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# AIR FORCE RPV OPERATORS: RATED VS NON-RATED

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October 1975

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THESIS

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Robert G. Kiggans
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THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the
Requirements for the Degree of

Master of Science

by

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## Preface

This thesis deals with one of the most controversial aspects of Air Force remotely piloted vehicle (RPV) development, the qualifications of the operators. Looking ahead into the 1980-90 time frame, this research attempted to examine operator requirements to determine both the feasibility and desirability of using other than rated officers as future RPV operators. Readers will find that the emphasis of this research is on the future Compass Cope program, but the analysis should be of some importance to other RPV operations as well.

I wish to acknowledge my indebtedness to my advisor, Major Edward J. Dunne, Jr., for providing suggestions and guidance. His questions and recommendations have made this report much more valuable than it would have been otherwise. My thanks also to Lt Colonel Adrian M. Harrell for his inspiration and aid in improving the readability of this report. Also, I am greatly indebted to Professor Joseph P. Cain for his insights regarding operator cost factors and to all the people who took time to answer my questions and give their opinions on operator qualifications. Their enthusiastic support will not soon be forgotten.

Undoubtedly, there are other relevant issues that have not been addressed by this research. I regret any such omissions and accept full responsibility for any errors or misconceptions that may be contained in this work.

Robert G. Kiggans

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## Abstract

The primary objective of this research was to examine criteria for Air Force RPV operators to determine both the feasibility and desirability of using other than rated officers as future RPV operators. The research methodology involved an analytical approach in which several sub-objectives were established. Past and present RPV operator criteria were identified initially, followed by an evaluation of the impact of emerging technology on future operator requirements. In order to enlarge this evaluation, the opinion of an experienced RPV community on future operator criteria was sampled. Differential operator costs were estimated as a final element of the investigation. Although special emphasis was placed on the Compass Cope operation, the analysis was intended to have application to other RPV operations as well.

# AIR FORCE RPV OPERATORS:

# RATED vs NON-RATED

## I. Introduction

### Background

Remotely Piloted Vehicles (RPV's), a phrase coined in the early 1970's, is the updated terminology for the earlier developed target drone and its derivatives. RPV's are generally distinguished from drones, however, in that real time control can be continuously maintained, while the drone is (essentially) pre-programmed with minimum inflight control. The current breed of RPV's has evolved from the Teledyne Ryan Q-2A target drone, developed in 1948 for manned aircraft training (Ref 41:4). RPV growth after that period has had its ups and downs, but two situations spurred more intensive interest: Francies Power's U-2 incident of May 1960, and the impact of full air combat over North Vietnam. The downing of Power's U-2 over Russia sent political shock waves around the world and dramatically pointed out the need for unmanned reconnaissance aircraft, and intensive air combat over North Vietnam emphasized the need for a more realistic, maneuverable target drone to train U.S. fighter pilots (Ref 12: 21).

Current Air Force RPV operations still rely on the basic Q-2A design with various modifications. Present operations are airborne in nature, utilizing the DC-130 aircraft for launch and the CH-3 or CH-53 helicopter for mid-air retrieval. Only rated officers fill the operator positions, with the primary input coming from navigators who have extensive additional training in electronic warfare. The existing operational units are located at Davis-Monthan Air Force Base under two commands: the 350th Strategic Reconnaissance Squadron under the Strategic Air Command (SAC) and the 11th

Tactical Drone Squadron under the Tactical Air Command (TAC). (A consolidated test squadron, the 6514th, is also in existence under the Air Force Systems Command at Hill Air Force Base.)

Several Air Force programs involving future RPV's are noteworthy. One such project involves a vehicle that employs a modularized multi-mission system. Three interchangeable noses allow the vehicle to operate as an electronic warfare, reconnaissance, or strike RPV. A follow-on program is the Advanced Multi-mission RPV which should be operational in the 1980s (Ref 14:27). Another program concerns low cost, expendable RPVs that can be deployed in large quantities as jammers and decoys to help in a tactical force penetration (Ref 19:30). One of the most promising programs is called Compass Cope, which involves a high altitude, long endurance RPV with ground launch and recovery capability. The operators of the Cope vehicle and other future RPVs are the focal point of this research.

