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MEMORANDUM

4 May 1951
M-1748

TO: Research Planning Committee: J.R. Goldstein, S. Enke, V.M. Hunt, J.E. Lipp, G.H. Putt.

FROM: John L. Kennedy *John L. Kennedy*

SUBJECT: Outline of a Procedure for Systems Study, With Particular Reference to Ground Reporting Systems. Addendum to LOGS-88.

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Authority: EO 13526
Chief, Records & Declass Div, WHS
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I. INTRODUCTION

The work of the Man-Machine Panel has raised the general problem of prediction of man-machine system reliability or probability-of-task-accomplishment. Definition and measurement of the task appear to be the most difficult requirements set by this statement of the problem, particularly when the task is a complex military operation involving expensive devices, large numbers of personnel and extensive logistics. The Air Defense System is an example of a complex system of men and machines for which the probability-of-task-accomplishment is difficult to determine experimentally. When the requirement is added that probability-of-task-accomplishment be assessed under combat conditions (Carhart's LOGS-13), one has the feeling that the problem has reached the stage where some chewing needs to be done to obtain chunks of a more easily digested size. This memorandum will consider factorization of the problem and will recommend ways of making progress toward the eventual goal indicated above.

The Ground Reporting System of ADC represents such a factor of the general problem. It is of sufficient size to exemplify a complex man-machine system but it has such a relatively limited task that the problem of task definition and measurement may possibly be handled.

Assuming that a performance criterion or measurement of task accomplishment can be obtained, one may begin to answer the following critical questions about any man-machine system:

1. At what points in the system should men be utilized as preferred instrumentalities and at what points should automatic devices be used?

2. When cost is introduced, which of several arrangements of men and machines is optimal?

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These questions may be studied at four levels of "reality."

1. Simulation by target devices or high-speed computers to inject synthetic inputs into an experimental system involving humans and automata.

2. Simulation by tests with pre-production models of real equipment.

3. Simulation by tests during training with the production equipment.

4. Tests during combat.

The following section will consider procedures which might be utilized in these four situations.

II. POSSIBLE PROCEDURES FOR SYSTEMS STUDY

A. Simulation by use of Computers

The RDB ad hoc Committee on Scientific and Synthetic Analysis has issued a report on the possibilities of use of high-speed computers in conducting experimental studies of complex systems. The computers could inject synthetic inputs of any desired reality into such a system. This program would really represent an extension of the Bavelas experiment to the problem of optimal arrangement of more complex organizations involving both men and machines. One might, for example, duplicate the proposed organization of the 1954 Ground Reporting System (Watson Labs. Memorandum Report No. ENRPS-2, "Proposal of a Ground Reporting System"), and experiment with several possible alternatives for arrangement of the system. It appears that the simulation methods could be applied to missiles problems as well as to the Air Defense type of organization. The advantages to studying systems at the simulation stage rather than the stage of completed hardware are obvious.

B. Simulation by Tests with Pre-production Models

During World War II, a substantial contribution to the arrangement of man-machine fire-control systems was made by subjecting such systems to test during the pre-production model stage. (See Summary Technical Report of Applied Psychology Panel, OSRD, Vol. 2). This procedure has the advantage of introducing real automata into the analysis but the general form of the system has already been fixed at this stage. Many desirable outcomes, however, may be gained, such as determination of optimal operational doctrine, preparation of instruction booklets, suggestions for selection and training of personnel and human engineering of displays and controls to make the system fit the human operators more effectively. Maintenance problems may also be anticipated and maintenance manuals produced in advance of field requirements.

C. Simulation by Tests During Training

The tests of the Air Defense System currently being conducted represent examples of the information about systems one can obtain at this stage. (See report now in preparation by Lee Attaway, summarizing British tests.) Ordinarily, such tests yield little reliable data of assistance in the construction of future systems. The manipulation of variables in the organization of the system appears to be a practical impossibility.

