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Report of the Panel on REMOTELY PILOTED VEHICLES

19-31 July 1971

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1971 SUMMER STUDY

Defense Science Board
Colorado Springs, Colorado

Office of the Director of Defense Research and Engineering

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Report of the Panel

on

REMOTELY PILOTED VEHICLES

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1971 Summer Study
Defense Science Board
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Office of the Director of Defense Research and Engineering

DEFENSE SCIENCE BOARD TASK FORCE
ON
REMOTELY PILOTED VEHICLES

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Northrop Corporation

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Willow Run Research Lab
University of Michigan

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The Rand Corporation

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Naval Weapons Center

DR. WILLIAM G. McMILLAN
University of California,
Los Angeles

Summer Study Attendee

LT. COL. DENNIS FANNING, USAF
Directorate of Operational Requirements and Development Plans,
Headquarters USAF

ODDR&E Staff Member

MR. G. RONALD WENNINGER

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I. Introduction

The Problem

Weapon system cost and losses to enemy counteraction are of increasing concern, with respect to manned aircraft. In some environments already experienced and forecast for the future, the need arises for alternative systems to complement the capability of manned aircraft, principally for the following reasons:

1. For some tasks manned aircraft may be too expensive to procure and operate, even without attrition from enemy action. (For example, reconnaissance beyond line of sight in support of ground patrols.)

2. Overflight by manned aircraft of enemy or neutral territory may be politically unacceptable because of treaties, rules of engagement, and risk of imprisonment for aircrews.

3. Increasing strength of enemy ground defenses may result in high attrition -- high enough to preclude sustained operation, to prevent achievement of the military objective, and/or excessive cost in human and material resources.

The third factor, is of special concern, because of the development and extensive deployment in many parts of the world of effective Soviet surface-to-air gun and missile defense weapons. Particularly in this context, substantial interest and activity on RPV's has been generated over the past year, prompting the Director of Defense Research and Engineering to establish the present Task Force on Remotely Piloted Vehicles.

RPV Task Force and Summer Study

The DSB Task Force on Remotely Piloted Vehicles (RPV) has been chartered to assess whether RPV's offer a solution to those military problems which are increasingly difficult to solve by manned aircraft; and if so, to recommend steps that DDR&E can take to bring about significant RPV capabilities for the Military Services.*

For the 1971 DSB Summer Study, the scope of the Task Forces's investigation was deliberately limited to encompass only those RPV tasks that contribute to the destruction of tactical targets in limited, non-nuclear warfare**. The Military Services, especially USAF, have a substantial body of experience of operating unmanned reconnaissance missions in combat zones, which, in fact, constitutes a signficant portion of the data base available for the present study. The Task Force intends to examine, at a later time what contributions advanced RPV-technology can make to other military missions not considered in the 1971 Summer Study.

* The Task Force Charter is shown in Annex 1 hereto.

** Annex 2 gives the Terms of Reference for the DSB Summer Study on RPV's.

Definition of an RPV System

The concept of remotely piloted vehicles (RPV's) is not new. The TARZON missile, developed during World War II, could be considered to fall within the definition, as could a number of B-17s and B-24s that were modified to perform special missions. These aircraft were taken off by a crew of two, who later bailed out, and were flown to target by remote control. Since the early RPV experimentation during World War II with but marginal technology, significant advances have been made in sensing devices, flight control systems, signal transmitting techniques, data processing, and displays. All of these elements contribute to the capability to remotely pilot an aircraft and perform a military mission.

In the context of present technology we can define an RPV as a vehicle (or "telecraft") which is controlled by one or more operators from a remote control center. The operator is cued by sensors on the vehicle. The information transmitted from the sensors to the remote operator and his instructions for control of the vehicle are on a real-time basis. Although he is not in the RPV, the remote pilot is "in the loop" by virtue of a two-way data link. He controls the vehicle through a set of instruments and by a visual display as if he were in the cockpit.

In military operations, the RPV system would be closely coupled with other manned or unmanned weapon systems, as illustrated in figure 1. Here a remotely piloted aircraft is used to designate with a remotelypointed laser beam a specific mobile target for attack by an artillery-launched projectile which homes on the laser-illuminated target.* Depending on the distance and terrain between the RPV and the control station, a relay may be needed to maintain two-way communication. The relay may be carried by an aircraft, a satellite, a balloon or mounted on a tower (as illustrated in figure 1).

Approach

Prior to the Summer Study, the Task Force examined a great variety of missions which are or might be suitable for remotely piloted vehicles, as shown in figure 2, as a basis for subsequent identification of military needs. The Task Force was briefed extensively on the considerable number of DOD programs that relate to some of the listed RPV missions, especially to classical reconnaissance and defense suppression.** The Task Force also surveyed the state of the art of the major RPV component technologies, by means of briefings and reports published by DOD agencies and industrial contractors, as a basis for assessing feasibility and cost of potentially desirable RPV systems.*** Applying during the two weeks

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* The laser terminally guided weapon could, of course, be launched from an airplane, a helicopter, another RPV, or a surface rocket launcher.

** Briefing topics, and the respective cognizant agencies are summarized in Annex 3.

*** Annex 5 summarizes the state of the art of RPV component technologies.

FIGURE 1

WHAT IS A REMOTELY PILOTED VEHICLE?

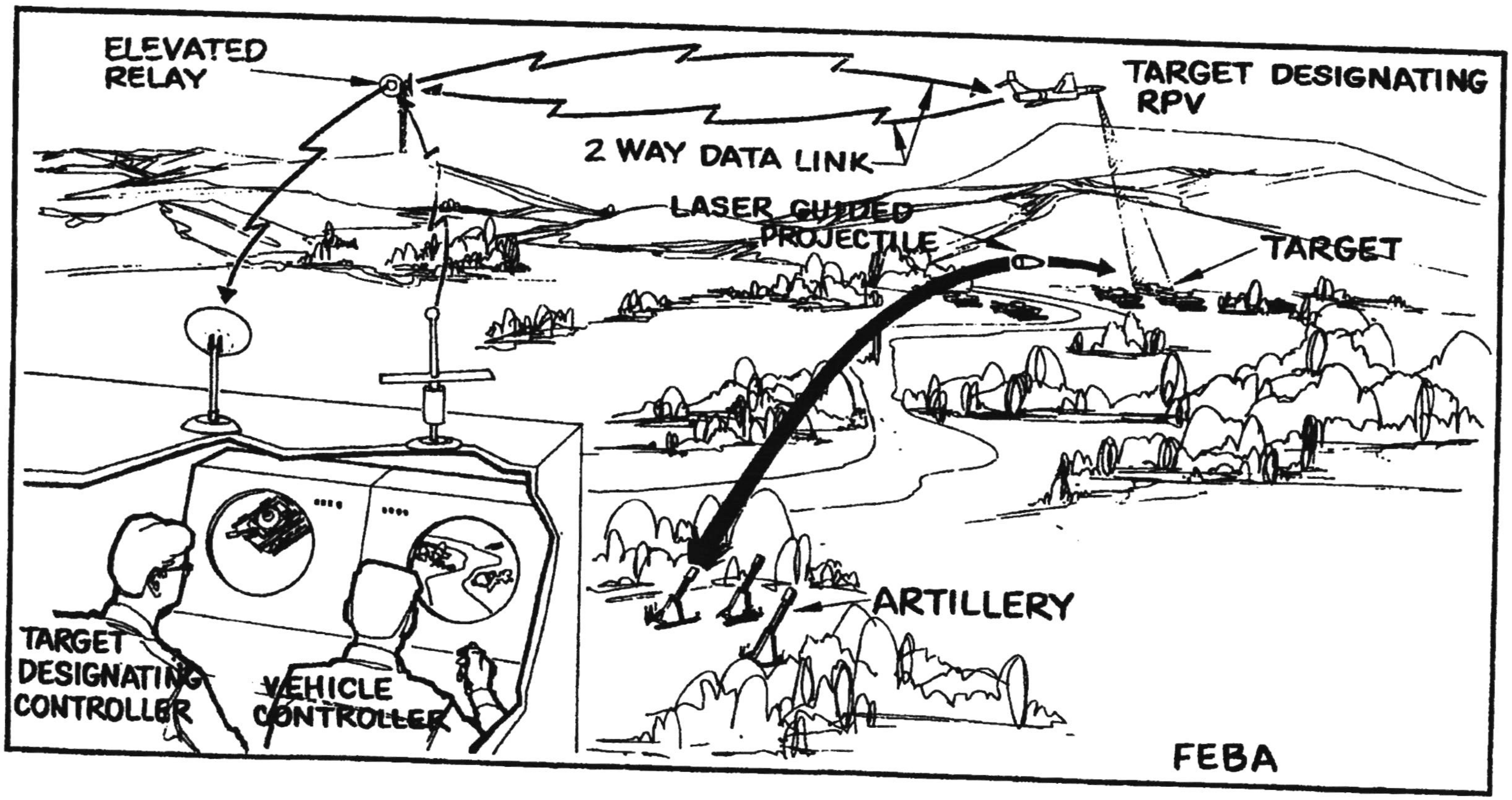

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FIGURE 2

SOME MISSIONS POTENTIALLY SUITABLE FOR RPV'S

Reconnaissance/Surveillance

Classical photo reconnaissance
Elint/Sigint
Battlefield surveillance
Location of enemy transmitters
Eye Ball extension for infantry patrols

Target Destruction or Assistance Thereto

Recce-strike of moving or fleeting targets
Destruction of prime tactical target (fixed or moving)
Defense suppression: roll back of SAM sites, airfield defenses, and army forward air defense
Destruction of enemy ships at stand-off range
Target locator for indirect fire weapons and artillery spotting
Target designation for terminally guided missiles or manned aircraft-launched weapons
Electronic countermeasures: jammers, chaff dispensors, decoys

Air to Air Combat

RPV dog fighter for air defense or escort of strike force
Fully-maneuvering target for air-combat pilot training

Summer Study its collective judgement and experience to this mission and technology data base, the Task Force arrived at the Conclusions and Recommendations given in the next two sections of this report. The subsequent five sections (IV through VIII) describe each of the actions recommended.

Additional material is contained in the several Annexes that are keyed in the text by footnotes.

II. Conclusions

The major conclusions of the Summer Study on Remotely Piloted Vehicles are as follows:

1. The principal advantages of RPV's are that they:

   - Keep man in the loop without exposure to injury or capture

   - Remove physiological restraints on vehicle size and performance; this exerts great leverage on reducing the vulnerability and cost of the airframe and increasing its maneuverability (if necessary).

2. RPV's complement manned aircraft and are more cost-effective in the "high attrition" part of the mission spectrum. *

3. Past program experience shows that RPV's:

   - Can be launched, controlled, and recovered

   - Can acquire, identify, and destroy targets

   - Were generally survivable in Vietnam.

