) personnel.

3. Ground personnel interviews, including Province Chiefs and their staffs, USA advisors, Division staffs, Ground Liaison Officers (GLOs), and Army of Vietnam officers (ARVN).

4. Enemy documents and the findings of a RAND team conducting interviews of enemy prisoners and ralliers.

GLOSSARY OF ABBREVIATIONS

AFTU	Air Force Test Unit (Vietnam)
ALO	Air Liaison Officer
ARVN	Army of the Republic of Vietnam
CTZ	Corps Tactical Zone
DASC	Direct Air Support Center
DOD/ARPA	Department of Defense/Advanced Research Projects Agency
FAC	Forward Air Controller - (USAF)
FO(A)	Forward Observer (Airborne) - (USA)
GLO	Ground Liaison Officer
IR	Infrared
MAC-V	Military Assistance Command-Vietnam
NCO	Noncommissioned Officer
PF/RF	Popular Forces/Regional Forces
SLAR	Side-Looking Radar
SVN	South Vietnam
TACC	Tactical Air Control Center
TAOR	Tactical Area of Operational Responsibility
TASS	Tactical Air Support Squadron
TOC	Tactical Operations Center
UMD	Unit Manning Document
USA	United States Army
USAF	United States Air Force
USAR-V	United States Army - Vietnam
VNAF	Vietnamese Air Force
VR	Visual Reconnaissance
2nd AD	Second Air Division
7th AF	Seventh Air Force

I. WHAT IS THE VR PROGRAM?

FUNCTIONS OF THE VR PROGRAM

The VR program is a combination of USAF, USA, and VNAF efforts directed toward the accomplishment of the following functions. The functions are not independent nor are they listed in order of priority.

- To secure timely intelligence on enemy forces, facilities, and activities.
- To detect the massing of enemy personnel and the movement of supplies.
- To become intimately familiar with normal activity and terrain so that abnormalities in the pattern may be detected through repeated and systematic coverage of the same VR area.
- To develop tactical targets.
- To determine areas of high VC activity and VC control.
- To provide battle-area information to ground commanders, including the disposition of friendly and enemy troops and after-action assessment.
- To provide timely response to requests for VR or photographs of areas of special interest.
- To provide a synopsis of local topography, salient terrain features, and seasonal weather.
- To obtain evasion and escape information for use by friendly personnel.

These goals are not explicitly stated in any VR directive; however, many of them can be inferred from 2nd AD regulation No. 55-53, "Operations, Visual Reconnaissance."

VR AIRCRAFT

The bulk of the VR effort in SVN is conducted by the various versions of the Cessna O-1 aircraft, referred to as the "Bird Dog" by friendly forces and the "Old Lady" by the enemy. This aircraft is exceptionally small and lightweight (wing span = 36 ft and normal in-theater maximum operating gross weight = 2600 lb). It is a two-place craft (tandem seating), although it is normally operated by the pilot alone. Its normal cruise speed is about 90 kn and top speed 100 kn.* Its ruggedness, the excellent visibility afforded to its aircrew, its wide range of radio communications gear, its relatively low maintenance costs, and its ability to operate out of extremely short rough airfields all contribute to its excellent VR performance. The O-1, however, has shortcomings which degrade its VR capability. It is vulnerable to small-arms fire at low VR altitudes due to its low rate of climb (600 ft per min), its lack of installed armor, and its 90-kn cruise speed.

Other liaison aircraft, such as the USA "Mohawk" (OV-1), are not generally used for VR. Therefore, unless stated to the contrary, VR in this study refers to VR operations by the O-1 aircraft. The O-1 has other missions, including strike control; visual, infrared and photo reconnaissance; administrative liaison; escort and air cover; and psy-war. VR is not the first priority for allocating O-1 aircraft and pilot resources in any of the services (USAF, USA, or VNAF).

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*Assuming the O-1E with fixed-pitch propeller. There are a number of O-1Fs in-theater that have a slightly higher top speed.

CONCEPT OF VR OPERATIONS

The concept of operations differs widely among the services. This is due to differing command relationships over the O-1 resources and the differing services' priorities for use of these resources.

USAF operations are founded on the theory that FACs and their O-1s should be stationed down to Sector (Province) level in order to become thoroughly familiar with friendly forces, civil administration, terrain, movements of the local populace, and enemy method of operations. In addition, USAF (ALOs) assigned to support ARVN are stationed at Division and Corps levels (in support of USA units, USAF ALOs are assigned down to Battalion level).

The assignment of FAC/O-1 resources to each Corps is determined at the TACC; assignment within each Corps is determined at the DASC. However, the day-to-day scheduling of VR is usually handled at Division level--generally by the ALO who considers airstrike-control needs, VR needs expressed by the FACs and the Sector Intelligence Officers (S-2s), and other O-1 mission needs. VR missions are scheduled after the strike-control missions have been assigned--that is, the amount of USAF VR depends upon the time remaining after strike control. Although a FAC's first mission priority is airstrike control, VR is one of the principal means of acquiring and verifying targets. VR may be performed immediately before a scheduled airstrike, often leading to a change in target (with the appropriate political and military approval).

Generally, a FAC works closely with and advises the Province Chief or his Deputy, the Sector Operations Officer (S-3), and the Sector Intelligence Officer (both USA and ARVN)--especially in the constant updating of reports of movements and significant changes in his area.

USA FO(A)/O-1 resources are classified in two categories: those "organic" to a Division (the relatively small number in U.S. Tactical Areas of Operational Responsibilities (TAORs), and those assigned to the four Light Observation Companies, one in each Corps Tactical Zone (CTZ). Each USA Corps Senior Advisor has direct control over one Company. Within each Corps the FO(A)/O-1 resources are more often shifted from area to area, and they are based at fewer locations than FAC/O-1 resources.

Missions for the USA Light Observation Companies, in approximate general priority, include: Artillery/Naval gunfire adjustment, radio relay, convoy/ship escort, VR, and courier/liaison support (generally, the FO(A) does not control airstrikes). USA VR tends to be concentrated on the battlefield area and its environs--concerned largely with observing and dealing with enemy activities and facilities which may pose an immediate threat to friendly ground forces.

Detailed information concerning VNAF O-1 utilization and concept of operations were difficult to obtain. Until very recently, the four VNAF Squadron Commanders had almost complete control over O-1 activities. Most VNAF flying was airstrike control, combat support, and administrative liaison support. Little VR flying was conducted and no VR debriefing reports, VR flying hour data, or maintenance data were available in U.S. channels.

VNAF observers (rated rear-seat officers in VNAF) are not based as widely as either USA or USAF O-1 pilots. Also, there were no VNAF ALOs stationed below Corps level.

RECENT CHANGES IN CONCEPTS AND ORGANIZATION

Agreement on O-1 Resources

The most significant recent development has been an agreement concerning O-1 resources in IV Corps. This agreement represents the first major step towards an integrated allocation of O-1 resources and an integrated VR effort.* The plan is being tested in IV Corps for possible application throughout Vietnam. The draft plan calls for the following changes relative to VR:

a. USAF/Corps/Division ALOs would have "operational control" of all USA non-organic O-1 resources ("operational control" is defined as "complete responsibility for aircraft utilization").

b. Scheduling of all O-1 missions would be done by the ALOs in response to the USA Corps Senior Advisor and Tactical Operations Center requirements.

c. The Corps Senior Advisor would prepare the VR plan and would assure that a Sector Intelligence Officer debriefs all pilots.

d. The list of O-1 mission priority is to be as follows: Airstrike control, artillery/Naval gunfire and adjustment, radio relay, VR, convoy/ship escort, other (liaison, courier, training).

e. The Army FO(A) may direct airstrikes when a FAC is not available.

In essence, the plan specifies that the USA Corps Senior Advisor will decide how the O-1s are to be used and the USAF ALOs will schedule aircraft to meet these requirements.

VNAF

It is understood that VNAF is planning to assign at least one FAC to each Province Headquarters for VR, to control airstrikes, and to advise--a concept pioneered by USAF FACs. Hence, the VNAF FAC will also be working closely with the province staff.

SPECIFICS OF THE O-1 VISUAL RECONNAISSANCE PROGRAM

The O-1 aircraft sortie utilization by mission type for the three services (USAF, USA, and VNAF) is shown in Chart 1. The ratio of VR missions to total missions varies among the services--roughly 0.63 for USA, 0.56 for USAF, and 0.11 for VNAF. For all types of reconnaissance, the corresponding figures are 0.78, 0.56, and 0.19, an even more marked difference. The explanation for these differences have been discussed above. These appreciable differences should be borne in mind when average

*Only in draft form when the RAND study team departed from Vietnam. Also, the extent of VNAF participation was not determined.

figures are quoted; e.g., although roughly half of <u>all</u> 0-1 flying hours are VR, the figure would be appreciably higher if VNAF were excluded.

Chart 2 shows the division of in-country VR effort among the three services for the month of January 1966. Measured in sorties, the effort is divided into 4800 for USA, 3500 for USAF, and 200 for VNAF; a total of 8500 sorties. Of the 12,500 total flying hours devoted to visual reconnaissance, USA flew 7200, USAF flew 5000, and VNAF flew 300.

The 0-1 aircraft are widely based throughout all of SVN. Many of the bases are suitably only for an aircraft of this type as they have rough fields and runway lengths as short as 1000 ft. The 53 USAF 0-1 bases as of January 1966 are shown in Chart 3. The maximum distance to any point within SVN from an 0-1 base is about 50 n mi or 1/2-hr flying time. To an extent, this large basing system diminishes the need for a FAC aircraft having appreciably higher cruising speeds, particularly if the higher speed aircraft are unable to operate at the extensive rudimentary bases from which 0-1 operations are conducted.