## Statement of Problem

RPV operators are those individuals who exercise some direct control over the RPV. The qualifications and status of these people are among the most controversial aspects of RPV development. The problem addressed in this thesis is that future RPV operator criteria have not yet been clearly defined. An example of this lack of definition can be seen in the operator projections for the future Compass Cope RPV. A prime prototype contractor for this project is specifying a four man operations team composed of two pilots and two radar technicians (Ref 37:6-7). Tactical Air Command, on the other hand, is specifying a six man team composed of three engineers and three radar technicians (Ref 69).

When looking ahead into the 1980-90 time frame, the following questions should be addressed. With future RPV operations shifting to ground level, will it become desirable to use non-rated personnel as operators? Will changing recovery tactics require a pilot to land and control the vehicle or will the RPV become so automated that a non-rated officer or non-commissioned officer (NCO) can handle the task? Should operators specialize in certain phases of the mission or will one man be able to handle the entire profile? Is there a significant cost difference between using rated and non-rated officers as operators? The answer to these questions should help determine man's future role in RPV operations.

Opinions about who should be the future RPV operator range anywhere from "the man off the street" to a highly qualified pilot with engineering background. Therefore, a close examination of future RPV operator requirements will be undertaken, with special consideration given to using other than rated officers. Emphasis in this study will be primarily geared to the Compass Cope Project; however, the findings should have some application to other key RPV programs as well.

## Significance of Problem

Certainly, Remotely Piloted Vehicles could become a significant force · our future Air Force inventory, but their long term viability will hinge on demonstrated cost advantages over manned aircraft. Statements indicating that RPV's are cheap based on low unit cost are no longer acceptable, mainly because changing Air Force philosophy now encompasses life cycle costing (LCC), which dictates a closer look at a broad spectrum of costs associated with using RPV's operationally. With advancing technology, the Air Force RPV program is cautiously moving toward the highly automated ground launch and recovery such as envisioned by the Compass Cope Project.

Due to this changing philosophy and advancing technology, there has become a definite need to evaluate the operator requirements for future RPVs and establish criteria for operator selection. According to Col Ward H. Hemenway, the Program Manager of the Air Force's Drone/RPV System Program Office, "the high cost item in system acquisition and operation is manpower and constant examination of the requirements for people in our drone/RPV system is necessary, striving to reduce both the numbers required and the skills of those needed (Ref 19:26)." He further stated that "the entire human factors area requires exhaustive research and thought before important decisions are made (Ref 14:28)."

The importance of proper resource utilization in the Air Force can not be over-emphasized. Although it might be desirable to use only rated officers as future RPV operators, it should be recognized that such resources are highly trained individuals, who must be considered valuable assets. It is, therefore, well to question whether other personnel might perform sufficiently as RPV operators if provided with appropriate displays and controls relative to their background and capacity.

## Research Objectives

The primary objective of this research is to examine RPV operator requirements to determine both the feasibility and desirability of using other than rated officers as future RPV operators. Although particular emphasis is placed on the future Compass Cope Program, the analysis should be of significance to other RPV operations as well.

In conjunction with the primary objective, the following four subobjectives have been established:

1. Ascertain and evaluate past and present criteria (and the constraints thereon) used to specify RPV operator requirements.

2. Examine and evaluate the impact of advancing technology on future RPV operator criteria.

3. Develop subjective operator selection criteria.

4. Investigate the economic implications of operator cost factors.

## Approach and Methodology

Past and Present Operator Criteria. The first step in the analysis was to establish and evaluate past and present operator criteria leading up to current RPV operations; thus, providing a foundation for examining future operations. Historical background was reconstructed through interviews with senior staff personnel from Davis-Monthan Air Force Base and former operators now working at the RPV Program Office at Wright-Patterson Air Force Base. Articles from professional magazines were also reviewed to supplement the information gathered through interviews.

Current operations were viewed first-hand at the 350th Strategic Reconnaissance Squadron at Davis-Monthan AFB. The following RPV operational areas were observed: mission planning, crew briefings, ground pre-programming, pre-launch, launch, and recovery. Three days were required to observe the entire operation. The mission planning and crew briefing phase required one full day prior to flight. Pre-launch, launch, and free flight were observed on board the DC-130, with pre-programming occurring prior to takeoff. Since the recovery phase was controlled from a ground based trailer, a third day was required to observe this operation (an observation of the recovery operation from the retrieval helicopter was not considered necessary for this study).