4. Current RPV activities exploit existing subsystems that are far from optimum, principally:

   - Vehicles that were designed for use as target drones or high altitude platforms.

   - Sensors, developed for high speed aircraft, in many cases more sophisticated and expensive than is appropriate for RPV's.

   - Weapons, stockpiled in past wars for manned aircraft use.

---

* "High attrition" denotes situations where sustained (tactical) operations with manned aircraft are impractical or unfeasible, as discussed in Section VI.

5. New tactical RPV systems are needed for:

   - o Real-time battlefield surveillance, target location, and laser designation of targets for terminally guided weapons.

   - o Destruction of armed vehicles and enemy mobile air defenses.

   - o Destruction of strongly defended interdiction and counter-air targets.

6. A jamming-resistant data link is needed for future RPV's under some combat conditions. Its development can be based on known spread-spectrum techniques.

III. Recommendations

Based on its study to date, limited solely to the applications of RPV's for the destruction of tactical targets, the Task Force recommends that DOD initiate the following actions:

A. Develop and test prototype RPV systems for:

1. Battlefield surveillance & target designation (Army*)

2. Attacking armor and forward air defenses (Army*)

3. Deep recce-strike of strongly defended targets (Air Force**)

B. Initiate the development of critical subsystems for advanced combat RPV's:

1. Jamming-resistant data link

2. Night sensors

C. Support specific Navy and Air Force RPV-related programs

These programs are identified in Section VIII.

At a future time, the Task Force may make additional recommendations concerning RPV's for other mission areas, such as long range reconnaissance, where excellent results have already been achieved by the Air Force.

* Also of interest to Marine Corps.
** Also of interest to Navy carrier-based aviation.

IV. Battlefield Surveillance and Target Designation

Briefly stated, there are three basic reasons why an RPV system is needed by the Army to perform its important battlefield surveillance and target designation functions:

(1) Increasing enemy mobility requires real-time targeting for indirect fire weapons. For the Lance missile, targeting is required to a depth of 30 to 60 km beyond the FEBA.

(2) Laser target designation for terminal guidance of laser homing weapons offers the best means to kill an identified tank (or other mobile target) with indirect fire weapons. Several laser-homing weapons are being considered by the Army, e.g. the Cannon Launched Guided Projectile (CLGP) and the helicopter-launched "Hellfire" missile.

(3) Presently available means for laser target designation have limited capability and are vulnerable to enemy action. Specifically:

- o Ground-based forward observers are both vulnerable and limited to enemy territory that is near the FEBA (say within 3 km).
- o Forward Air Controllers (FAC's) and Helicopter Scouts are very vulnerable to strong AAA and SAM defenses.*

A laser-designator equipped RPV system of the type described below is uniquely suited to overcome the current problems in battlefield surveillance. Both the technology available today for a surveillance RPV system and the recommended prototype approach for developing the system differ substantially from the technology and development approach that characterized the Army's surveillance drone program of 1955-67.**

* RPV's will be vulnerable also, but no man is lost, their attrition rate should be lower due to reduced signatures, and these vehicles are less expensive than manned aircraft.

** See Annex 4 for a brief narrative account of this surveillance drone program.

Remotely Piloted Aerial Observer-Designator

This name has been coined to identify the recommended RPV system for Battlefield Surveillance and Target Designation. As envisioned by the Task Force, this system has the following major subsystem characteristics:

The RPV's payload consists of a gimballed TV camera with a zoom lens and a laser designator which is boresighted to the camera. This payload is estimated to weigh about 40 lbs and will provide a daylight capability. (When cheaper, light weight IR sensors are developed, a night capability can be added).

The data link has a 5 MHz information bandwidth (for real-time TV transmission from the telecraft to the control station), uses a steerable antenna on the RPV, and a simple elevated relay, such as a tower or a balloon. (Spread spectrum anti-jamming features will not be provided for this first system.)

Radio navigation accuracy of 50 to 100 meters can be achieved either with retransmission of LORAN signals from the vehicle to the control station, or if LORAN is not available a mobile TOA/DME System can be provided. Position fixing computations are performed at the control center.

The relatively low speed RPV can be propelled by an existing internal combustion engine (reciprocating or Wankel) in the 35 hp class driving a propeller, fan, or rotor.

The RPV would have approximately the following performance:

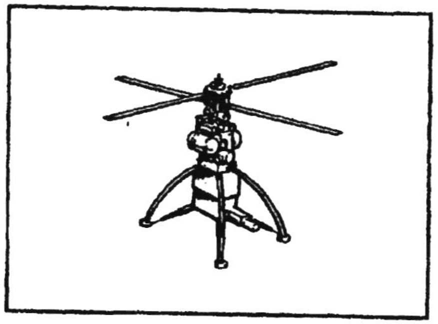
SPEED, KT		ALTITUDE, FT, A.G.L
45	T.O./Landing	0
110	Enroute	1000-3000
80-90	Over Target	300-1000

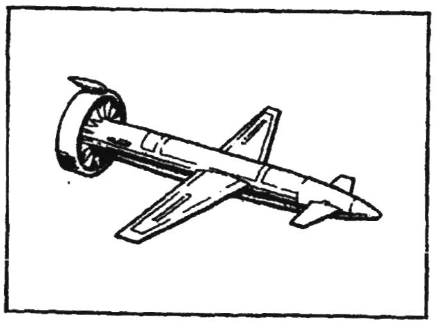
RPV Maneuverability: 3g sustained
8g for 10 seconds

When sized for a mission duration of 2 to 3 hours, the RPV's gross weight is expected to be about 240 to 280 lb for typical configurations (see figure 3). Its fly-away cost is estimated at about $15-20,000 when produced in quantity.

FIGURE 3

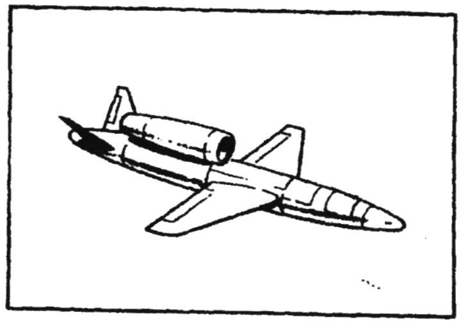
TYPICAL RPV CONFIGURATIONS TO BE EXPLORED

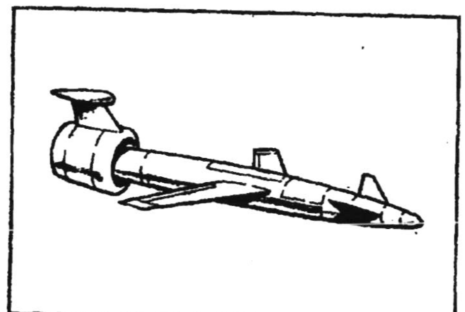




APPROX SIZE

SPAN	= 12-14 FT
LENGTH	= 8-10 FT
GROSS WT	= 240-280 LB
PAYLOAD	= 40 LB





System Concept for Remotely Piloted Aerial Observer-Designator

Figure 4 shows schematically the deployment and employment of a "squadron" of 4 to 6 recoverable RPV's in support of an armored or mechanized division. The division commander calls on the RPV squadron (during the daytime) for real time tactical reconnaissance, identification of key fixed and moving targets, and designation by laser of specific targets for attack by indirect fire weapons. The surveillance sector covered by the squadron extends 10 km along the FEBA and 60 km into enemy territory.

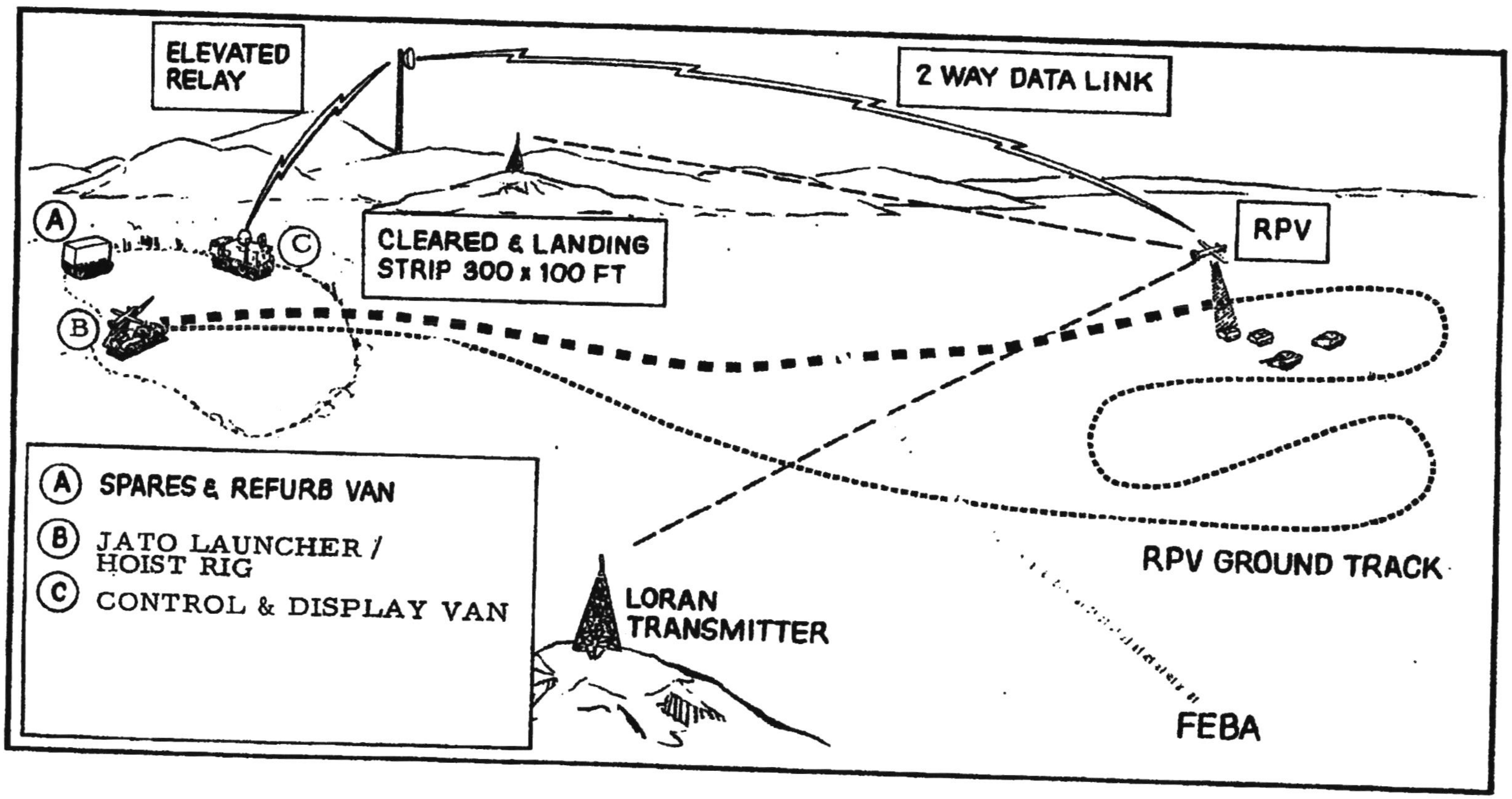
Located near its Division Headquarters, the squadron is in direct communication with the Division Commander and the tactical fire control system (e.g. TACFIRE). The Aerial Observer-Designator squadron consists of 4-6 RPV's, a mobile launcher, a control van, relay unit, hoist rig, and a van for spares and refurbishment of RPV's between sorties. The squadron has a complement of 15 to 20 men, including RPV controllers, ground crews and maintenance mechanics.