The portion of the total 0-1 force devoted exclusively to VR can be determined from the ratio of VR flying hours to total flying hours. Chart 4 shows the owned 0-1 force and the portion which can be considered as in-country "VR Only" aircraft. The ratios of "VR Only" to total aircraft are 0.77 for USA, 0.42 for USAF, and 0.11 for VNAF. Of an all-service total of 362 0-1 aircraft, 177 (or 49 percent) may be considered "VR Only" aircraft.

Chart 5 shows the average daily coverage of the 214 VR areas into which SVN has been divided. About 65 percent of the areas (or an average of 140 areas) are covered daily. Of the 170 areas covered, some 30 were covered by more than one service. Chart 6 shows the average daily coverage by CTZ. The poor weather in I and II Corps in January, particularly in the mountainous regions, accounts for the lesser VR coverage by these two Corps. Coverage by the U.S. Marine Corps airborne observers in I Corps is not included.

II. WHAT USE IS BEING MADE OF VISUAL RECONNAISSANCE?

Some understanding of the uses of VR can be gained by studying the recommendations for further action shown on VR debriefing forms. Chart 7 shows VR pilot* recommendations for additional reconnaissance or for direct military action, and shows how often he controlled or assisted in immediate military action. Of the 434 sightings during the two-week period 7-20 December 1965 for all four Corps, the VR pilot recommended military action against 103 sightings. In 32 cases, the same VR pilot, while still airborne, directed or assisted the military action; in 17 of the cases he directed an airstrike, in 14 cases he directed or adjusted Naval gunfire or artillery, and in one case he assisted the ground commander in attacking a Viet Cong force. Hence, it is seen that a considerable fraction (24 percent) of all reported sightings were of "lucrative" targets; further, at least 29 percent of these targets were of such a nature that immediate military action was taken against them.**

In addition to generating immediate-action targets, the VR program is a prime source of the preplanned air-targeting effort; during the USA FO(A) seminar at Dalat in February 1966, the USA III Corps G-2 was quoted as saying "60 percent of my air targets come from the VR program." All Corps intelligence officers indicated that VR was their most important and their most responsive intelligence collection effort. The VR program is basic to MACV's (2nd AD) in-country air-targeting effort. At higher Hq, VR intelligence is often correlated with other intelligence sources (such as radio direction finding, infrared photography, and side-looking radar (SLAR) missions) not usually available to the Sector (Province) Operations Intelligence Center.

Finally, VR and flash reports from FAC missions are the major sources of in-country bomb damage assessment and major contributors to all after-action assessment.

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*The term "VR pilot" is used to designate both USAF FACs and USA FO(A)s when they perform VR.

**The study team did not ascertain the additional number of targets for which relatively immediate military action was taken under the direction and control of another (subsequent) FAC/VR pilot.

III. WHAT ARE THE RESULTS OF THE VISUAL RECONNAISSANCE PROGRAM?

The results of any intelligence collection effort are difficult to measure, but some subjective evaluation can be obtained by looking at the number and types of sightings and at the effect of subsequent military action. The data to be discussed are "significant" sightings, i.e., VR pilot observations which were felt to be sufficiently important to merit formal reporting.*

Although a relatively large number of "significant" sightings are reported each day (roughly 65), they occur relatively infrequently per VR sortie or flying hour: during last December and January there was roughly one significant sighting every four VR sorties, or every 6-1/2 VR flying hours. A significant sighting involving "movement" occurred about 1/4 as often. Movement sighting is a sighting of activity or equipment which is not expected to be in its sighted location a short time later. Movement sightings generated by the VR effort are especially important since they provide targets that are not available from other sources (such as aerial photography or agent reports) in time to be attacked. Chart 8 (2nd AD Form 13)** illustrates the form on which significant sightings are reported.

For analytical purposes, a detailed listing of sighting categories was developed by the team. It is divided into three broad classifications: facilities, equipment, and activities. Some 40 subclassifications were used in the study itself. Facilities include trails, bridges, cultivated areas, caves, huts, fortifications, and trenches. Equipment includes military weapons and vehicles (elephants, water buffalo, and sampans). Activities include unidentified persons or Viet Cong hiding, running, shooting at the VR aircraft, engaged in combat or otherwise moving.

Chart 9A shows the number of significant sightings reported in I Corps for each of the three major sighting categories and for both services, USA and USAF.*** The USA had more sightings than the USAF for this period, largely due to the fact that USA had 32 O-1 aircraft assigned to I Corps, while USAF had only 18. Further, in this Corps (by local agreement), USAF flies principally along the Laotian border and in the interior of SVN (both of these areas are relatively low population areas), whereas the USA flies the more densely populated coastal areas. In I Corps, since there are few USA forces, the FO(A)s sometimes support the U.S. Marine Corps by having a Marine Observer in the rear seat.

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*However, it must be noted that some sightings by VR pilots are not reported if immediate military action cannot be taken due to fear of compromise.

**This form is currently used by USAF FAC/VR pilots, by USA FO(A)s and is intended for VNAF use. It is obvious that this form is of little use unless the remarks section is filled out. Fortunately, U.S. pilots have generally been entering the exact nature of the sighting in the remark section. However, the usefulness of the VNAF reports in U.S. channels is likely to present difficulty due to the language problem.

***During this sample period, 7-20 December 1965, and all subsequent sample periods, no VNAF VR sightings were found in any of the U.S. intelligence channels. However, the identical comment is applicable to the USA in IV Corps through mid-March. Also, USA in II Corps often reported "no significant sightings." USAF sightings reports from IV Corps, and in particular from DASC-Alpha, were extremely meager per VR flying hour. A uniform reporting system should substantially increase the number of significant sightings and hence our knowledge of VC activities, particularly in II and IV Corps Tactical Zones.

Charts 9B through 9D show the detailed breakdown of significant sightings for all of SVN for the same time period (7-20 December 1965). Chart 9E compares, for given target categories, the percentages of total sightings reported by USA and USAF in the various CTZs. Note the general similarity of the USA and USAF sighting percentages in I Corps and the dissimilarity for III Corps.

IV. HOW CAN THE VISUAL RECONNAISSANCE PROGRAM BE IMPROVED?

The effectiveness of VR may be markedly improved through a combination of changes, including the hour-of-day distribution of VR flying, the choice of VR search areas, the exchange of VR experiences and information concerning VC activities and ruses, the VR "organization," and mechanical aids to the VR pilot including NVDs.

HOUR-OF-DAY VR FLIGHTS

The relative productivity of VR flying at various hours of the day was an area of prime interest during the study. Only the VR sightings associated with movement were examined, since the other types of sightings should not be appreciably affected by the time of day (excluding nighttime). Four types of movement were defined: (1) vehicular movement, (2) personnel trying to hide or evade, (3) firing on the VR aircraft, and (4) all types of movement, excluding ground fire of an unknown source.

Chart 10A shows the VR productivity for all types of movement, given as the probability of a sighting per VR flying hour. The most productive hours for sightings are just prior to the noon siesta period, in the late afternoon, and in the early evening. This curve was developed by dividing the number of movement sightings in any one hour interval by the number of VR hours flown in the same hour interval.* Chart 10B, similar to Chart 10A, is based on the sighting of people who try to hide or evade when the VR aircraft approaches.

Chart 10C shows the probability that the VR aircraft will be fired upon is essentially constant in the morning daylight hours, drops during the siesta period, and then increases in the late evening hours. Chart 10D, the probability of vehicle movement sightings, is similar to Chart 10C.

Chart 11, the flying hour distribution, shows the average number of VR aircraft in the air for each hour interval.** It is seen that the VR flying was largely concentrated around 9 to 10 a.m. and 2 to 3 p.m., with little flying in the early morning or early evening hours. Since there was virtually no nighttime activity, it is not too surprising that no movement sightings (as shown in Charts 10) occurred prior to 6 a.m. or after 8 p.m.

When the differences in the VR flying hour distribution (Chart 11) and the most productive hours distribution (Charts 10) were revealed, 2nd AD took action to insure a more even distribution of flying hours, with special emphasis on early morning, late afternoon, and early evening flying. It is suggested that charts such as Charts 10 and 11 should be kept current to detect any shifting in the hours of VC activity and movement, and to make appropriate changes in VR flying hour distribution.

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*The sighting data are for all four Corps while the distribution of VR flying hour data is taken only from USAF III Corps records. However, the distribution of VR flying with hour-of-day appeared to be approximately the same for all Corps and services.

**These data are taken from 19th Tactical Air Support Squadron (III Corps) records, Form 781, for the first three weeks in January 1966.

Chart 12 shows the distribution of USAF VR mission duration in III Corps in January 1966. The very short duration "missions" result largely from missions which were primarily FAC during which VR was performed and logged. Note that the high points of the distribution occur at even multiples of 30 minutes.

IMPROVED CHOICE OF SEARCH AREAS

It is also possible to improve VR productivity by directing VR to areas where VC activity is expected. For example, there will often be sightings of individual VC or VC units in the region from 4 to 15 km ahead of the sweep of a military unit, even though the unit may have little or no contact with the enemy. This so-called "bow-wave" effect has been noted by some FO(A)s and FACs, but has not been exploited by assigning additional VR aircraft to the areas ahead of the ground units.