D. Combat Tests

Little opportunity for studying organization of a man-machine system is afforded by combat or war conditions, where the collection of basic data is a very minor responsibility of the command. Information as to inadequacies of systems emerges slowly from this source but experimentation as to the causes of the inadequacies is usually impossible to perform. "Combat is the payoff" of organizational decisions made years before. One is tempted to conclude that tactical questions of the Operations Research Group sort may be answered by information obtained under combat conditions but that the problem of man-machine organization is a strategic question, to be solved by experiment, not by experience alone. Usually, the feed-back on design from combat experience is too slow to have any major affect.

III. VALIDATION OF MODELS

By validation, we mean the check of model performance with the real world of actual performance. Ordinarily, this procedure requires a criterion or measure of real world performance. If one wishes to predict success or failure in selling life insurance by a test, one first defines success or failure in preformance, such as success = selling $250,000 or more life insurance during the first year and failure = selling less than $250,000. This section will consider the validation problem in each of the situations described in Section II.

A. Validation of Simulation by Computers and Humans

The validity of this model rests almost entirely with the degree to which the functions of the human and automatic links of the system may be made explicit, written down and codified. It depends upon the degree to which the rules of the game are adhered to. Some check with real world data may be possible, however, through utilization of British Air Defense Test Data.

A computer-human simulation of the British system should yield results of the same order of magnitude. But the primary sources of validity of this model would rest upon the face validity of the situation. The measure of performance would be the speed and accuracy of tracking all targets through the system to a central plot.

B. Validation of Simulation by Pre-production Tests

The validity problem is considerably improved by the use of real automata but the opportunity for studying the organization of the system is reduced. One may compare results obtained on an old real system with the new pre-production system to determine whether or not improvements have been realized. One may also carry out important but relatively minor re-arrangements of system components. Again the criterion measure would be speed and accuracy of plotting all targets.

C. Validation of Simulation During Training

During training, the system never reaches stability because new men are continually being injected into it. The real equipment has been built and the system organization stabilized. Data obtained at this stage have their primary application to the training and selection problem and are not very useful in the study of system organization.

D. Validation of System Organization in Combat

Information as to the adequacy or inadequacy of system decisions is obtained from combat sources. This information, which is usually non-quantitative, should be fed back to system designers at all levels. The fundamental questions of system organization, however, cannot be solved by combat information.

IV. A RAND PROGRAM OF EXPERIMENTAL SYSTEM SIMULATION

The preferred choice for a RAND program, when faced with the decision between the four alternatives mentioned, would appear to be simulation by combinations of humans and computers. It is recommended that such a project be set up physically at RAND for the following reasons:

1. The proximity of personnel, of the RAND hardware divisions, to guide the simulation of inputs by computers.

2. The proximity of high-speed data-handling personnel and equipment.

This project may grind out data at an alaraming rate.

A guess at the additional physical facilities required for the project might be as follows:

1. large room with booths, desks and chairs
2. telephone circuits
3. plotting boards
4. tape recorders

Personnel required to operate a typical Ground Reporting System (Watson Labs. No. ENRPS-2) might run as high as 20 people at the unskilled labor level and five or six at the skilled clerk level. They should come from stable, trainable segments of the population.

The procedure might be somewhat as follows:

Simulated targets, provided by computers, are started through the system at a given density or rate. Each operation performed on the target (detection, identification, height, size) is recorded in terms of time and accuracy and passed to plot. Measures of rate of plotting and accuracy of plotting, information lost and saturation may be obtained. Alternative combinations of units may be tested.

V. APPROXIMATE YEARLY BUDGET

1. Personnel

1 Project Director....................	10,000
1 Asst. Project Director.............	8,000
6 Permanent Staff Clerks @3,000......	18,000
20 Part-Time Subjects @ 1,000.........	20,000
	$76,000

2.	Rental of Space......................	5,000
3.	Secretarial Work.....................	4,000
4.	Supplies and Materials...............	5,000
5.	Statistical Work.....................	10,000
	Total......	$80,000

JLK/vg