The RPV mission cycle has the following characteristics:

- Launch by JATO from mobile rail launcher
- Flight duration of several hours
- Recovery by skid landing in cleared area (100 x 300 ft)
- 2-3 sorties per day per vehicle, during daylight hours
- 1-2 hour turn around time, with more major maintenance performed at night.

FIGURE 4

EMPLOYMENT OF R.P. AERIAL OBSERVER-DESIGNATOR SYSTEM



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Recommended Prototype Program

There are a number of technical and operational questions concerning the practicality and effectiveness of an RPV system for battlefield surveillance and target designation. The Task Force believes that these questions can best be resolved by extensive operational testing of competitively developed prototype systems.

The major technical risks and other issues that need resolution by the prototype development and test program can be categorized as follows:

- Vehicle Cost: (a) prove that RPV unit flyaway cost can be less than $30,000; (b) determine total system cost, including operations and maintenance costs.
- Surveillance Effectiveness over various types of terrain, weather, and for various levels of illumination.
- Target Designation Effectiveness: demonstrate ability to fix laser spot on a tank for several minutes.
- Simultaneous Control of several RPV's from one control station.
- Launch and Recovery: establish realistic levels of vehicle loss rates and of effort for post-mission refurbishment of the reusable RPV.
- Survivability: through field tests establish
  (1) Simulated enemy capability to detect and destroy the RPV
  (2) Ability of the RPV controller to detect and evade AAA and SAM defenses.
- Data Link suitability: Determine enemy effort required to jam the link, and the relative utility of a tower and a tethered balloon to support the elevated relay.
- Fixed versus rotary wing configurations.

The prototype program that is needed to resolve the above risks and uncertainties has two principal phases:

(1) Two or three contractors develop several fixed and rotary wing RPV configurations, such as those illustrated in figure 3, and appropriate ground equipment.

(2) Extensive fly-off tests are conducted by the Army using the facilities of MASSTER, CDEC, and other appropriate agencies. An appreciable number of RPV's of each type, perhaps 20, must be procured to obtain meaningful test results and to allow for some initial loss of flight vehicles, as in missile testing. These tests will be useful for the experimental development of tactics and operational techniques, as well as for the resolution of the issues listed above.

The Task Force estimates that a sound competitive program will take about 3-1/2 years from go-ahead to the decision to produce and field a Remotely Piloted Aerial Observer-Designator system, with a total expenditure of $40 to 50 million. This program cost includes the Army's test operations as well as contract costs for development of the prototype RPV systems and limited production of vehicles for development and operational testing. Figure 5 gives an estimate of the time phasing and cost breakdown of the competitive prototype program, as visualized by the Task Force.

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FIGURE 5

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R.P. AERIAL OBSERVER-DESIGNATOR

PROPOSED RDTE PROJECT FOR PROTOTYPE DEMONSTRATION

TIME FROM START (MO): 0 6 12 18 24 30 36 42 48

Task	Army ($ millions)	Contracts ($ millions)
• 4 MO CONCEPT FORMULATION STUDY BY 4 CONTRACTORS	0.3	0.8
• 18 MO PROTOTYPE DESIGN, FABRICATION AND CONTRACTOR TESTS: 2-4 CONTRACTORS	2.0	24.0
• 12 MO EXTENSIVE ARMY FLYOFF TESTS AT MASTER, CDEC, HUACHUCA (PLAN, DO)	10.0	2.5
• 6 MO DETAILED ANALYSIS OF (2 CONTRACTORS) - PRODUCTION. PLANS, COST - O & M TACTICS, BOI, TOE, COSTS - INTERFACE WITH TRICAP, TACFIRE, CSSS	1.0	2.0

DECISION TO PRODUCE AND FIELD ▲

TOTAL PROTOTYPE PROGRAM COST: $ 40 - 50 M

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V. Attack of Armor and Forward Air Defenses by RPV

There exists today the opportunity to meet an Army need for a cost-effective armor-destroying capability by complementing the heavy firepower systems under development with a light-weight RPV system based on model-aircraft technology. Such a system would be employed primarily to defeat the enemy's forward air defense units that accompany his armor, as well as the latter. It is proposed that a radio-controlled model aircraft, such as the "Hawk 750" shown in figure 6, be equipped with a light-weight television camera, a simple autopilot and a small shaped-charge warhead. This warhead is capable of destroying a tank or forward air defense weapon, given a direct hit on a vulnerable part of such a target.

Operation of this Remotely Piloted Attack Vehicle system takes place as follows:

> The RPV is catapult-launched near the FEBA, and flown to the target area previously located by the Remotely Piloted Aerial Observer Designator or by other means. The Remotely Piloted Attack Vehicle is then manually steered to impact against the vulnerable part of the armor or forward air defense target. (If, after extended loiter, a suitable target is not found, or the mission is aborted for another reason, the RPV can be recovered by landing on skids at a suitable recovery area.)

The Remotely Piloted Attack Vehicle has approximately the following characteristics:

Sensor: Light Weight Television Camera (525 lines)
Control: Manual and Autopilot

Airspeed: 40 to 50 knots
Propulsion: 2-cycle piston engine (2 hp) driving propeller

Warhead: Shaped-charge anti-tank round weighing about 5 lb.

RPV Gross Weight: 30 to 40 lb.

Vehicle Unit Cost: $2 - 3,000

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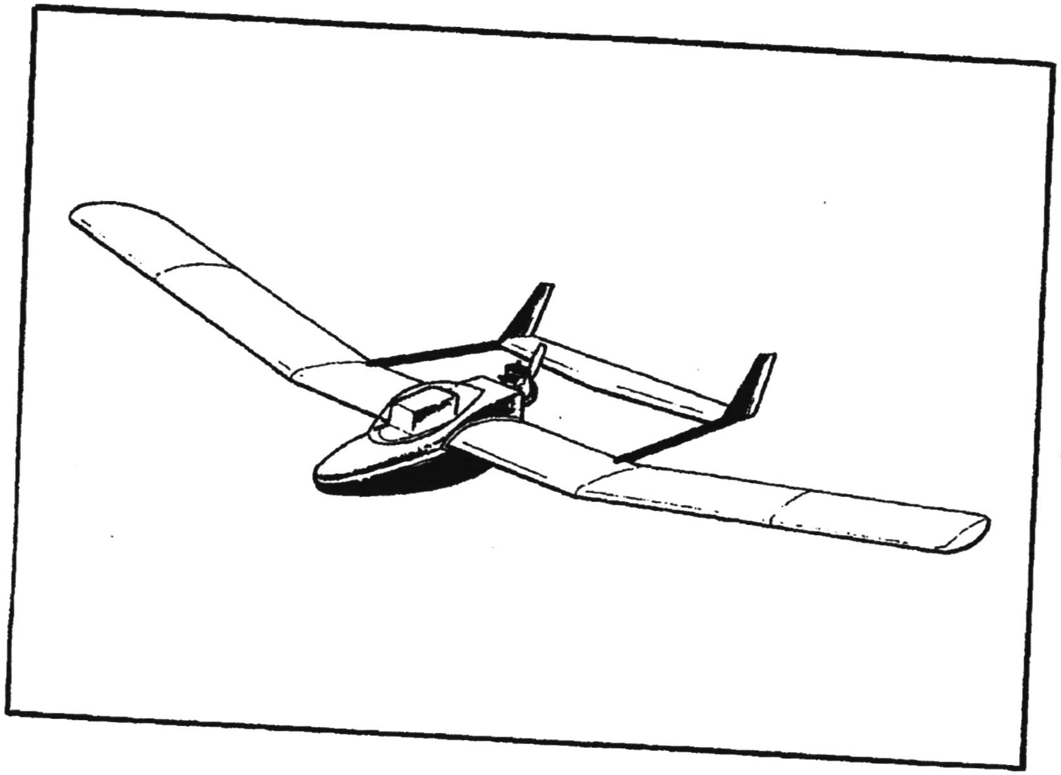
FIGURE 6

HAWK 750 MODEL AIRPLANE



7.5 FT WING SPAN

35 LB GROSS WEIGHT

40 KTS CRUISE SPEED

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A competitive approach using a similar system propelled by a slow-burning rocket may be advantageous in situations where the target coordinates are known (from other independent sensors) and quick reaction is needed. Such a rocket powered vehicle would be delivered ballistically into a "basket" and then piloted to the target.

The recommended prototype program for developing and testing the Remotely Piloted Vehicles has two principal phases:

(1) Integration of the proposed RPV systems using existing components, followed by development tests, by one contractor for each system. This can be done for approximately $3 million.

(2) Competitive evaluation by the U. S. Army user agencies of the two RPV prototype systems to establish operational advantages of the two approaches.

VI. Deep Recce-Strike of Strongly Defended Targets

In the judgment of the Task Force, there are three major reasons which point to the need for an Air Force RPV recce-strike system:

- o Attack of the most heavily defended targets by manned aircraft is forecast to be prohibitive, where sustained operations are involved.
- o Political considerations may rule out the exposure of manned aircraft in some situations.
- o Potentially more effective delivery of stockpiled unguided ordnance with RPV's than with manned aircraft.

Cost Effectiveness of RPV's

By way of elaboration on the first point above, consider the cost-effectiveness comparison shown in figure 7 between manned aircraft (F-4) and RPV's when employed to destroy SAM sites*. In this particular study, both the recoverable and expendable (Kamikaze) RPV were designed using current high-cost component technology, and have not been optimized extensively. The costs shown are based on the number of sorties required to achieve a kill, and account for the cost of attrited airplanes and RPV's, and of all expendables used. The principal parameters affecting the comparison between manned aircraft and RPV's are whether laser-guided or G. P. (dumb) bombs are used, and the severity of the defenses encountered. Use of laser guided bombs by manned aircraft, incidentally, reduces the cost to destroy the SAM-site by more than a factor of two.