In addition, research* is beginning to show patterns of movement of a VC regional force (the 514th Battalion). Due to feasible marching distances, the number of reasonably secure camping spots, the availability of water, etc., there are a limited number of places where a VC unit can camp. According to the unpublished research, the 514th Battalion has generally followed a clockwise movement within its region of operation. When the Battalion has been observed to deviate from its "normal" movement pattern, an attack has often occurred. Using such patterns of VC movement, VR effort can be directed to potential camp areas (where a higher sighting probability exists) and can assist in alerting friendly forces which may be subjected to attack.

VR AIDS

The effectiveness of the VR program can also be improved through the use of binoculars, cameras, and tape recorders. Binoculars are government-issued equipment for USA FO(A)s.** However, because of the combination of vibration and narrow field of view, many of the pilots have become nauseated when using conventional binoculars. A test of stabilized binoculars conducted in Vietnam in 1964 was not completely successful because the gyro-stabilized binoculars were bulky and heavy and hence difficult to use. However, Bell and Howell has recently developed stabilized zoom binoculars, 2-1/2 to 10 power, weighing only 4 lbs. It is understood that these will soon be available for testing by the USA.

Cameras have also been used to provide permanent records for later reference and for demonstrating to other pilots or to target intelligence personnel the exact nature of VR sightings. A recent test of the Nikon F camera was felt to be largely negative, not because of deficiencies in the camera, but because (in USAF photo channels) it took from 7 to 21 days to process the 35-mm black and

*Study by [redacted] Consultant to RAND in Vietnam.

**USAF has some zoom binoculars for its FACs.

VC ACTIVITY INFORMATION AND EXCHANGE

A prime function of the VR effort is the development of familiarity with the normal activity and terrain through systematic and repeated VR of a given area; this familiarity leads to provisional indicators of abnormal activity.

Currently there is no organized USAF effort to provide the VR pilot with VC activity information (such as contained in Prisoner of War (POW) interview material) or to provide the pilots an opportunity to exchange their experiences. Hence the "learning time" for a VR pilot is excessive.* The USA has used the seminar as an effective device for transferring experience from one VR pilot to another and from one area to another. One of these seminars was held in Dalat in February 1966 and, although the subject of the formal sessions dealt largely with aircraft utilization, a wealth of information on VC activity was exchanged during these sessions and during informal conversations that followed. It must be recognized that decisions on what is and what is not VC activity is in most cases inherently complex and subject to change. Both characteristics call for periodic seminars with appropriate dissemination to other intelligence activities. Examples of the type of valuable information which has been learned are:

> In I Corps a FO(A) could not identify the movement of VC units through his area. He soon recognized that the only major and legitimate movements of groups of people were the movements of farmers and peasants to and from the markets, so he plotted the location of each market and noted the hours and days on which they operated. With this knowledge, he was able to concentrate his VR and identification effort on those groups of people who were moving contrary to the normal market activity movement.
>
> POW interrogations revealed that when the VC learned that the Americans believed the myth that all VC guerrillas wore black pajamas, an order went out to wear more white clothing. In addition, if VC units were observed on the road by VR aircraft, it was suggested that they stop and wave at the American pilots. This virtually guaranteed freedom from fire and succeeded until the VR pilots learned of an American unit being ambushed after passing through these white-clothed "peasants."

It is suggested that a handbook be written which discusses patterns of VC activity and other useful VR information. The development of such a handbook (and it must be loose-leaf) will require the systematic effort necessary to extract and identify these patterns of activity, ruses, etc., from the bulk of intelligence data available.

VR ORGANIZATION

The desired improvements in the VR effort will require the establishment of a recognized "VR Program." At present, the VR effort is split among USA, USAF, and VNAF; between intelligence and operations; and for USAF between the TACC and the 505th Tactical Control Group.

An integrated capability should be developed to compile, monitor, and analyze the VR intelligence, and to maintain detailed knowledge of the current methods of VR operation and actual and likely VC counteractions. This will result in a VR program which can be effective and remain effective under changing conditions.

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*VR pilots state that it takes them one to two months before they feel that they are reasonably effective.

white film. Second AD is understood to be installing processing equipment in each of the four Corps to decrease the processing time.

As more intelligence detail is required, the pilot finds it difficult to enter all the information on his map or window. A few of the pilots have purchased and are using tape recorders during their missions to record all the information for later transfer to their files or for use in formal reports or debriefing.

Because of the reasonable cost of binoculars, cameras, and tape recorders and because some pilots find them extremely useful, they should be available to those pilots who wish them.

Night-Vision Devices

A major improvement in the effectiveness of VR could be obtained through (1) an increase in nighttime VR activity and (2) the use of night-vision devices (NVD). Insufficient experience in nighttime VR activity using the O-1 aircraft is available to evaluate its effectiveness. Certain VR pilots said that VR was possible on moonlit nights along roads, rivers, and canals; others said that nighttime VR was not possible because of terrain hazards and the types of airfields from which the O-1 is operating. However, there are some examples of highly effective night VR. For example, in the Song Be area, a VC unit kept rebuilding a bridge across the river at night, while a FAC kept it out of commission in daytime. One night the FAC performed low-altitude VR over the area and noticed the bridge being reconstructed; he requested and directed an immediate airstrike. The bridge was destroyed and many of the construction workers were killed, ending the VC attempt to rebuild the bridge.

The NVDs tested in Vietnam by the AF Test Unit (AFTU) ("Starlight," and the Crew-Served Weapons Night-Vision Sight, made by Electro-Optical Systems, Inc.) have been greeted with mixed reactions. The enthusiasts point to the marked success of "Starlight," which, installed in an AC-47 flying at 2500 ft, detected a VC Battalion moving across a rice paddy at night in early March; since 57 VC bodies were still in the area on the following morning, it is believed that roughly 200 fatalities were achieved. Other persons feel that, even on moonlit nights, the performance of the tested NVDs is marginal; however, this may be caused by their narrow field of view, jitter (leading to nausea and air sickness), necessity for refocusing, etc. In any event, in order to make effective use of NVDs, it will be necessary to use them in relatively narrow geographic areas where there is a high probability of VC activity (i.e., roads and canals). An example of this limited, but productive, area search is the USA's usage of IR and SLAR on canals.

RAND has just completed a study of NVDs which suggests the immediate assembly and test of a system capable of detecting and striking enemy troops in the open on clear, moonless nights. It is believed that this system could be operational before 1967.*

(b)(6) [redacted] Night-Vision System for Counterinsurgency (U), to be published, Secret.

V. SHOULD THE LEVEL OF VR EFFORT BE INCREASED?

Implementation of the suggested measures for VR effectiveness, such as hour-of-day productivity and improved choice of search areas, should result in a markedly improved VR program. Given these improvements, should the VR flying effort be expanded, held constant, or reduced? Unfortunately this question cannot be answered without consideration of the relative effectiveness of alternative usages of the O-1 resources (such as increased FAC missions within SVN or in support of the SVN Pacification Program, or increased FAC and VR missions in out-country operations).

The study team has not attempted to address the alternative usage problem. However, it is of the firm conviction that the VR flying effort should be at least doubled. And, since it is indicated (in the next section) that an appreciable increase in O-1 flying hours could be effected with essentially in-theater resources, and assuming that the present division of O-1 resource allocation is appropriate, then the alternate usage question may be somewhat academic.*

Commanders were questioned as to what they would do with various levels of VR effort. Chart 13 shows four levels of effort: 1, 1-1/2, 2, and 2-1/2, corresponding roughly to the number of times each VR area in SVN could be covered on a single day. The present VR flying hour program of 12,500 hours per month is slightly less than the "1" level. As can be seen, in all cases the commanders would expect to handle all special VR requests; their coverage of "critical" VR areas (such as the border and coastal areas) would increase from once to twice a day; coverage of "routine" VR areas would range from twice a week to once a day depending on the level of VR effort; night VR ranges from none to "some." Lack of a complete understanding of the potential utility and productivity of VR is clearly shown: all levels were simply scaled upwards. No mention was made of items such as an appreciably expanded nighttime VR program, utilization of the additional flying hours for a vastly expanded reconnoitering of VC movement routes, or a concentrated effort in particular sub-sections of the individual VR areas.

The reasons for suggesting an increased VR effort are discussed below.

WHY INCREASE THE VR EFFORT?

Moving Targets

Except for ground operations, VR is essentially the only means for generating moving targets. Movement sightings are of particular importance since they provide targets that are not available from other sources (such as air photography or agent reports) in time to be attacked. Many of the

*The O-1s available for FAC missions should also be increased. For example, in III Corps for the months of December 1965 and January 1966, some 1300 preplanned mission requests received at the DASC (out of a total of 3800 requests) were not honored due to lack of FAC aircraft or fighter aircraft. Roughly 2/3 of the 1300 nonhonored requests were due to lack of FAC aircraft while only 1/3 were due to lack of fighter aircraft.

movement sightings are highly lucrative targets--sampans and VC units. During last December and January in III Corps, some 23 percent of all requests for immediate air response were for use against "fleeting" targets. However, during the same time period, movement sightings of all types were only being reported at the rate of 17 per day (0.4 per Province per day). Yet the POW-Interview material indicates that many VC units move daily. As yet our VR effort is not generating even a small fraction of the potential moving targets. A doubling of the VR effort, with emphasis on enemy LOCs, should more than double lucrative VC movement targets.