Future Operator Criteria. The second step in the analysis involved the examination and evaluation of the impact of emerging technology on future operator criteria. The findings of current RPV research were integrated to determine what qualifications will or will not be required for future RPV operators. To aid in the accomplishment of this subobjective, close liaisions were established with the following Air Force Laboratories, where RPV simulations are being conducted: Aerospace Medical Research Laboratory (AMRL), Flight Dynamics Laboratory (FDL), and Human Resources Laboratory (HRL) (all three labs are located at Wright-Patterson Air Force Base). Information gathered from completed studies maintained at the Defense Research Library was also analyzed to supplement current studies. While no research on hand directly confronted the issue of whether it is feasible to use other than rated officers as future RPV operators, enough data was collected and analyzed to aid in the determination (refer to Appendix B for key technological impact references).

Future operator requirements were divided into three phases: mission planning, enroute operations, and take-off/landing operations. First, the mission planning area was examined to determine the amount of navigation background necessary to construct and/or understand the mission profile. The task could become highly automated in the future, or the operator may be required to manually plan each detail of the RPV mission. Drone Control and Data Retrieval Systems (DCDRS) Preliminary Design Study conducted by Sperry Univac Defense Systems was the primary source used to evaluate this area.

Next the enroute phase was examined, with three key dependent factors identified: remote control system design, navigation system capability, and communications capacity. It was important to determine if rated skills were needed for enroute control, navigation, and detection of communication jamming. Various control system designs were evaluated, as well as some of the more promising future navigation systems. Current technology regarding communication data links was also reviewed. First-hand observations of Aerospace Medical Research Laboratory RPV System Simulation Study III and IV in conjunction with the summary report of Simulation Study II results were used to help evaluate the enroute operater phase. Supplemental material was gathered from several key Navy investigations, Rand papers, and Air Force Air University studies.

Finally, the launch and recovery phase was examined, emphasizing the Compass Cope vehicle, which will take off from and land on runways as do conventional aircraft. Remote ground recovery operations were reviewed, as well as the progress in automatic flight control systems and microwave guidance systems. It was critical at this point to determine if anyone other than a pilot could handle the task, especially the remote landing. Therefore, the remote operator's role within an automatic take-off and landing system was evaluated. The importance of TV imagery was also addressed.

To support this effort, an analysis was made of studies and simulations being conducted by Flight Dynamics Laboratory and Aerospace Medical Research Laboratory. First-hand observations were made of automatic landing system demonstrations and operator performance following automatic system failure. Supplemental material was obtained from interviews with personnel conducting the simulations and their subjects, as well as from relevant periodicals.

Subjective Operator Selection Criteria. The third step in the analysis involved the development and analysis of a comprehensive nucleus of knowledgeable opinion on future operator criteria. The results of this analysis were intended to augment earlier findings. A relatively large, experienced group was interviewed. An important source of information came from the operator area; that is, the two operational squadrons at Davis-Monthan Air Force Base and the 6514th Test Squadron at Hill Air Force Base.

Another key source of information came from the RPV Program Office at Wright-Patterson Air Force Base. This office contained a wealth of experience consisting of previous operators, RPV program managers, and engineers with various RPV systems experience. The Air Force laboratories were also an excellent data base, containing RPV simulation study directors and knowledgeable console design engineers.

An array of open-ended and closed-formed questions were addressed by the interview group (see Appendix D). The open-ended questions were asked initially to gain a broad perspective of future operator criteria. At the end of the interview a check-off selection sheet was provided to aid the interviewee in crystallizing his thought patterns. The opinions of the group were established and analyzed, and baseline operator criteria emerged when a convincing majority of the group indicated a preference for a certain category of operator. Opinions of various sub-groups were also identified, but no attempt was made to establish statistical significance from the viewpoints rendered.

Differential Operator Costs. The fourth step in the analysis was to investigate operator cost factors to determine if significant savings could be realized by using non-rated officers as future RPV operators. Distinctive costs were identified with various operator groups. Based on the information from directive interviews, differential cost comparisons were made between the following classes of operators: pilots, electronic warefare officers, navigators, and non-rated officers (equal rank was assumed; thus, any basic pay effects were ruled out). The comparisons were based on the premise that the Compass Cope Program would have a key operational mission in the near future with a life span of about ten years.