* Data from RAND Corporation Study, R-710; see page 45.

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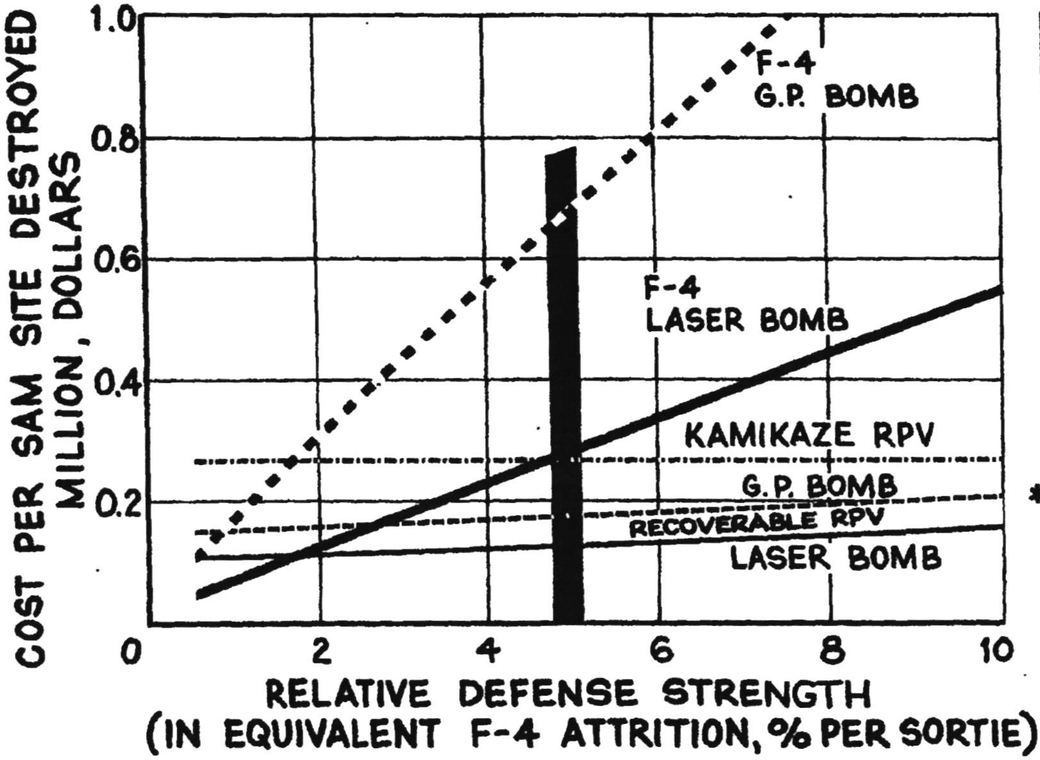
FIGURE 7

COST TO DESTROY A SAM SITE
(SA-2)



ATTRITION PER SORTIE %	CREW TOUR* SURVIVAL PROBABILITY %
0.1	93.4
0.2	87.4
0.5	71.1
1.0	50.5
2.0	25.5
5.0	3.2

*100 MISSIONS FLOWN
32 % OF DOWNED CREWS RESCUED

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The severity of enemy defenses is used as the abscissa of figure 7, the scale having been normalized to read in percent of attrition inflicted on penetrating F-4's by Soviet AA guns and SAMs. The cost per target kill of the Kamikaze RPV (similar to Condor), the smallest of the aircraft considered here, is insensitive to defense strength; but is relatively the greatest for light defense, since the Kamikaze is always expended. For defense causing F-4 attrition on the order of 1% or less, the recoverable RPV has a higher target-kill cost than the F-4 due to its (assumed) non-combat loss of 10% per sortie during launch or recovery. For severe defenses (F-4 attrition greater than 2% in this example), the recoverable RPV is clearly more cost-effective than the manned aircraft.

Furthermore, in a sustained tactical campaign, average loss rates of manned aircraft must be kept well below 1 percent per sortie, as illustrated by the table on the right side of figure 7, to maintain realistic tour-survival probability for the aircrews. Thus the RPV can be considered to complement the manned aircraft, in the sense that an RPV force could destroy (at relatively moderate cost) just those strongly defended targets which, in a prolonged tactical campaign would be attacked only rarely by manned aircraft.

RPV's also offer substantial savings in peace-time operating costs (figure 8), since (like munitions) only a small fraction of the "stockpile" is used for training missions. Furthermore, if convenitional landing gear

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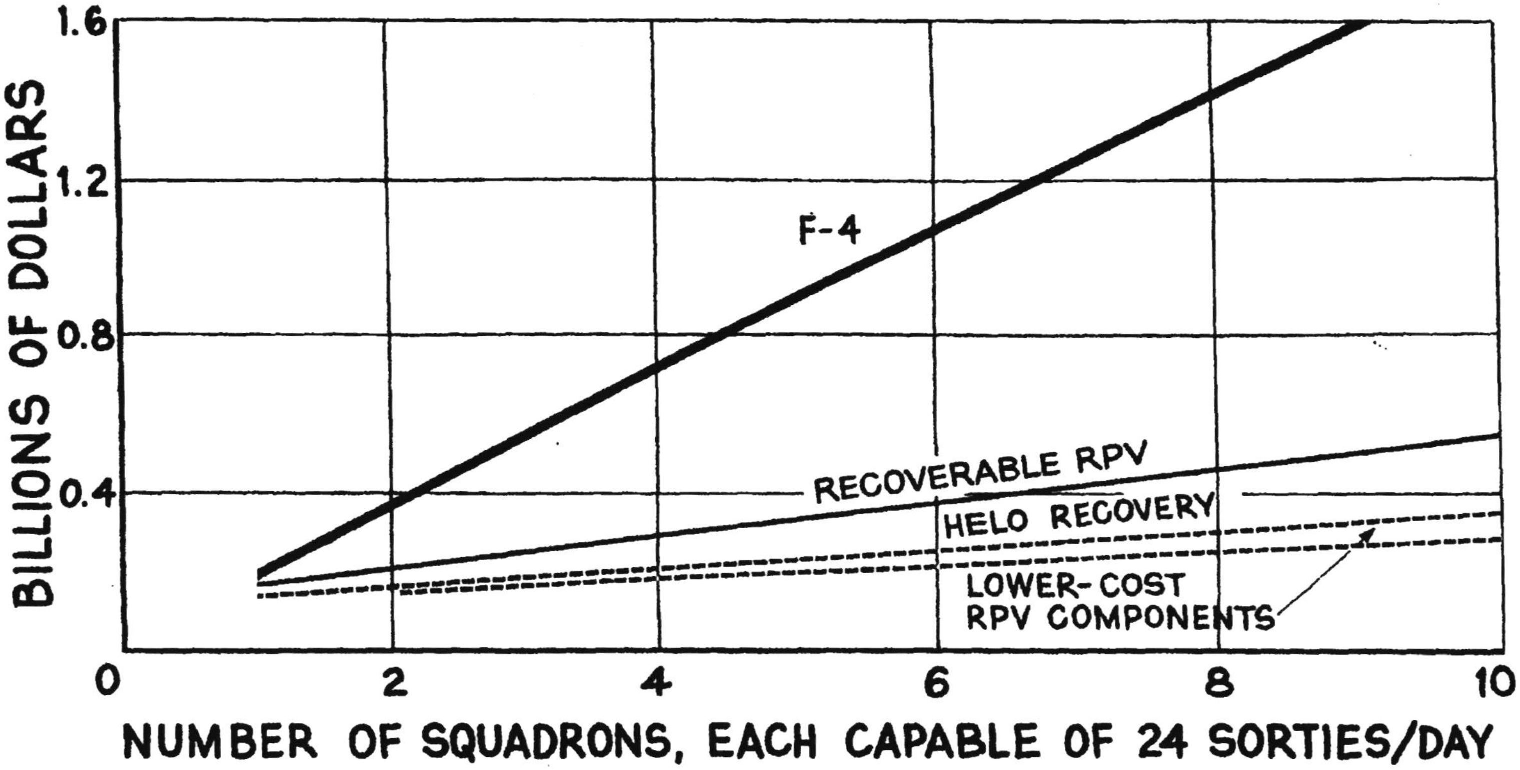
FIGURE 8

TEN YEAR PEACETIME SYSTEM COST



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recovery of the RPV were used rather than its recovery by helicopter (as assumed in figure 7), a 40% reduction in peace-time RPV system cost could be attained. Use of future low cost RPV components would further reduce RPV system cost.

Delivery of Stockpile Ordnance by RPV

The above-mentioned concept of accurate and economical delivery of stockpiled (unguided) conventional ordnance by means of a recoverable RPV is illustrated in figure 9. Several factors combine to offer, at least theoretically, a 20 fold improvement in dive bombing CEP relative to that for manned aircraft; these factors are a lower dive speed and a 12g pull-out maneuver which permit bomb drop at 500 feet (rather than 5,000 ft), and corresponding reduction in slant range at bomb release which reduces the aiming error.

The more expensive components, i.e. the data link and "terminal guidance" equipment, (such as perhaps an angle-rate bombing system) are recovered with the RPV and can be used several times, which results in a more economical system than a kamikaze, such as CONDOR. Even with a combat attrition as high as 15 percent (which would be unacceptable for a manned aircraft) the RPV could be used four times, assuming that there is a 10% loss of RPV's due to non-combat causes.