Static Targets

Currently, many knowledgeable people are questioning the usefulness of attacking certain of the D3 Strategic Interdiction Targets* which comprise essentially half of all of the preplanned missions which are supported (i.e., flown per the Fragmentary Order). Further, out of those missions which are honored (i.e., for which Fragmentary Orders are written), roughly half are not supported (i.e., not flown per the Order). Roughly 1/4 of these nonsupported missions were diverted to immediate requests (defined as response in less than 3 hours) for air support, while roughly 3/4 were utilized against "more lucrative" targets than those of the Fragmentary Order.**

Hence, there are two interrelated problems: (1) certain of our currently preplanned targets are perhaps of marginal value, as indicated by the fact that essentially half of the preplanned missions are not flown as scheduled, and (2) the nature of the environment is such that it does not lend itself to the lag of one day between planning and execution.*** The nature of the environment is the crucial item. The lag between intelligence acquisition and action must often be short (a few hours at most) if the action is to be effective. For example, "static" targets, e.g., VC concentrations, are actually "mobile" targets temporarily at rest. Although many of these targets may be received through agent reports which fix the general location, extensive VR is often required to fix their exact location before military action can be applied. For targets of this type,

*Mission priority is

A. Troops engaged with the enemy
B. Major ground operations support
C. Air cover (generally escort of convoys or ships)
D. All other
 D1 - affecting current operations
 D2 - Fleeting Targets
 D3 - Strategic ID Targets

**For example, in III DASC last December and January, 1572 preplanned missions were scheduled, but 701 of those missions were not flown against the planned target. Of the 871 preplanned missions which were supported, 447 were against the lowest priority targets (D3).

***All preplanned mission requests are to be in the DASCs by approximately 10 a.m. They are then passed along to the TACC for possible scheduling the following day.

sufficient O-1 resources should be available to permit an intensive VR effort, such as simultaneous search of the general area by several VR aircraft.

Certain targets, such as VC bases or storage areas, can only be determined through prolonged and intensive VR effort. For example, in the highlands of I Corps, agent reports gave the approximate location of a large VC base; however, it required 14 successive daily VR missions before a single structure of the base was located. The base was then bombed for several successive days since VR following each strike uncovered new strike areas.

VI. CAN THE LEVEL OF VR EFFORT BE INCREASED?

Given additional resources, effort can always be increased. The question explicitly addressed in this section is, "Can the level of VR effort be appreciably increased without appreciable augmentation of the in-theater resources?" It is indicated that the level of VR effort can be essentially doubled immediately provided that:

- If the fraction of VR effort to total effort remains as at present, the O-1 aircraft flying hours (per aircraft per month) can be increased to 70 hours for VNAF, 140 for USA, and 190 for USAF. However, if the non-VR flying remains at its present level, then the utilization rate would only have to increase to 43 hours for VNAF, 124 for USA, and 135 for USAF. Utilization of as much as 200 hours per month per airplane appears wholly practicable for the O-1 type aircraft.
- All O-1 pilots in-theater can average on the order of 85 to 100 flying hours per month.
- The 100-hour periodic checks on aircraft can be more carefully scheduled and/or the periodics can be performed at more locations. The Unit Manning Document (UMD) for critical specialists can be filled; additional stocks of O-1 parts are acquired.

For a sustained increase in effort, additional aircraft and pilots will be required, particularly if the O-1 attrition rates again return to the high levels experienced during the first eight months of 1965.

A commander has three types of resources to generate flying hours: aircraft, affected by the attrition rate, not because of the cost of the aircraft, but because of the relatively few O-1 aircraft that are available; pilots, each affected by the expectancy of survival during his tour and the number of hours he can reasonably be expected to fly each month; maintenance, affected primarily by the utilization rate of the aircraft, which is interrelated with aircraft scheduling, the number and training of the maintenance personnel, and spare parts stockage.

REQUIRED NUMBER OF AIRCRAFT

Chart 14 shows the effect of aircraft utilization on the number of "VR Only" aircraft required to obtain different levels of VR effort. Three utilization rates are illustrated: 35 hours a month per aircraft, the present rate for VNAF; 70 hours per month, the programmed rate for USA; and 95 hours per month per aircraft, the recent USAF rate. The vertical line indicates the present level of VR flying hours (12,500 hours per month) for January. This level of effort could be obtained with 132 "VR Only" aircraft using the current USAF utilization rate, 179 aircraft using the USA rate, or 357 aircraft using the VNAF rate. Looking at the problem differently, with the 177 aircraft, which compose the in-country "VR Only" portion of the O-1 fleet, only about 6200 flying hours per month can be generated with the VNAF utilization rates, but about 16,700 flying hours per month using the USAF rate.

It is definitely feasible to consider increasing 0-1 utilization to 6 to 7 hours per day (or to about 200 hours per month) even assuming that VR flying is limited to the daylight hours. Chart 15 shows that the current VR effort can be nearly tripled if a utilization rate of 200 hours per month per equivalent "VR Only" aircraft can be achieved. Such a utilization rate is practicable since the VR effort will be flown fairly uniformly throughout the daylight hours, and the daylight limit (360 hours a month) is adequate to permit a reasonable turnaround of the aircraft during the daytime hours. Chart 16 shows the incremental number of "VR Only" aircraft required (over the current 177), corresponding to various levels of VR effort and aircraft utilization rates. Note, however, that the utilization rates in Charts 15 and 16 apply only to the "VR Only" aircraft and not to the entire 0-1 fleet.

Hence, for a doubling of the VR effort (assuming the fraction of VR effort to total effort remains as at present), the 0-1 flying hours per aircraft per month would only have to increase to 70 hours for VNAF, 140 for USA, and 190 for USAF. And, if the non-VR flying were to remain at its present level, then utilization would only have to increase to 43 hours for VNAF, 124 for USA, and 135 for USAF.

PILOTS

Chart 17 shows the number of VR pilots required to achieve a given number of total VR flying hours per month as a function of the average monthly flying hours per pilot. The average rate for USAF FAC pilots currently is approximately 80 hours per month per pilot. However, certain FACs stated that they occasionally flew 100 to 120 hours per month.

The March 1966 USAF UMD provided for 287 FAC/ALOs (0-1 pilots) for in-country operations. Although the USAF has about 300 0-1 qualified pilots in-theater (as of mid-March 1966), excluding certain of the key DASC and TACC personnel, certain of these personnel are temporarily assigned to out-country projects. The USA and VNAF, since they own some 231 0-1 aircraft, probably have at least 300 0-1 pilots. Hence, the total number of 0-1 pilots in-therter is probably in excess of 600. If doubling the VR effort were considered (again assuming the VR effort remains at roughly half of the total 0-1 flying effort), then roughly 250 to 300 "in country VR only" pilots are already available. If all of these pilots can average from 85 to 100 flying hours per month, the goal of doubling the VR effort without bringing additional pilots into the theater would be achieved.

MAINTENANCE

The achievement of a higher utilization rate may require additional maintenance personnel. Lack of maintenance scheduling for the 100-hour periodic check and lack of key specialists and parts appear to be the critical factors in the USAF 0-1 utilization at this time. The USAF UMD provides four maintenance personnel per aircraft, or approximately nine hours of direct and indirect maintenance per flying hour.* This contrasts with one to two hours of direct and indirect maintenance in the United States for aircraft of similar complexity.

ATTRITION

Aircraft attrition is particularly important, not only because of pilot casualties, but because of the limited number of VR aircraft which are currently available in-theater. The 0-1 attrition rate--combat losses plus operational losses--recently has been about one aircraft per 4000 flying hours. As shown on Chart 18, USAF has had an 0.26 attrition rate per thousand flying hours for the last seven months;** USA had 0.23 for all of 1965; VNAF (for all VR aircraft) had 0.20 for 1965, about half operational and half combat. As expected, the 0-1 attrition is believed to be highly correlated with flight altitude. USA officers have indicated that most of their aircraft losses are believed to have occurred below 300 ft; USAF personnel of the 505th Tactical Control Group believe that most of their losses have occurred below 500 ft. However, since many of the losses involved crews killed in action or missing in action, flight altitudes are generally not known and the vulnerability of the 0-1 aircraft with flight altitude cannot be established from the theater loss data. Chart 19 shows the USAF monthly 0-1 losses and aircrew losses for 1965 and the first two months of 1966. It is seen that both losses have been very roughly constant with time. However, Chart 20 shows that the USAF 0-1 aircrew losses per 1000 flying hours have shown a decrease in recent months, from about 0.38 in the first eight months of 1965 to on the order of 0.1 more recently.*** There are several possible explanations for this reduction: (1) in the earlier period most of the flights were FAC missions involving target marking, while starting about September of 1965 an increasing number of missions have been VR missions (Chart 21 shows the USAF 0-1 flying hour increase resulting largely from initiation of the VR program), (2) both FAC and VR pilots have been flying large portions of their flights at increasing altitudes--in 1964 most 0-1 flying was at 500 to 800 ft while at present it is at 1500 to 2000 ft, and (3) the VC may have recently told their personnel not to fire on VR aircraft unless the VR pilot continues to keep them under observation.

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*Nine maintenance hours per flight hour is only slightly higher than the number of hours of direct maintenance required in South Vietnam for aircraft such as the F-100 and the F-5, which are substantially more complex than the 0-1.

**The time period for which we have 0-1 flying hour data from maintenance (DM) records (see Chart 21).

***It should be noted that the differences in aircrew death rates per thousand flying hours, although marked, do not appear to be statistically significant; e.g., if it is assumed that the death rate is constant with time and has a value of 0.2 per 1000 hours, then we would have expected 1.6 deaths for the time period January - April 1965, 3.7 for May - August 1965, 9.1 for September - December 1965, and 4.8 for January - February 1966. The probability of encountering the observed or greater deaths (for those time periods in which the observed deaths are greater than expected) or of encountering the observed or lesser deaths (for those time periods in which the observed deaths are less than expected), if it is assumed that the Poisson distribution is applicable, is 0.22 for January - April 1965, 0.08 for May - August, 0.05 for September - December 1965, and 0.30 for January - February 1966.

In addition to fatigue, the pilot's monthly flying hour rate may be constrained by his expectancy of survival if he has a fixed-time tour length, as at present. Chart 22 shows the expectancy that the pilot will survive his tour of duty as a function of the death rate per 1000 flying hours and the number of hours the pilot flies each month. If a pilot flies 100 hours a month, for a one-year tour with the current level of USAF aircrew loss rate (about 0.1 per 1000 hours), the pilot's tour survival expectancy is about 0.9. On the other hand, if aircrew loss rates again return to their higher level (about 0.38 per 1000 hours), then the pilot's survival expectancy is about 0.5 for a one-year tour and 0.75 for a six-month tour. Although aircrew survival does not currently appear to be a problem even with the high flying hour rate assumed (100 hours per month per pilot), if the loss rate goes back up to its previous level, decreasing the length of the O-1 pilot field-duty assignment should be considered.

VII. WHAT IS THE FUTURE OF THE VISUAL RECONNAISSANCE PROGRAM?

The future of VR depends on the strategy and tactics of the VC, the Vietnamese, the Free World, and the U.S. forces. It appears that the most difficult contingency for VR will arise from the VC reducing the number of unit actions and using smaller units, i.e., returning to the guerrilla actions which are characteristic of the "Phase II" of limited war. This would be one reasonable strategic response of the VC to increased U.S. force levels. Another contingency is that the enemy could choose to engage in an enlarged antiaircraft effort by introducing heavier caliber machine guns and antiaircraft weapons in SVN.

If the VC chooses to return to largely guerrilla actions, VR will become even more important as a responsive source of intelligence for targeting. This suggests an increased VR effort, as well as a shift in the utilization of our strike aircraft. Since the enemy activity would probably be focused more toward villages and hamlets, rather than toward friendly military units, air power should give vastly more support to the hamlets and to the Regional and Popular Forces. However, since few of these Vietnamese forces or village and hamlet officials speak English, communication with U.S. FAC/VR or U.S. strike pilots will pose a severe problem. Further, the VC will become even more difficult to find since as guerrillas they will be recognized more by their activity than by any obvious differences such as uniforms. Hence, it will be essential to have a detailed knowledge of the culture and environment of SVN and of VC activities and methods of operation. The needs for communication in Vietnamese and cultural and environmental knowledge suggest that a Vietnamese observer will be needed in all future U.S. VR aircrews.

As the targets become smaller--units of fewer men--and can disappear into the environment more rapidly, it becomes more difficult to provide timely air response by fighter aircraft. This raises the question of the desirability of mounting guns on the VR aircraft. Although there are good reasons for not equipping reconnaissance aircraft with guns (they may tend to become strike aircraft), a VR aircraft with guns could provide the necessary quick response. Guns were requested by 25 of 99 USAF FACs answering a FAC questionnaire early this year. These FACs felt that guns would be useful in those cases where small perishable targets, such as a few VC, are sighted. The USA uses 30-caliber machine guns on VR aircraft in certain special situations, such as when the "Mohawk" (OV-1) is assigned to perform VR in front of moving U.S. units. Although these weapons are used primarily to keep detected VC from moving until airpower can be directed on them, if the target is only a few VC, they may be used to attack the target directly.

The possible introduction by the VC of heavier caliber antiaircraft weapons leads to aircraft vulnerability considerations. The O-1 aircraft is marginally adequate in the present relatively benign environment. Modifications to the O-1--more powerful engines and some armor--have been suggested to improve its performance, particularly zoom capability, and to provide additional protection to the pilot. Higher performance aircraft can decrease vulnerability if these heavier weapons are introduced. Little data exist, however, on the changes in vulnerability or the effectiveness of VR with increased speed. Although most pilots indicated that 80 to 100 kn is the best speed for VR, many of them feel that an increase to 150 kn would not seriously degrade their VR capability. To resolve these questions, it may be desirable for USAF to test a higher speed aircraft; at the minimum, an attempt to compare sighting data from the USA "Mohawks" (OV-1) with the USA O-1s should be made.

Much of the VC activity is currently at night. As VR becomes more effective in the daytime, the VC may shift even more of their activity to nighttime. Yet at present we do not really know what our nighttime VR capabilities are. It is suggested that unassisted VR be conducted at night (when the moon is visible) to determine our night VR capability (as a function of phase-of-the-moon) without the assistance of NVDs. The same types of tests (but including times when the moon is not visible) should also be made utilizing various types of NVD, both active and passive.

Unless escalation of the in-country war occurs, VR will continue to be an all-important source of responsive intelligence information; with de-escalation, VR will have an even more important intelligence role. If de-escalation occurs, then particular emphasis should be placed on putting Vietnamese observers in all VR aircrews and on the identification of VC patterns of activity.

The VC may bring in heavier antiaircraft weapons; the desirability of improving O-1 performance or of utilizing some other aircraft for VR is dependent on the effects of increased aircraft speed on both vulnerability and VR sighting capability--and little is known about either of these two effects.

The desirability of adding minimal armament to the VR aircraft, particularly should de-escalation occur, requires further study.

The VC may increase their nighttime activity to exploit a weakness in the present VR capability. Response to this is also dependent on information not yet available--the effectiveness of clear-night unassisted VR and of the utility of NVDs.

Hopefully, many of these uncertainties can soon be resolved through a combination of field testing and further study.

MISSION TYPE	USAF*	USA	VNAF
PHOTO RECCE	–	8	–
IR RECCE	–	3	–
VISUAL RECCE	3,979	4,781	182
OTHER RECCE (INCLUDING COMBAT RECCE)	–	1,212	142
FAC	2,405	267	546
ADMINISTRATIVE, LIAISON	247	814	407
ESCORT, AIR COVER	109	(IN OTHER)	206
PSYWAR	38	—	128
RADIO DIRECTION FINDING	—	—	54
TRAINING	172	72	—
MAINTENANCE	21	179	—
OTHER	176	300	6
TOTAL SORTIES	7,147	7,636	1,675
OWNED AIRCRAFT	131	148	83
REPORTED FLYING HOURS	11,863	9,358	2,076

* INCLUDES OUT-COUNTRY OPERATIONS

CHART 1. O-1 AIRCRAFT SORTIE UTILIZATION BY MISSION TYPE (JANUARY 1966)

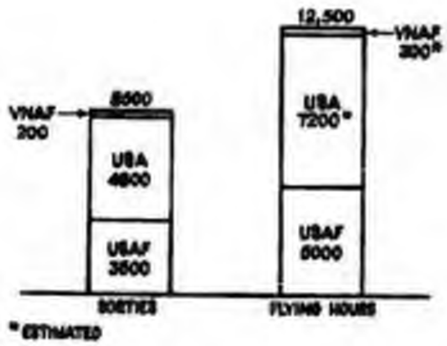

CHART 2. VR LEVEL OF EFFORT IN COUNTRY
(JANUARY 1966)

CHART 3. USAF 0-1 BASES IN SOUTH
VIETNAM (JANUARY 1966)

	OWNED O-1 AIRCRAFT	EQUIVALENT IN-COUNTRY "VR ONLY" AIRCRAFT
U.S. ARMY		
LIGHT OBSERVATION COMPANIES	128	
ORGANIC AIRCRAFT	20	
TOTAL	148	113
U.S. AIR FORCE	131	55
VNAF	83	9
TOTAL	362	177

CHART 4. "VR ONLY" AIRCRAFT

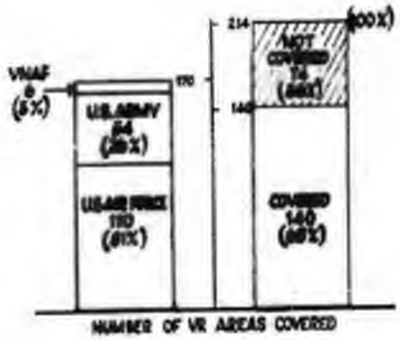

CHART 5. AVERAGE DAILY VR COVERAGE
(JANUARY 1966)

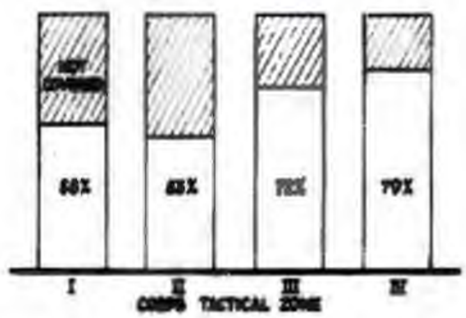

CHART 6. AVERAGE DAILY VR COVERAGE BY CORPS TACTICAL ZONE (JANUARY 1966)