System Concept for Recce-Strike RPV

These RPV's are intended to operate jointly with manned aircraft,

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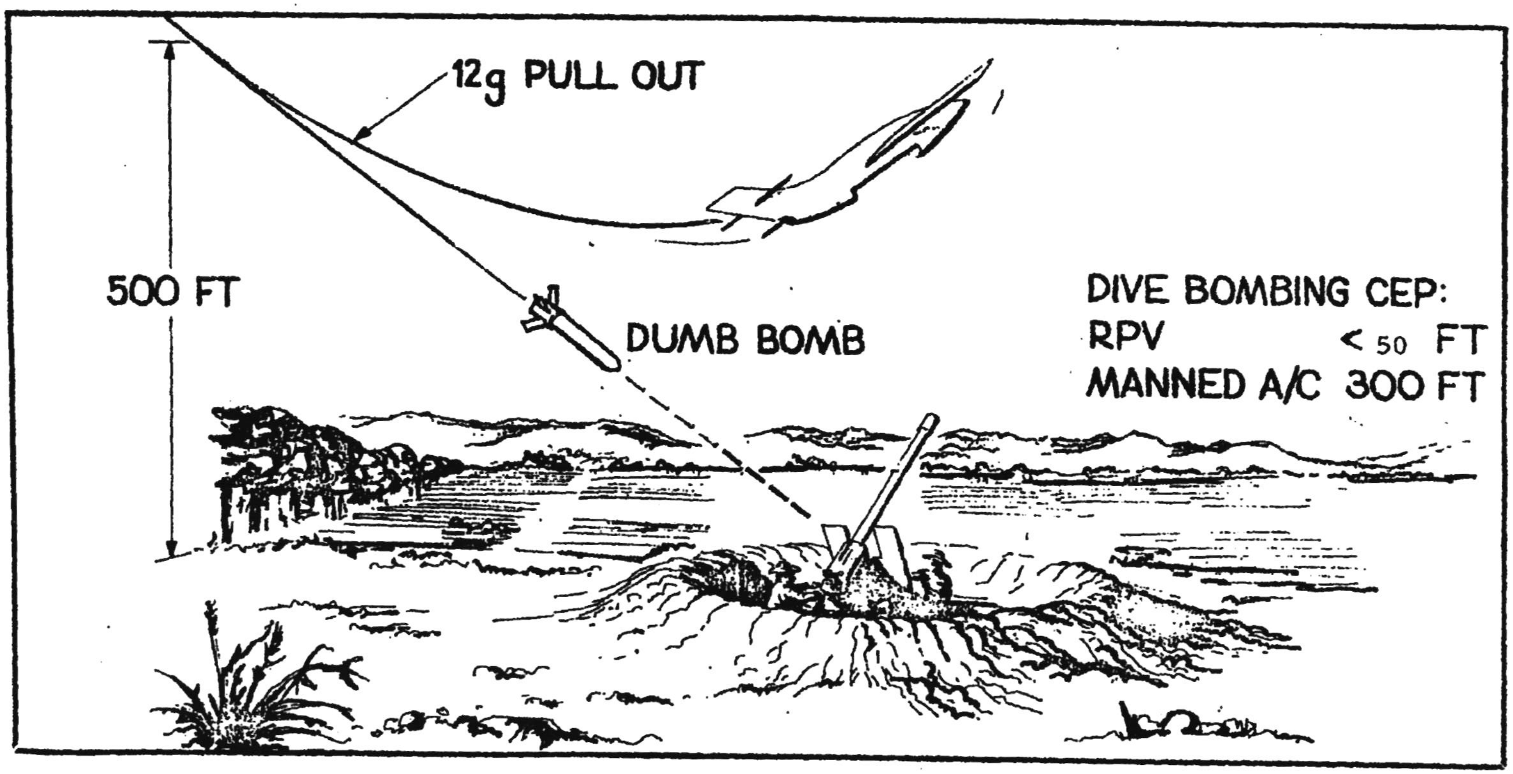
FIGURE 9

RECCE - STRIKE RECOVERABLE RPV



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and are assigned to strike the most difficult targets, as far as 250 nautical miles from the launch area. Such targets include:

- o Deep tactical targets: SAM sites, radars, A/C shelters, runways
- o Interdiction: bridge abutments, railroad tunnel, mining of roads and trails, trucks, agent boats
- o Battlefield hard targets: revetted and mobile artillery, AAA, tanks, APC's, bunkers, caves, hillside fortifications.

To be capable of striking so great a variety of targets the RPV must be compatible with stockpile and developmental ordnance of all types*: unitary bombs, cluster munitions, terminally guided weapons.

These recce-strike RPV's are operated by an RPV "unit" which has the capability to generate 20 to 30 sorties per day. Such a RPV unit operates jointly with manned aircraft units and could be land or carrier-based. The RPV control center is compatible with and in direct communication with the Tactical Air Control Center (TACCS).

Subsystem Characteristics for Recce-Strike RPV

At this relatively early stage in the evolution of RPV's, the Task Force considers it appropriate to explore via prototype tests both recoverable and expendable (kamikaze) RPV configurations. As indicated below, the smaller kamikaze could be air launched from a manned fighter aircraft,

* A detailed listing of such weapons is given in Annex 5.

as well as ground launched; the larger recoverable RPV would be launched from and recovered on the surface.

The following characteristics are common to both the recoverable and kamikaze versions:

Sensors:	Gimballed TV camera with zoom and boresighted laser designator
Data link:	5-10 MHz information bandwidth, RPV-mounted steerable antenna, airborne relay for deep strikes
Navigation:	Retransmission of LORAN, or TOA/DME system
RPV propulsion:	Turbojet or Turbofan. Initially the engine being developed for the Harpoon Missile can be used. Subsequently the "Ordnance Turbojet" engine being developed jointly by the Naval Weapons Center and NASA could be used to lower the cost of the propulsion system.
RPV speeds:	Above 400 kts.
Maximum radius:	250 n. mi.

The remaining RPV characteristics, given below, are different for the recoverable and kamikaze versions.

	Recoverable RPV	Kamikaze RPV
Max. maneuverability	12g	8g
Launch	surface	air or surface
Recovery	runway	-
Maximum weapon load	2000 lb	200 lb
Approx. gross weight	4500 lb	1000 lb
Unit fly-away cost (quantity production)	$50,000	$30,000

Note that for these estimated vehicle unit costs, the recoverable RPV would lead to a more economical system, if it can be reused at least once, and neglecting differences in cost of ground support equipment.

The Recommended Competitive Prototype Program

As was the case for the Battlefield Surveillance and Target Designation RPV described in Section IV, there are a number of technical risks and other issues which should be resolved by means of operational prototype testing of deep recce-strike RPV's. The following list comprises the most significant such issues and operational test objectives:

- Establish the unit cost of RPV's, and the costs of support systems and operations.
- Target acquisition effectiveness
- Control of multiple RPV's and manned aircraft in the same airspace
- Launch and recovery: establish realistic loss rates for land based and carrier operations
- Survivability: through field tests establish
  - (1) simulated enemy capability to detect and destroy RPV
  - (2) ability of RPV controller to detect and evade AAA and SAM's
- Data link: enemy effort required to jam data link with and without the aerial relay.
- Develop tactics and operational techniques.

The prototype program, as recommended by the Task Force, consists of:

- the selection of two or more contractors to develop recoverable and expendable RPV system configurations for
- extensive operational fly-off tests by the Air Force and Navy. The prototype program should be managed by the Air Force, with Navy participation.
- applicable experience derived from current RPV defense suppression and reconnaissance efforts should be exploited. *

* See page 39.

VII. Critical Subsystems for Advanced Combat RPV's

In its survey of the state of art of the principal RPV-component technologies*, the Task Force found that:

(1) Considerable improvement in components is possible, especially with respect to reducing their weight, bulk and cost.

(2) Ongoing and planned DOD and industry efforts appear generally adequate to evolve such lower cost components for RPV's

(3) There are, however, no development programs for two components of particular importance for "advanced" combat RPV's, such as will be in demand if the recommended prototype programs are successful and cause the enemy to take countermeasures. These components are:
- o a jamming resistant data link, and
- o night sensors.

This last fact prompted the Task Force's recommendation (item B Section III) to initiate development programs for these two advanced RPV components. The chief features of these development programs are described below.

Jamming-Resistant Data Link

Several methods are known for obtaining secure communications by spreading the information to be transmitted over a wider bandwidth in a pseudo-random fashion. These include pseudo-random noise, and fast frequency hopping (in a pseudo-random manner). Due to likely limitation of the spectrum available for RPV use, say several hundred mega-hertz,

* See Annex 5

additional means must be used to attain the needed anti-jam margin (on the order of 60 db) for the wide-band (TV) data link, such as higher RPV transmitter power and highly directional beams produced by phased array antennas. Therefore a development program for a jamming-resistant data link is recommended that embodies the following tasks:

- o Choose a preferred spread-spectrum technique (100 MHz) by competitive testing among:
  - pseudo-random noise
  - fast frequency hopping
- o Develop solid state, high power, light weight, low cost, on-board transmitter
- o Develop low-drag "conformal" phased array antenna

Night Sensors

Currently available night sensors of the low light level television (LLLTV) and infrared varieties are too heavy, bulky, and costly for use on the types of RPV's described in the preceding Sections (IV, to VI). Due to the generally lower speeds of RPV's and their ability to approach closer to targets (relative to manned aircraft), it should be possible to trade off some night-sensor performance and sophistication for lower cost and size. Furthermore, considerable additional cost reduction should be achievable through redesign for quantity production of night sensors, such as the FLIR's and LLLTV which have been built in only small quantities, largely for experimental use on manned airplanes and helicopters.

In addition, infrared sensors have the demonstrated capability to penetrate dust and smoke. This capability would be very useful for RPV's operating in daylight under some realistic battlefield conditions, or to negate enemy smoke-type countermeasures.

The Task Force recommends, therefore, that night sensor development for RPV's emphasize low cost and weight versions of:

- Low light level television with laser illumination of the scene (active LLLTV)
- Passive imaging infrared sensor (FLIR)
- Active, covert (IR) laser line scanner.

VIII. Service RPV Programs Recommended for Continued Support

Many of the current Air Force and Navy RPV and RPV-related programs have contributed greatly to the general establishment of feasibility of the RPV concept; and if they are adequately supported (rather than prematurely terminated) promise to (1) provide an initial operational capability for defense suppression and (2) supply valuable information and experience for the battlefield surveillance and deep recce-strike RPV systems recommended by the Task Force.

We list below those specific programs which the Task Force believes should receive continued and, in some cases, augmented support. For each selected program the development goal or operational objective is indicated.

Air Force RPV Programs Recommended for Continued Support*

1. Defense suppression via RPV technology (AFSC)

   a. Extended-range HOBO with video link
   b. BQM-34 with video link, ASM, smart & dumb bombs

   Objectives:

   o Option for early operational RPV units for strong-defense situations

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* Only programs related to tactical target destruction missions are considered here. Strategic or reconnaissance-oriented programs have not been examined, and no significance should be attached to the omission of such projects from the listing.

- o Discover (and solve) practical problems with RPV hardware

- o Achieve compatibility between USAF USN equipment and environment

2. Expand defense suppression demonstration program to develop tactics, discover and solve operational problems.

Navy RPV-Related Programs Recommended for Continued Support

1. Data link version of Walleye:

   o Provide night and radiation-seeking capability by adapting Long Wave IR and Anti Radiation Missile-heads under development

2. Condor

   o Continue operational testing for RPV-experience

   o Emphasize cost-reduction program for "simplified Condor"

3. Harpoon

   o Examine the operational utility for target identification of the TV video link that is being developed for the Harpoon test program

4. BQM-34

   o Gain operational experience with TV remote guidance

5. Control of target drones in formation flight

   o Adapt to control of other multi-RPV operations.

ANNEX 1

April 8, 1971

CHARTER AND TERMS OF REFERENCE FOR DSB TASK FORCE ON REMOTELY PILOTED VEHICLES

Task Force Objective. The objective of the Task Force is to determine the context in which Remotely Piloted Vehicles (RPV's) can supplement manned aircraft and satellites in performing both strategic and tactical missions, and thereby to determine appropriate directions for future research, technology and development of RPV's.