	FACILITIES	ACTIVITIES	EQUIPMENT	ALL	
TOTAL SIGHTINGS	285	105	44	434	
RECOMMENDED:					
ADDITIONAL VR	173	69	40	282	
PHOTO, INFRARED	29		1	30	
GROUND ACTION	1	1	—	2	103
ARTILLERY	—	7	—	7	
NAVAL GUNFIRE	—	2	—	2	
AIR STRIKES	53	33	6	92	
CONTROLLED/ASSISTED:					
GROUND ACTION	—	—	1	1	32
ARTILLERY	3	8	1	12	
NAVAL GUNFIRE		2		2	
AIR STRIKES	2	14	1	17	

CHART 7. VR PILOT ACTIONS, DASC REPORTED SIGNIFICANT VR SIGHTINGS (7-20 DECEMBER 1965)

MISSION DEBRIEFING FORM
MAU GIAI TRINH SAU PHI VU

(To be filled out on completion of flight)
(De dien vao sau khi hoan thanh phi vu)

1. PILOT (Name & Grade) HOA TIEU (Ten va cap bac)	2. TAKEOFF TIME GIO CAT CANH		3. TOUCHDOWN TIME GIO HA CANH		4. DATE NGAY THANG
5. SIGHTINGS/INCIDENTS: CAC DIEU THI SAT/BIEN CO	1	2	3	4	5
6. CORPS/RECON AREA/TIME:* QUAN DOAN/VUNG THAM SAT/THOI GIAN*					
7. COORDINATES:* (In Tiger Code When By Voice) TOA DO* (Bang Mat Ma Tiger Khi dung vo tuyen)					
8. SIGNIFICANCE* (Check One) Y NGHIA (Danh dau 1 cai)*					
a. NEW TARGET Muc tieu moi					
b. TARGET STATUS CHECK Kiem soat tinh trang muc tieu					
c. ROUTINE Thuong					
9. INDICATORS:* (Check One or More) CHI HIEU (Danh dau 1 cai hay nhieu hon)*					
a. GRD FIRE (Indicate Type in Remarks) Hoa luc duoi dat (Chi ro loai trong muc Cuoc Chu)					
b. DEFENSE POSITION ACTIVITY Hoat dong dia vi-tri phong thu)					
e. TRANSPORT/SUPPLY ACTIVITY Hoat dong chuyen cho va tiep lieu)					
d. CHANGE IN HUMAN ACTIVITY Thay doi trong hoat dong con nguoi)					
e. CAMOUFLAGE Nguy trang					
f. CONSTRUCTION EVIDENCE Dau hieu xay cat					
p. NEW TRAILS Duong mon moi					
h. OTHER (See Remarks) Cac dieu khac (Xem muc Cuoc chu)					
10. RECOMMENDATIONS* (One only) DE NGHI* (1 cai thoi)					
a. AIR STRIKE* Danh kich					
b. BLACK & WHITE PHOTOGRAPHY Chup hinh trang va den					
c. RED HAZE CORROBORATION Kiem soat lai bang hong ngoai tuyen					
d. CONTINUOUS VR Thi sat lien tiep					
11. HAND HELD PHOTO ACCOMPLISHED:* HINH CHUP BANG MAY CAM TAY:*	☐ YES CO,	☐ NO. If yes, Enter Altitude in Hundreds of feet KHONG. Neu co ghi cao do bang hang tram bo.			
12. REMARKS CUOC CHU					
* Items to be transmitted to Corps by Voice * Tai lieu chuyen giao den Quan Doan bang vo tuyen					

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CONF. GP4 (when filled in)
KM (Khi da lam xong)

CHART 8

TYPE	USAF	USA	VNAF	TOTAL
FACILITIES	57	130	DNA[*]	187
EQUIPMENT	4	15	DNA	19
ACTIVITIES	20	39	DNA	59
TOTAL	81	184		265

[*] DATA NOT AVAILABLE

CHART 9A. 1 DASC REPORTED VR SIGHTINGS
(7-20 DECEMBER 1965)

TARGET TYPES	I CORPS*	II CORPS**	III CORPS*	IV CORPS**	TOTAL
FACILITIES					
BOAT LANDINGS	1	-	-	-	1
BRIDGES, CROSSINGS	8	3	6	-	17
TRAILS	8	4	10	-	22
FERRIES	1	-	-	-	1
CULTIVATED AREAS	20	1	5	-	32
"FACTORIES"	-	1	-	1	2
RADIO ANTENNAS	2	-	-	-	2
CABLES	1	-	-	-	1
HUTS, HUTCHES	11	10	8	2	31
HOUSES	12	5	-	-	17
HOLES	2	4	2	-	8
CAVES, TUNNELS	9	1	2	-	12
FOXHOLES	10	11	1	-	22
TRENCHES	46	2	4	-	52
GUN POSITION	35	3	2	-	40
FORTIFICATIONS	9	1	1	2	13
ANTIHELI STAKES	2	1	-	-	3
ROAD BLOCKS	6	2	4	2	13
ROAD OR TRAIL TRAPS	1	-	-	-	1
TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* USAF PLUS USA ONLY
** USAF ONLY

CHART 9B. DASC REPORTED VR SIGHTINGS
(7-20 DECEMBER 1965)

TARGET TYPES	I CORPS*	II CORPS**	III CORPS**	IV CORPS**	TOTAL
ACTIVITIES					
SA FIRE (KNOWN)	3	2	7	2	14
SA FIRE (UNKNOWN)	6	4	–	1	11
AA FIRE (NOT SA)	1	-	-	1	2
MILITARY CONSTRUCTION	6	-	-	-	6
UNITS STATIONARY	6	2	-	1	9
UNITS MOVING	6	-	-	-	6
ROAD BLOCKS	-	-	-	-	-
UTS STATIONARY	6	3	2	1	12
UTS HIDING	10	9	-	1	20
UTS MOVING	10	2	4	-	16
FIRES	-	2	-	-	2
CIVILIAN CONSTRUCTION	5	-	2	-	7
TOTAL	59	24	18	7	108

*USAF PLUS USA ONLY
**USAF ONLY

CHART 9C. DASC REPORTED VR SIGHTINGS (7-20 DECEMBER 1965)

	FACILITIES	ACTIVITIES	EQUIPMENT	ALL	
TOTAL SIGHTINGS	285	105	44	434	
RECOMMENDED:					
ADDITIONAL VR	173	69	40	282	
PHOTO, INFRARED	29		1	30	
GROUND ACTION	1	1	—	2	[illegible]
ARTILLERY	—	7	—	7	
NAVAL GUNFIRE	—	2	—	2	
AIR STRIKES	53	33	6	92	
CONTROLLED/ASSISTED:					
GROUND ACTION	—	—	1	1	32
ARTILLERY	3	8	1	12	
NAVAL GUNFIRE		2		2	
AIR STRIKES	2	14	1	17	

CHART 7. VR PILOT ACTIONS, DASC REPORTED SIGNIFICANT VR SIGHTINGS (7-20 DECEMBER 1965)

MISSION DEBRIEFING FORM
MAU GIAI TRINH SAU PHI VU

(To be filled out on completion of flight)
(De dien vao sau khi hoan thanh phi vu)

1. PILOT (Name & Grade) HOA TIEU (Ten va cap bac)	2. TAKEOFF TIME GIO CAT CANH		3. TOUCHDOWN TIME GIO HA CANH	4. DATE NGAY THANG	
5. SIGHTING/INCIDENTS: CAC DIEU THI SAT/BIEN CO	1	2	3	4	5
6. CORPS/RECON AREA/TIME:* QUAN DOAN/VUNG THAM SAT/THOI GIAN*					
7. COORDINATES:* (In Tiger Code When By Voice) TOA DO* (Bang Mat Ma Tiger Khi dung an thoai)					
8. SIGNIFICANCE* (Check One) Y NGHIA (Danh dau 1 cai)*					
a. NEW TARGET Muc tieu moi					
b. TARGET STATUS CHECK Kiem soat tinh trang muc tieu					
c. ROUTINE Thuong					
9. INDICATORS* (Check One or More) CHI HIEU (Danh dau 1 cai hay nhieu hon)*					
a. GRD FIRE (Indicate Type in Remarks) Hoa luc duoi dat (Chi ro loai trong muc Cuoc Chu)					
b. DEFENSE POSITION ACTIVITY Hoat dong dua vi-tri phong thu)					
c. TRANSPORT/SUPPLY ACTIVITY Hoat dong chuyen cho va tiep lieu)					
d. CHANGE IN HUMAN ACTIVITY Thay doi trong hoat dong cua nguoi)					
e. CAMOUFLAGE Nguy trang					
f. CONSTRUCTION EVIDENCE Dau hieu xay cat					
g. NEW TRAILS Duong mon moi					
h. OTHER (See Remarks) Cac dieu khac (Xem muc Cuoc chu)					
10. RECOMMENDATION:* (One only) DE NGHI* (1 cai thoi)					
a. AIR STRIKE* Danh kich					
b. BLACK & WHITE PHOTOGRAPHY Chup hinh trang va den					
c. RED HAZE CORROBORATION Kiem soat lai bang hong quang tuyen					
d. CONTINUOUS VR Thi sat lien tiep					

11. HAND HELD PHOTO ACCOMPLISHED:* ☐ YES CO, ☐ NO. If yes, Enter Altitude in Hundreds of feet:
HINH CHUP BANG MAY CAM TAY:* KHONG. Neu co ghi cao do bang hang tram bo.

12. REMARKS
CUOC CHU

* Items to be transmitted to Corps by Voice
* Tai lieu chuyen giao den Quan Doan bang an thoai

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CONF. GP4 (when filled in)
KM (Khi da bao song)

CHART 8

TYPE	USAF	USA	VNAF	TOTAL
FACILITIES	57	130	DNA*	187
EQUIPMENT	4	15	DNA	19
ACTIVITIES	20	39	DNA	59
TOTAL	81	184		265

* DATA NOT AVAILABLE

CHART 9A. 1 DASC REPORTED VR SIGHTINGS
(7-20 DECEMBER 1965)

TARGET TYPES	[illegible]*	[illegible]**	[illegible]*	[illegible]**	TOTAL
FACILITIES					
BOAT LANDINGS	1	-	-	-	1
BRIDGES, CROSSINGS	8	3	6	-	17
TRAILS	8	4	10	-	22
FERRIES	1	-	-	-	1
CULTIVATED AREAS	[illegible]	1	5	-	[illegible]
"FACTORIES"	-	1	-	1	2
RADIO ANTENNAS	2	-	-	-	2
CABLES	1	-	-	-	1
HUTS, HUTCHES	11	16	5	2	[illegible]
HOUSES	12	[illegible]	-	-	[illegible]
HOLES	2	4	2	-	8
CAVES, TUNNELS	9	1	2	-	12
FOXHOLES	16	11	1	-	28
TRENCHES	44	2	4	-	[illegible]
GUN POSITION	26	2	2	-	30
FORTIFICATIONS	9	1	1	2	13
ANTIHELI STAKES	2	1	-	-	3
ROAD BLOCKS	8	[illegible]	4	2	[illegible]
ROAD OR TRAIL TRAPS	1	-	-	-	1
TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*USAF PLUS USA ONLY
**USAF ONLY

CHART 98. DASC REPORTED VR SIGHTINGS
(7-20 DECEMBER 1965)

TARGET TYPES	I CORPS*	II CORPS**	III CORPS**	IV CORPS**	TOTAL
ACTIVITIES					
SA FIRE (KNOWN)	3	2	7	2	14
SA FIRE (UNKNOWN)	6	4	-	1	11
AA FIRE (NOT SA)	1	-	-	1	2
MILITARY CONSTRUCTION	6	-	-	-	6
UNITS STATIONARY	6	2	-	1	9
UNITS MOVING	6	-	-	-	6
ROAD BLOCKS	-	-	-	-	-
UIS STATIONARY	6	3	2	1	12
UIS HIDING	10	9	-	1	20
UIS MOVING	10	2	4	-	16
FIRES	-	2	-	-	2
CIVILIAN CONSTRUCTION	5	-	2	-	7
TOTAL	59	24	18	7	108

*USAF PLUS USA ONLY

**USAF ONLY

CHART 9C. DASC REPORTED VR SIGHTINGS
(7-20 DECEMBER 1965)

TARGET TYPES	I CORPS*	II CORPS**	III CORPS**	IV CORPS**	TOTAL
EQUIPMENT					
ELEPHANTS	1	-	-	-	1
WATER BUFFALO	3	1	-	-	4
SAMPAN	4	-	11	5	20
BOATS	7	5	-	1	13
MILITARY WEAPONS	-	-	-	-	-
VEHICLES	-	1	-	-	1
CONSTRUCTION SUPPLIES	1	1	-	-	2
FOOD SUPPLIES	3	-	-	-	3
COMMUNICATION EQUIP	-	-	-	-	-
TOTAL	19	8	11	6	44
GRAND TOTAL	265	84	64	20	434

*USAF PLUS USA ONLY
**USAF ONLY

CHART 9D. DASC REPORTED VR SIGHTINGS (7-20 DECEMBER 1965)

	I CORPS		II CORPS (II DASC + ALPHA DASC)		III CORPS		IV CORPS	
	USAF	USA	USAF	USA	USAF	USA	USAF	USA
FACILITIES	[illegible]	[illegible]	[illegible]	0	43.6	37.3	34.5	DATA NOT AVAILABLE
TRANSPORT	7.6	8.5	13.6		8.1	14.9	2.8	
PRODUCTION	2.5	14.1	6.2		4.8	6.0	2.0	
COMMUNICATIONS	1.2	1.0	4.2		0	0	0	
HOUSING/STORAGE	13.6	15.5	28.0		6.5	3.0	8.0	
MILITARY	45.7	36.5	16.6		34.2	13.4	23.0	
ACTIVITIES	[illegible]	[illegible]	17.6	0	35.6	41.8	48.0	
MILITARY	12.3	4.6	13.6		34.5	32.4	40.0	
UNIDENTIFIED	17.4	10.4	4.1		1.6	16.4	8.0	
EQUIPMENT	4.9	8.2	7.2	0	30.6	14.9	18.0	
TRANSPORT	3.7	6.6	6.1		27.4	14.9	16.0	
MILITARY	0	0	0		0	0	0	
PRODUCTION	1.2	1.7	2.1		3.2	0	2.0	
SIGHTINGS PER DAY PER A/C	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	
SIGHTINGS PER VR HOUR	[illegible]	—	[illegible]	0	[illegible]	—	[illegible]	
TOTAL SIGHTINGS	61	184	94+3	0	62	67	56	
AVERAGE SIGHTINGS PER DAY	5.38	13.13	6.83	0	5.17	5.80	1.19	

[illegible]

[illegible]

CHART 9E. DASC REPORTED VR SIGHTINGS (7-20 DECEMBER 1965)

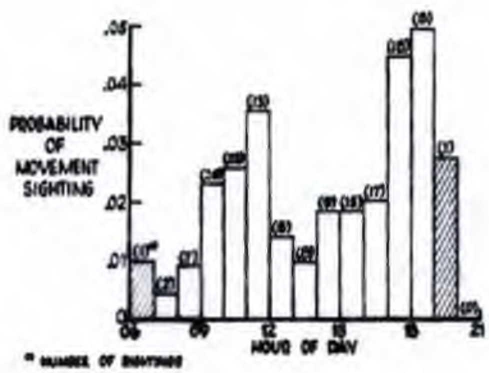


CHART 10A. VR PRODUCTIVITY

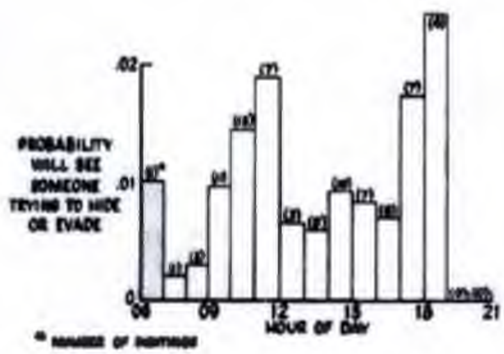


CHART 10 B. VR PRODUCTIVITY

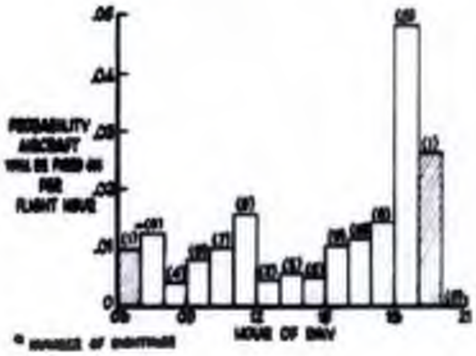


CHART 10C. VR PRODUCTIVITY

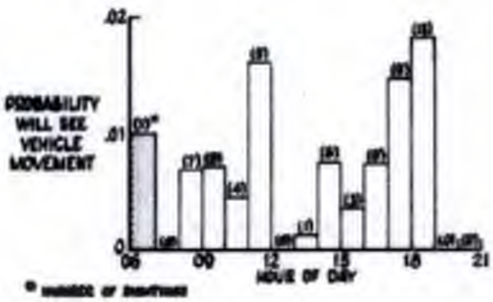


CHART 10D. VR PRODUCTIVITY

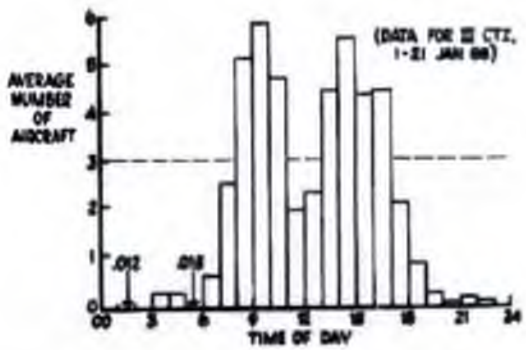


CHART 11. AVERAGE NUMBER OF O-1 AIRCRAFT ENGAGED IN VISUAL RECONNAISSANCE

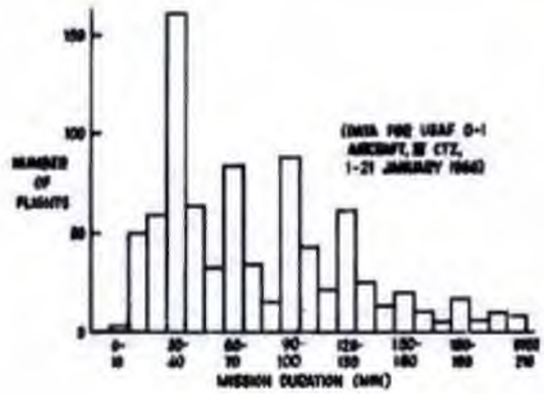


CHART 12. VR MISSION DURATION

LEVEL OF VR EFFORT	"1"	"1½"	"2"	"2½"
APPROXIMATE COVERAGE:				
SPECIAL VR REQUESTS	YES	YES	YES	YES
CRITICAL VR AREAS	1/DAY	2/DAY-	2/DAY	2/DAY +
ROUTINE VR AREAS	2/WEEK	4/WEEK	1/DAY +	2/DAY
NIGHT VR	NONE	NONE	SOME	SOME
NUMBER OF FLYING HOURS PER MONTH	16,050	24,100	32,100	40,150