The use of RPV's for gathering national intelligence is specifically excluded from consideration.

The Problem. At varying levels of international tension, manned aircraft operations may be compromised by operational/political restrictions and sanctuaries or, in the case of actual hostilities, by severe air defense systems. In such cases, RPV's may be viewed as complementary to manned aircraft.

Task Force Approach. The Task Force should first concentrate on determining the feasibility of RPV's to perform significant military missions such as interdiction, close air support, air superiority, reconnaissance, etc. Secondly, the Task Force should establish criteria for evaluation of manned vehicles vs. RPV's and thereby to evolve the conditions for complementary use of the two technologies. Thirdly, the Task Force should lay out an "RPV technology roadmap" for the purposes of exploiting the high payoff capabilities of RPV's.

Task Force Interactions. The Task Force is expected to interact closely with the Services and to consider and present Service views in its report. Task Force interactions with intelligence agencies should be limited to obtaining performance characteristics and operational statistics on RPV's, where the data is not available from other agencies.

Task Force Schedule. The Task Force is constituted for one year and will submit two reports; one after six months and the second at the conclusion of the effort.

Task Force Outputs. The Task Force should write, or provide the basis for writing, an Area Coordinating Paper on RPV's. The paper should include:

1. An evaluation of the role of RPV's vs. manned aircraft.

2. An identification of the capabilities and limitations of RPV's in performing various missions.

3. An identification of promising system concepts.

4. An identification of technological innovations which can lead to major improvements in RPV capabilities.

5. An RPV technology roadmap.

Membership. Composition of the Task Force should be in concert with the multi-Service nature of the problem and with a need to draw out innovative approaches from both governmental and industrial sources. It is not required that all members have access to special intelligence. The Deputy Director (Tactical Warfare Programs) will act as the cognizant Deputy and provide a staff member to support the Task Force.

3 June 1971

ANNEX 2

TERMS OF REFERENCE FOR DSB SUMMER STUDY OF REMOTELY PILOTED VEHICLES

Study Objective. The objectives of this Summer Study -- as part of the effort of the DSB Task Force on Remotely Piloted Vehicles (RPV's) -- are to ascertain the capability of RPV's to destroy or assist in destroying strongly defended tactical targets, and to identify research and development activities needed to realize such a capability.

The Problem. Recent U.S. experience in South East Asia has demonstrated Soviet resolve and capability for providing strong ground based air defense by means of several complementary systems that are mutually supportive and mobile. Soviet buildup of Egyptian air defense weapons but also the introduction of newer weapons, including the use of infrared and electro-optical guidance techniques. Thus, realistic assessment of the future tactical air combat environment points to an increasing number of situations where attrition of manned aircraft would either be unacceptably high for a sustained tactical campaign, or the cost of providing adequate support forces for ECM, defense saturation, etc., would become prohibitively high. In addition, more situations can be expected to arise where politically-derived rules of engagement will prohibit the presence of U.S. aircrews in a combat zone. On the other hand, indirect fire weapons are less constrained by strong enemy defenses but face the problem of accurate real time position determination of point and mobile targets that are out of range of a forward observer. RPV's appear to offer solutions to all three aspects of this problem of destroying tactical targets. The validity and implications of such solutions need to be examined.

Study Approach. This DSB Study should concentrate on illuminating the various aspects of and approaches to destroying tactical targets with the assistance of RPV's -- e.g., destruction by RPV's of defense weapons, their control facilities, or other prime targets; target designation for terminal guidance of stand-off weapons; ECM support of strike aircraft. While reconnaissance missions will not be addressed as a prime objective of the summer study, past and present U.S. activities in this field do constitute the "state-of-the art" in RPV technology, and operation and this must be clearly delineated by the Study Group before projecting needed technological developments. This project must also take into account relevant technical advances in the fields of electronic countermeasures, surveillance and intelligence which have not been transferred to related applications, such as RPV's, due to security-related organizational boundaries.

Study Areas. The following areas cover most of the key factors to be considered by the DSB Summer Study.

1. Required Sensor and Display characteristics for target acquisitions, weapon aiming, and mid-course navigation.

2. Data Link characteristics with respect to information bandwidth, multiple RPV operation, resistance to jamming, and use of relays (including satellites).

3. Unconventional vehicle configurations that are not constrained by the presence of man; low cost vehicle construction, and equipment techniques to render expendable RPV's economically feasible.

4. Alternatively, measures to enhance RPV survivability -- e.g., small size, low radar cross section -- thereby permitting recovery and re-use.

5. Basing, Launch Control and Recovery techniques that are compatible with the operational environment.

6. RPV payloads, including ordnance, and techniques to assist manned systems in the target destruction function, e.g., RPV-carried target designators, repeaters for precise location of enemy emitters, and active or passive ECM payloads.

Scenarios. The following scenarios will be used as a basis for exploring the capabilities of RPV's to perform important future Army, Navy and Air Force missions across a spectrum of realistic situations. The first two scenarios deal with a large scale conventional attack by Warsaw Pact Forces against NATO in Central Europe. The third and fourth sceanrios relate to limited warfare in the middle East.

1. Defeat Heavy Armored Units, Central European Front.
In the postulated situation, part of a mid-to-high intensity conventional war in Central Europe, a Warsaw Pact mechanized Division (comprising heavy tanks, armored personnel carriers with Strella missiles, tracked artillery and radar-directed anti-aircraft guns) is sensed to be massing for an attack on opposing NATO forces. In the subsequent 12-hour period RPV reconnaissance systems may be able to reveal the enemy's massing tactics to permit proper deployment of NATO units. Ground force effectiveness would be greatly improved, if the RPV system can localize with real time precision individual enemy mobile units (especially his heavy tanks) for destruction by the RPV itself and/or by NATO indirect fire weapons.

2. Air Superiority, Central European Front
In the postulated situation of a Warsaw Pact attack against NATO forces through the Fulda Gap, NATO attack aircraft are vitally needed to counteract the (local) numerical superiority of Pact ground forces. Air superiority is mandatory for such close air support operations. RPV's may be

able to play a vital role in achieving air superiority (without excessive attrition of manned attack aircraft) by destroying SAM and anti-aircraft gun units that are defending both Pact airfields and their advancing ground forces.

3. Preventing an Egyptian Canal Crossing [redacted]

OSD 3.3(b)(5),(6)

4. Naval Support in U.A.R. [redacted]

Study Tasks. The Study of RPV's for Destruction of Tactical Targets should:

- o Evaluate the effectiveness and deficiencies of such RPV's as have been used operationally or in demonstration tests.
- o Identify promising system concepts which can be implemented with (a) existing technology, (b) achievable but presently unavailable technology. Detailed systems characteristics required for Weapon System definition will Not be developed.
- o Identify needed research projects for realizing key technology building blocks for promising RPV systems (b above).

Membership. The Remotely Piloted Vehicles Summer Study will be conducted by a task force of the Defense Science Board. Composition of the task force should be in concert with the multi-Service nature of the problem and with a need to draw out innovative approaches from both governmental and industrial sources. The Deputy Director (Tactical Warfare Programs) will act as the cognizant Deputy and provide a staff member to support the task force.

ANNEX 3

BRIEFINGS & REPORTS RECEIVED BY TASK FORCE

The Task Force on Remotely Piloted Vehicles was briefed extensively on RPV systems and the relevant component technologies by the cognizant staffs of the U.S. Air Force, Army and Navy, of the Advanced Research Projects Agency (OSD), the Institute of Defense Analysis, and of industrial contractors active in these fields. The excellent cooperation received from all of these groups is gratefully acknowledged by the Task Force.

The respective briefing topics and agencies are listed below in chronological order. This is followed by a list of published reports on or related to RPV's that the Task Force considers useful reference documents.

Briefings

June 15, 1971 at Eglin Air Force Base, Florida

1. Remotely Piloted Vehicles for Defense Suppression
   (Task - 05), USAF Aeronautical Systems Division (AFSC)

2. Modular Guided Glide Bomb
   (Defense Suppression Task - 01), USAF Armamament Development and Test Center (AFSC)

June 29, 1971 at Naval Weapons Center, China Lake, California

3. Remotely Piloted Vehicle Programs at NWC
   Walleye I and II
   Condor
   BQM/SSM
   Drone Control (including flight demonstration)

4. RPV-related Technology Projects at NWC
   Airframe, Infrared-sensing systems, Radio Frequency systems, Warhead Technology, Echo Range

5. "Ordnance" (Low Cost) Turbine Engines
Naval Weapon Center and NASA Lewis Laboratory

July 15, 1971 The Pentagon, Washington, D. C.

6. Range-Cost Trade-off for Stand-off Weapons (AGMIS)
Vehicle Cost Reduction
Institute for Defense Analysis

7. Stand-off Sensors and Precision Interdiction
Advanced Research Projects Agency

8. U. S. Army Briefings:

Army interest in RPV's, OCRD

History of Army Drone Programs, Electronics Command

Remotely Controlled Surface Vehicles,
Mobility Equipment Research and Development Center

Signal Intelligence and Electronic Warfare, OCRD

9. U. S. Air Force Briefings (HQ USAF):

History of Air Force Drone Program

Inventory of Air Force Drones

Drone Operation Technical Problems

Threat Forecasts

10. U. S. Navy Briefing

Deputy Chief of Naval Operations (Air)

July 16, 1971 The Pentagon, Washington, D. C.