CHART 13. REQUIRED FLYING HOURS FOR VARIOUS LEVELS OF VR EFFORT

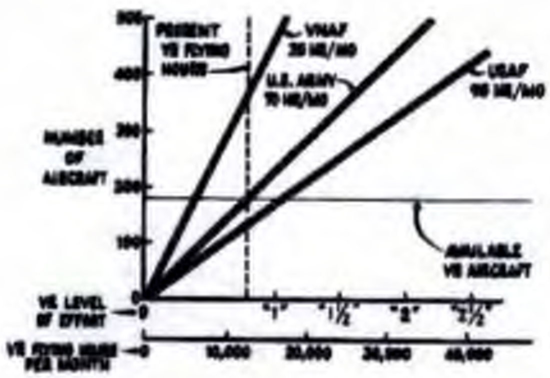


CHART 14. REQUIRED AIRCRAFT FOR VARIOUS UTILIZATION RATES

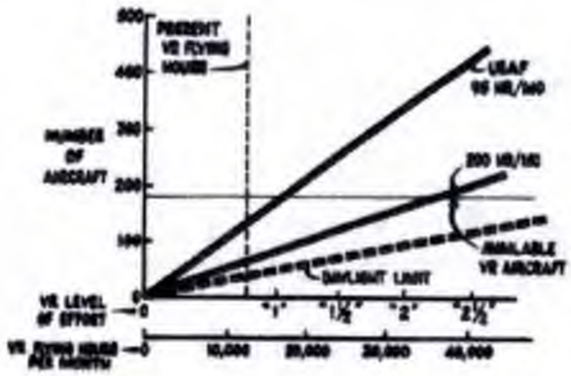


CHART 15. REQUIRED AIRCRAFT FOR VARIOUS UTILIZATION RATES

LEVEL OF VR EFFORT	"1"	"1½"	"2"	"2½"
FLYING HR/MO	16,050	24,100	32,100	40,150
NUMBER OF REQUIRED AIRCRAFT:				
90 HR/MO	178	268	357	446
200 HR/MO	80	120	161	201
ONE YEAR ATTRITION*	48	72	96	120
AIRCRAFT REQUIRED FOR ONE YEAR:				
90 HR/MO	226	340	453	566
200 HR/MO	128	192	257	321
AVAILABLE "IN COUNTRY VR ONLY" AIRCRAFT	177	177	177	177
REQUIRED INCREMENTAL AIRCRAFT:				
90 HR/MO	49	163	276	389
200 HR/MO	(49 EXCESS)	15	80	144

*0.25 AIRCRAFT LOSS PER 1,000 FLYING HOURS

CHART 16. INCREMENTAL AIRCRAFT FOR VARIOUS LEVELS OF VR EFFORT

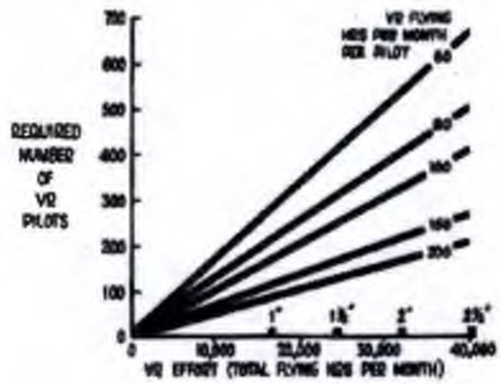

REQUIRED NUMBER OF VR PILOTS
VR FLYING HRS PER MONTH PER PILOT
60
80
100
150
200
700
600
500
400
300
200
100
0
0
10,000
20,000
30,000
40,000
VR EFFORT (TOTAL FLYING HRS PER MONTH)

CHART 17

	USAF	U.S. ARMY	VNAF	TOTAL
LOSS RATE PER 1,000 FLYING HOURS	.26	.23	.20[A]	
LOSS RATE TO GROUND FIRE	.14	.07	DNA	
DAMAGE RATE BY GROUND FIRE	.92	DNA	DNA	
AVERAGE MONTHLY LOSSES (JANUARY 1966 FLYING RATE)	3.2	2.1	0.5	5.8

[A] LIAISON AIRCRAFT, ALL TYPES, 1965

CHART 18. O-1 LOSS RATES

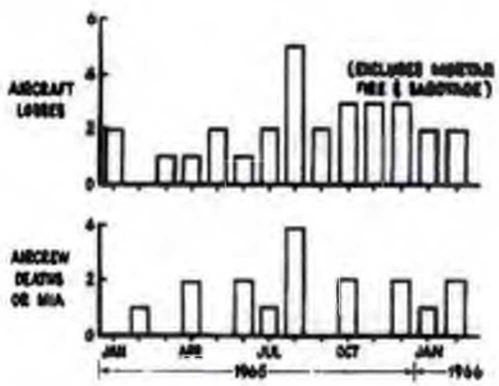


CHART 19. USAF O-1 AIRCRAFT AND AIRCREW LOSSES
(COMBAT PLUS OPERATIONAL)

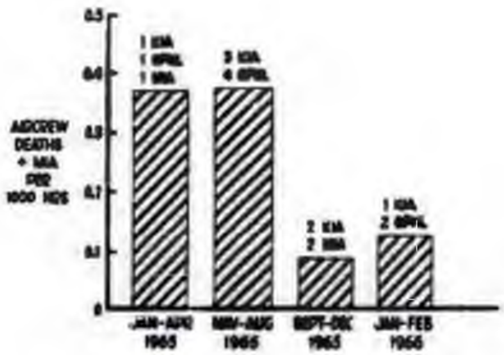
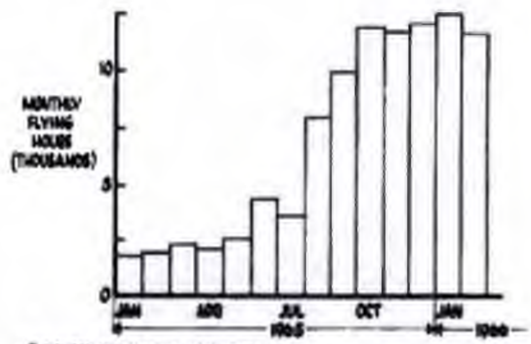


CHART 20. USAF O-1 AIRCREW LOSSES (DEATH OR MIA)



*INCLUDES OUT-COUNTRY OPERATIONS.
DATA PRIOR TO AUGUST FROM DO RECORDS, THEN FROM DM RECORDS.

CHART 21. USAF O-1 AIRCRAFT FLYING HOURS*

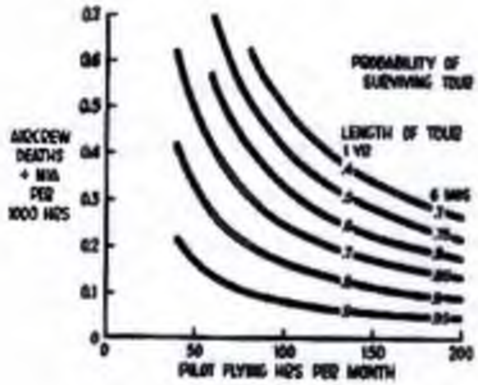

PROBABILITY OF SURVIVING TOUR
LENGTH OF TOUR
1 YR
6 MOS
AIRCREW DEATHS + MIA PER 1000 HRS
0
0.1
0.2
0.3
0.4
0.5
0.6
0
50
100
150
200
PILOT FLYING HRS PER MONTH

CHART 22

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) Willow Run Laboratories, Institute of Science and Technology, The University of Michigan, Ann Arbor	2a REPORT SECURITY CLASSIFICATION SECRET — NOFORN
	2b GROUP 1

3 REPORT TITLE

CIRADS PROCEEDINGS, Volume I, Part 2

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

Counterinsurgency Research and Development Symposia, Meeting of 14-16 June 1966

5 AUTHOR(S) (Last name, first name, initial)

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b. PROJECT NO.		
c.	9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d.		

10 AVAILABILITY/LIMITATION NOTICES

In addition to security requirements which must be met, this document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Advanced Research Projects Agency.

11. SUPPLEMENTARY NOTES Part 1, 4613-137-X(1), contains papers classified through SECRET	12. SPONSORING MILITARY ACTIVITY Advanced Research Projects Agency, Department of Defense, Washington, D. C.

13 ABSTRACT

CIRADS Proceedings, Volume I, comprises papers presented at or prepared for the first meeting of the Counterinsurgency Research and Development Symposia, held at Arlington, Virginia, on 14, 15 and 16 June 1966, under the sponsorship of the Advanced Research Projects Agency of the Department of Defense, Project AGILE. Papers prepared for but not presented at the meeting are included.

The purpose of the meeting was to provide a forum for the exchange of technical information in the area of counterinsurgency research and development. The subject matter ranges from the technology of reconnaissance and weapons through tactical and strategic analyses to research in the biomedical and social sciences.

Part 2 contains papers classified through Secret and not releasable to foreign nationals. (U)

DD FORM 1 JAN 64 1473

UNCLASSIFIED

Security Classification

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Counterinsurgency						
Reconnaissance						
Guerilla warfare						
Insurgency						

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