11. Presentations on their RPV-related activities by the following industrial contractors:

The Boeing Company
Fairchild Hiller Corporation
Goodyear Aerospace Corporation

Grumman Aerospace Corporation
Gyrodyne Company of America, Inc.
Hughes Aircraft Corporation
Lockheed Aircraft Corporation
North American Rockwell Corporation (Columbus Division)
Northrop Corporation
Teledyne Ryan Aeronautical
Texas Instruments, Incorporated

July 19, 1971 USAF Academy, Colorado Springs, Colorado

12. Survey of Worldwide Drone Activities
Battelle Memorial Institute

July 20, 1971 USAF Academy

Briefings on Communications, Radio Navigation and Avionics:

13. Integrated Communication, Navigation and Identification (ICNI)
Rome Air Development Center

14. Communication

Spread Spectrum Techniques for Secure Data Links*

Airborne Modems for Communication
AF Avionics Laboratory

Satellite Communication**

Laser Communication, AF Avionics Laboratory

15. Navigation and Sensors

Time of Arrival (TOA) for position fixing
Rome Air Development Center

* Presented by specialists from the electronics industry:
* Dr. Charles Kahn (Magnavox)
** Mr. Eugene Shaparenko (Philco Ford)

Inertial Guidance, AF Avionics Laboratory

Electro-Optical Sensors, AF Avionics Laboratory

Airborne Radars & Microwave Technology
AF Avionics Laboratory

16. Ground-based Electronic Components

Displays and Computers*

Data Processing, AF Avionics Laboratory

July 21, 1971 USAF Academy

Briefings by Air Force Systems Command Staffs:

17. Aeronautical Systems Division (ASD)

Drone Program Overview

RPV In-House Studies

Multi-Mission RPV System Study

RPV Man/Machine Interface

Avionics and Weapons Development Programs for RPVs

18. RPV Technology Presentations by Air Force Laboratories

Flight Vehicle Technology, AF Flight Vehicle Laboratory

Propulsion Systems, AF Aero Propulsion Laboratory

Structural and IR & Visual Camouflage Materials
AF Materials Laboratory

RPV Support, Aerospace Medical Research Laboratory

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* Presented by specialist from the electronic industry:
Dr. David Shore (RCA)

Published Reports

1. Remotely Piloted Vehicles ("An Idea Whose Time Has Come") -- Report of the Proceedings of the AFSC/RAND Symposium of May-July 1970 (U)

   Volume I: Technology Base, June 1971 SECRET

   Volume II: Applications, August 1971 SECRET

   (Available through DDC)

2. "An Analysis of Remotely Manned Systems for SAM Site Attacks (U)" by J. Lau et al

   RAND Corp. Report R-710, September 1971 SECRET

3. "Final Report Overseer Study Effort (U)"

   Booz, Allen Applied Research Inc., Report No. 882-1-S, 1966

   Volume I: Compendium, SECRET NO FOREIGN

   Volume II: Reliability and Mission Availability, SECRET

   Volume III: Mission Requirements and Perofrmance, Operational Implications, Analysis for Planning Documentation, and War Games, SECRET NO FOREIGN

   Volume IV: Costs and Cost/Effectiveness, SECRET

4. "Proceedings of the TACRAC I Land Warfare Symposium (U)" February 17-19, 1971. Sponsored by Advanced Research Projects Agency

   Published by Research Analysis Corporation (RAC Log No. 142403) SECRET

5. "An R&D Perspective of Land Warfare (U)" by N. R. Augustine, 11 June 1971

   Vought Missiles and Space Company, MSD/ES 3082, Item 38 SECRET NO FOREIGN

6. "Production Cost-Reduction Case Studies of Three Tactical Missiles (U)"
C. Leatherbury, A. Kresse, D. Weimer

Institute for Defense Analyses (Systems Evaluation Division)
Paper P-672, September 1970, SECRET

Page determined to be Unclassified
Reviewed Chief, RDD, WHS
IAW EO 13526, Section 3.5
Date: 13 JAN 2016

ANNEX 4

HISTORY OF U. S. ARMY SURVEILLANCE DRONE PROGRAM

In 1955, the Radioplane Company* initiated an in-house program to modify an OQ-19 propeller driven target drone into a camera-carrying reconnaissance drone. This was named the RP-71. It used the standard OQ-19 control system and guidance.

In 1956, the U. S. Army decided to initiate a drone program. The Army procured a total of 29 Northrop* RP-71 drones and changed their designation to AN/USD-1, and also provided the radar system from the WW II 75 mm AA (Sky Sweeper) gun for positioning of the drones. This radar was designated as AN/MPQ-29. This initial training system was intended to prepare Army users for future reconnaissance drone equipment, to be derived from four development programs that were also established at about this time. These programs were labeled AN/USD-2, AN/USD-3, AN/ USD-4 and AN/USD-5, and had the following characteristics and purposes:

The SD-2 was planned to be the second generation equipment similar to the SD-1. The SD-2 development was intended to improve the characteristics of the SD-1 training system as required for a fully operational system. The competition for development of the SD-2 was won by the Rheem Corporation.

* Radioplane Company became a Division of the Northrop Corporation in 1957.

The SD-3 and SD-4 were advanced concepts using non-state-of-the-art vehicles, sensors and guidance/control for mid-range operations. The SD-3 and 4 programs were won by Republic Aviation.

The SD-5 was a very long range (600 km) concept, using a vehicle large enough to carry multiple sensors, a wide-band data link with an extremely complex guidance and control system.

The entire program, SD-2 through SD-5, was initiated as a materiel development effort without prior complete study of Army requirements or understanding of the manner in which these systems would be deployed. The entire program was modestly funded, and within weeks of its initiation, overruns were incurred. The SD-3 and SD-4 were in trouble from the very beginning because of the relatively advanced concepts of the systems. The developer of the SD-3 twin-boom pusher type drone was never able to recover the system. Upon attempted deployment, the recovery parachute immediately fouled the propeller, terminating the flight in disaster. Both the SD-3 and SD-4 were cancelled as impractical within about 12 to 18 months after initiation. About 1960, Rheem sold its aerospace efforts to Aerojet General, who then took over the SD-2 development program.

By 1965-66, the SD-5 cost had escalated into many millions of dollars, which resulted in its cancellation by the Army. About this time, the Army decided that it needed an operational surveillance drone system before the SD-2 development could be completed. Merely by "the stroke of a pen" the SD-1 (training) system was declared to be an operational system and was redesignated as MQM-57; no changes were made to the inadequate command guidance system that used the AN/MPQ-29 radar and poorly designed beacons on the drone.

Many of the original ambitious requirements of the cancelled SD-3, 4 and 5 systems found their way into the requirements for the SD-2. Thus the SD-2 (later designated as MQM-58A) changed rapidly from a simple second-generation photographic surveillance drone system to a highly complex multi-sensor system. After two or three years of continued effort, it was found that the SD-2 system now was far too complex for employment by Army troops. In addition, the SD-2 was to use the Integrated Tracking and Control System (IGACS), which was so costly that the Army could not afford to convert it to solid state for production. About 1967, the entire SD-2 program was therefore cancelled. This left only the SD-1/MQM-57, which had in the meantime been deployed worldwide, and was doing remarkably well under the circumstances of using World War II equipment for guidance and control.

By Department of the Army direction, further reconnaissance drone R&D activity was deferred pending completion of the TARS-75* study. The restatement of a surveillance drone requirement by TARS-75 brought

* Tactical Aerial Reconnaissance Systems for 1975

the MQM-57 operations under close scrutiny. Although a thorough study by the Department of the Army Staff had recommended that the MQM-57 be maintained in the Army inventory, but be up-dated with modern, radar guidance equipment, the MQM-57 program was cancelled. About $800 million had been spent on the several surveillance drone programs described.

To meet the surveillance requirements defined by TARS-75, that study recommended the development of three unmanned systems:

(1) Un-manned Aerial Surveillance System (UASS), a short range, vertical rising and hovering system.

(2) Unmanned Aerial Vehicle System (UAVS)

(3) Unmanned Aerial Observation System (UAOS).

Subsequently, Qualitative Military Requirements (QMR) were issued for UASS, and UAVS. No development has been initiated to date in support of these stated Army requirements.

The Remotely Piloted Aerial Observer-Designator RPV recommended herein by the Task Force* is capable to perform the surveillance functions required for both UASS and UAVS, and in addition is capable of laser-designation of targets.

* Described in Section IV

ANNEX 5

RPV TECHNOLOGIES

Members of the Task Force surveyed the state of the art and current R&D efforts in the several key technologies on which RPV systems depend. A brief summary of this is given below. Relatively few serious deficiencies in component technologies were noted. The most significant deficiencies are (1) the lack of a jamming-resistant data link employing one of several known spread-spectrum techniques, and (2) night sensors having sufficiently low weight and cost.

1. Airframe

Current airframe technology is adequate for application to all RPV missions, in fact, modifications of available drone airframes are being used in exploratory RPV operations, although, such airframes are not optimal from the standpoint of cost, performance or operational suitability.

Airframe technology improvements should be and are directed primarily toward reduced cost with some performance and maneuverability improvements resulting from recent advances such as supercritical wing technology and the control configured vehicle concept. Additional improvements in airplane economics should result from the modular concept for configuring several RPV's for different missions from the same basic airframe, and from a relaxation of the more stringent specifications used for manned aircraft, regarding factors of safety, quality assurance, and long life.

2. Propulsion

Current technology in propulsion is generally adequate for the engines required for RPV application with the exception of cost. Low cost engines are available in the 30 to 450 horsepower range for the small, low-speed mission that would be satisfied with reciprocating or Wankel engines driving propellers. Both engine and propeller can be silenced as required by the mission. For missions involving RPV speeds above 350 kts, currently available turbojet and turbofan engines are suitable but expensive, costing from $20 to $100 per lb. of thrust. In the 100 to 1000 pound static thrust range of interest for most RPV applications, so few developed engines exist, that usually an engine is selected that is larger than necessary.

The primary advances required in propulsion technology are to reduce costs while maintaining acceptable performance. Current Navy and NASA R&D programs are developing lower cost, shorter life turbojets and turbofans, which may achieve costs as low as $10 per lb. of thrust. These include the competitive development of the short-life turbojet for the Navy Harpoon cruise missile, and the "Ordnance" Turbojet/Turbofan being developed by NASA (Lewis Research Center) and the Naval Weapons Center. Use of the much simpler pulsejet, at about $3 per lb. of thrust, should be considered for those of the kamikaze RPV's for which the higher engine noise is not objectionable.

3. Launch and Recovery

Many schemes have been demonstrated for launch from the surface or an aircraft, and for recovery on land or sea, or by an aircraft. There are no fundamental unsolved problems, but it is important for a specific RPV application to select a method for launch and recovery which is compatible with the military environment of the system, and whose cost is not an excessive part of the overall system cost. Commercially available RATO units, for example, weigh about 6% of the RPV gross weight and cost about 30¢ per lb. of RPV per launch. On the other hand, parachute recovery with air snatch by a helicopter is expensive and can account

4. Sensors

Great strides have been made in recent years in sensor performance for many parts of the spectrum. However, except for daylight TV, sensors of low weight and cost with adequate (not maximum) performance do not exist and would require a concerted advanced development effort. In selecting parameters for developing such sensors, their compatibility with data link band width and duty cycle, ground display, weapons (if any) and mission characteristics must be considered. For the classes of missions considered in Sections IV to VI, the following sensors are judged to be most appropriate:

SENSOR		CAPABILITY
(1)	Daylight TV with at least two fields of view	Remote piloting, and acquisition of targets for which the location is known to a fraction of a mile. Also, laser designation of targets of opportunity on trails, railroads, etc.
(2)	FLIR or TV with illuminator (illuminator in the .7 to 1 micron band for convertness)	A night capable version of (1). FLIR would also provide the capability to see targets obscured by dust or smoke.
(3)	Laser line scanners	High quality day-night target search over reasonably large areas (swath width of a mile or more).

The competition between the FLIR and active TV, indicated in (2) has yet to be resolved on the basis of cost, weight, reliability, and performance. At this time laser line scanners appear to offer the most promise for greatly advancing the sensor capability for RPVs. In the longer term, versatile laser systems (raster and line scan modes) promise to provide a high quality, day-night capability. The presently available AVD-4 laser line scanner should be considered in RPV evaluation studies and demonstrations, even though its weight (about 200 lb) is too great for operational RPV's.

Standard TV type displays are considered adequate for most real-time display needs of RPV's used in target destruction functions. However, for real time display of higher quality imaging sensors (such as the AVD-4) it would be necessary to develop higher resolution displays with, say, 5 or 10 thousand line capability; or to put the data on film and project the image, provided that the fraction of a minute time delay is acceptable, such as for a surveillance mission.

5. <u>Data and Control Links</u>

A number of microwave data and control links have been developed, none of which offer resistance to jamming beyond what is provided by the directionality of some of the antennas used. Those developed for drone or RPV control include: the Microwave Command Guidance System (MCGS) (AN/UPQ-3), operational in X band for drone control; the Tri-Service, Integrated Target Control System (ITCS) (AN/USW-3), a current development effort using C Band; the Condor link operating in K band; the Nite Gazelle data link (operating selectively in L - Band to C-Band) being flight tested. The JIFDATS tri-service data link (in qualification testing) has greater capability, weight and cost than appropriate for the operational RPV's envisioned here.

If RPV's without anti-jamming provision prove at all successful, the best countermeasure available to an enemy will be to jam the RPV's wide-band data link. Hence it is desirable to equip at least advanced operational RPV's with a jamming-resistant data link. This can best be provided by one or more of the known spread-spectrum techniques, such as pseudo-random noise encoding, or fast-frequency-hopping. These spread spectrum techniques offer several additional important advantages for RPV operations: enhanced probability of signal reception; lower detectability by the enemy; high accuracy ranging (for navigation or weapon delivery); multiple access of simultaneously operating RPV's to the same frequency channel; precise time synchronization for sensing, or weapon delivery. Several spread-spectrum modems have been built, but they are too heavy and expensive for use on RPV's.

An important need is for the development of a secure light-weight, low cost spread-spectrum data link for common use in a variety of RPV systems. To achieve this objective development effort is also required on high-power solid state linear amplifiers, and ("conformal") phased array antennas which can be installed on the RPV with low drag and weight penalty.

6. Navigation

It is generally agreed that high grade inertial systems are too expensive and/or bulky for RPV application, and that several available radio navigation systems can yield satisfactory position determination (with accuracies of better than 500 ft.) for purposes of reconnaissance and target identification. Radio navigation systems suitable for tactical RPV's include: (1) Rebroadcast by the RPV of signals received from established LORAN stations for computation of the RPV's position at the ground control station; (2) time difference of arrival of microwave signal (TOA), distance measuring equipment (DME), or TOA and DME in combination (TOA/DME) to determine RPV position. For RPV's operating beyond line of sight, various relay platforms can be used -- towers, balloons, manned aircraft, drones, and satellites.

Spread spectrum signals (see paragraph 5 above) are particularly well suited for accurate time (distance) measurement. For example, a 100 MH_z pseudo-noise spectrum signal could have pulse durations of 10 nanoseconds which permit distance determination to 1 foot.

Pending definition of RPV systems configurations, present R and D efforts on TOA systems should be continued.

7. Ordnance

Many ordnance items developed for delivery by manned aircraft are compatible for use with RPV's, especially those capable of carrying payloads of 1000 lbs. or more. Weight and dimension of RPV-compatible bombs, cluster bombs, mines, rockets, guided weapons and guns are tabulated in Figure 10. A number of ordnance development projects underway at the Naval Weapons Center and at the Air Force Armament Development and Test Center should result in useful future weapons for delivery by RPV; these include penetrating munitions and proximity (vt) fuzes, as shown in Figure 11.

8. Remote Control Systems

Control of multiple RPV's operating in a tactical combat theater must be integrated with the prevailing overall control system of the air-space and the land combat zone. The control center for RPV's (CCRPV), here described in terms of a subsystem of the Air Force Tactical Air

FIGURE 10

TYPICAL RPV-COMPATIBLE ORDNANCE (1500# PAYLOAD)

TYPE	DESIGNATION	WEIGHT (LBS) LOW	HIGH-DRAG	DIMENSIONS (IN) LENGTH	DIAMETER	SUBMUNITION
GP						
	MK 81	260	301	75	9.0	UNITARY
	82	531	560	90	10.8	UNITARY
	83	985	---	118	14.0	UNITARY
	M 117	799	900	87	16.1	UNITARY
FRAG/CLUSTER (AP/AM)						
	AN-M1A4	128	---	46	8.9	
	CBU-24/B	830	---			BLU-261B AP/AM
	CBU-24/A etc.	409	---			BLU-3/B AM
	CBU-3A/A	350	---			BLU-7A/B AT
	CBU-34/A	824	---			BLU-42/B (WAAPM)
	MK 20 MOD 2	496	---			ROCKEYE II
COFRAM (CLUSTER AP)						
	CBU-1A/A	830	---			BLU-4A/B AP
	CBU-7A	800	---			BLU-18/B AP
CHEMICAL (CS)						
	CBU-15A	560	---			BLU-19/B23
	BLU-52/B	350	---	151	18.5	CS-1 or 2
FIRE						
	BLU 23/B	500	---	119	15.8	NAPALM
	CBU 55/B	500	---	90	14.0	Et_2O FAE (USN)

FIGURE 10 (continued)

TYPICAL RPV-COMPATIBLE ORDNANCE (continued)

TYPE	DESIGNATION	WEIGHT (LB)	DIMENSIONS (IN) LENGTH	DIMENSIONS (IN) DIAMETER	SPECIFICS
MINES					
	MK 36	560	90	10.8	Magnetic
	M117D (BLU-71B)	900	82	16.0	
	MK 52, MODS 1-7	1,100	70	18.8	UW, Acoustic, Magnetic
ROCKETS					
	MK 1, MODS 1-5	18	48	2.75	HE
	MK 5, MOD 0	18	48	2.75	HEAT
	XM 229, (AP)	28	65	2.75	HE, VT 429 Fuze
	MK 24, MOD 0	44	94	5.0	HE
	MK 32, MOD 0	44	105	5.0	ATAP (Shaped Charge)
GUNS					
	MK 24 20MM				--
	M 61 20MM				VULCAN
	XM 140 30MM				Developmental
	M 75 40MM				Grenade Launcher
GUIDED WEAPONS/MISSILES					
	M 117 LGB	894	105	16	PAVEWAY
	GW MK 1 MOD 0	1,100	136	15	WALLEYE
	AGM-12B	565	126	12	BULLPUP A
	AGM-45A	395	127	8	SHRIKE
	AGM-64A	100	65	7	HORNET
	AGM-65A	475	98	12	MAVERICK
	AGM-78A	1,367	180	13.5	Standard Arm.
	ARPA LG FFAR			2.75	Prototype

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FIGURE 11

PROMISING DEVELOPMENTAL ORDNANCE FOR RPVs

TYPE/DESIGNATION	CHARACTERISTICS	STATUS
HARD STRUCTURES MUNITION	2-STAGE, PENETRATING	ENGINEERING DEV. (ADTC)
HARPOON WARHEAD	1-STAGE, PENETRATING	ENGINEERING DEV. (NWC)
USAF FAE	PROPANE/PROPYL NITRATE	DEAD
MK 36 - PAVEWAY	500 LB. LG MAGNETIC MINE	REQUIRES USN-USAF COOPERATION
VT FUZE	SMALL, CHEAP, RELIABLE	NOT THE FMU-57!
ANTI-HANGARETTE BOMB	PENETRATING, VOID SENSING	EXPLORATORY DEV. (ADTC)
RUNWAY-CRATERING BOMB	PENETRATING	EXPLORATORY DEV. (ADTC)
LASER VT FUZE	BISTATIC	PROTOTYPE (ADTC) (NWC)
APAM	1-1/4" DIA. SHAPED CHARGE WITH FRAG CASE	PROTOTYPE (NWC)
MGGB	WINGED HOBO, ALL-UP RPV	ENGINEERING DEV. (ADTC)

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Control System (TACS), should be mobile, air transportable and of modular construction to facilitate deployment in several configurations. (Microwave control and communications systems were covered in paragraph 5 above.)

The Task Force examined (for illustrative purposes) a CCRPV for the Defense Suppression Mission which is demanding from a control point of view, since it involves target strike, damage assessment as well as ECM. Six command and control functions are identified to execute such a multi-RPV mission:

(1) Mission (controller) commander

(2) Launch/Recovery Controller (physically located near the launch/recovery site, not in the CCRPV)

(3) Enroute Flying Controller

(4) Attack/Strike Controller (A/SC)

(5) ECM Controller (for ECM equipment in strike or special ECM-RPV's)

(6) Immediate Assessment Controller (uses same displays as the ASC and also serves as a backup AS/C)

Individual RPV's are "handed over" from one controller to another, as these RPV's progress through their various mission phases.

Current hardware technology is adequate to implement the functional requirement defined for the CCRPV. (Display technology is considered in paragraph 9 below) Soft-ware development, however, will be a major task.

9. Ground Displays and Data Processing

Display console requirements can be met with modular multi-purpose consoles that can be used in any functional role. Further analysis is required to define specific control functions to be initiated by the operators, and performance characteristics of the display devices, such as brightness, contrast, resolution, character size, display density, etc. Developments such as the AN/USA-26 display and the AN/YUK or L-304 computers reflect the practical requirements for small volume, lightweight, rugged and reliable equipment.

To achieve further reduction in the physical size of the equipment, further emphasis should be placed on developments of flat plate displays, such as a flat screen plasma display. This would remove the major size limitation of current consoles that use bulky CRT displays.

Since a large data base is envisioned for the CCRPV, further development of small militarized bulk memory devices would also be beneficial. Current mass memory technology is represented by the random access, militarized plated wire memory developed by RADC.

10. Human Factors and Training for Remote Operators

For training purposes, a system of duplicate displays could easily be provided to permit trainees to observe RPV missions in real time.

Furthermore, actual RPV missions could be recorded for future play back through training systems located at U. S. training bases. The training system would be structured to provide the same information to the trainees that RPV "pilots" had while conducting the actual mission. The trainees' actions could then be evaluated and compared with the actual mission at a later time.

Experienced personnel can similarly perform practice missions to maintain their remote control proficiency. Furthermore, an unsuccessful mission can be played back for analysis to evolve new tactics.

It is also possible to combine reconnaissance data from a prior mission with other data on enemy order of battle, weather, etc., for complete simulation of combat conditions. This would permit the development of tactics, and practice in executing them for, say, coping with enemy defenses.