Development of Findings and Recommendations. A basis for projecting future RPV operator requirements was established by examining past and present operator criteria. An evaluation of progressing technology, as well as an analysis of knowledgeable opinion, made possible a feasibility determination regarding the use of non-rated personnel as future RPV operators. And, through differential cost comparisons, the desirability of using such personnel was investigated. By synthesizing the findings of the various sub-objectives, conclusions and recommendations were developed relating to RPV operator criteria.

# II. Current RPV Operations

## Operator Criteria

Prior to the 1960s, drones were assigned only peripheral roles such as targets for manned aircraft and ground gunners. In early 1962, however, a contract was let to build the first reconnaissance drone (nicknamed "Lightening Bug"), and it was delivered to the Air Force 91 days later (Ref 12:21). Finding the "unmanned aircraft" an operational home was not so easy, however. When asked to accept operational control, Tactical Air Command said not only "No" but "Hell No!" (Ref 12:21). The idea was finally sold to the Strategic Air Command's Deputy Chief of Operations, then Major General Butch Blanchard, and within two years the first operational sortie was flown over China (Ref 12:21-22).

Initial testing of the reconnaissance drone relied heavily on Non-commissioned officers (NCOs) as operators because they had worked on target drones prior to that time and were knowledgeable in drone systems. In 1963 the Strategic Air Command (SAC) sent two of their DC-130 air crews to the Air Force Missile Development Center at Holloman AFB, New Mexico, to aid with the testing, and it soon was concluded that the NCO operators were lacking in certain skills (Ref 50). The RPVs had become somewhat more complex with the inclusion of a self-contained guidance system, camera, and other subsystems; therefore, electronic warfare officers (EWOs) were designated to assume the role as RPV operators in order to take advantage of their navigation, intelligence, and electronics background.

Use of remotely piloted vehicles in Southeast Asia began in the mid-1960's. As reconnaissance operations grew larger in scope, the RPV ground recovery control site was positioned some distance from the main operating base. The Strategic Air Command then began training pilots to become ground recovery operators so that they could be used in a dual capacity, serving also as the site commander. At that time, electronic warfare officers were not permitted to command flying operations, due to Section 8577 of Title 10, U.S. Code (Ref 5:1). Title 10 stated that all flying units would be commanded by a pilot, but this law was repealed by Congress in December 1974 (Ref 6:11).

In 1972, the Air Force experienced an electronic warfare officer shortage; therefore, a short range, stopgap decision was made to start training navigators to fill some RPV operator slots. A small group of navigators was initially chosen, many of whom were high ranking officers serving in their terminal assignment (Ref 50). As the Viet Nam War phased down, however, the EWO shortage diminished and the change-over was never completed. The current 350th Strategic Reconnaissance Squadron RPV operators are all rated personnel. Electronic warfare officers are used for the launch control and airborne remote control phase and pilots are used for the ground recovery phase.

Tactical Air Command's formal entry into the RPV operations occurred recently with the formation of the 11th Tactical Drone Squadron in 1971. Its mission is to provide the Air Force with a tactical reconnaissance and electronic countermeasures capability. This unit was formed as an outgrowth of the Combat Angel task force, a group organized in the late 1960's to operate chaff dispensing drones in Southeast Asia (chaff dispensing simply involves releasing particles in the air to confuse enemy radar). Composed of former Stragegic Air Command RPV crews, this task force was never deployed operationally. Tactical Air Command uses electronic warfare officers to man all RPV operator positions.

Command Operational Philosophies

Although physically located at the same base, the two commands' RPV operations are philosophically different in many respects. While operator required skills are very similar, the TAC and SAC operator philosophies are very dissimilar. A pervasive difference in philosophies involves the "crew concept." SAC's idea of the crew concept involves the entire air crew (i.e., the DC-130 flight crew members as well as the RPV air operators). The DC-130 pilot commands the team and acts as the overall decision-maker, with responsibility for analyzing and reporting individual crew member effectiveness.

Tactical Air Command, on the other hand, does not embrace this expanded crew concept, although it does attempt to maintain a more loosely structured, RPV operator crew. Its policy, as now being implemented, generally designates the highest ranking operator as the RPV crew commander, rather than the flight crew pilot, as is the case with SAC's operation (the DC-130 pilot still retains final authority as to whether the RPV will be launched, but he has no control over RPV operator effectiveness ratings, which are usually written by the highest ranking operator).

Probably the most glaring difference in philosophies involves the recovery position. SAC, as mentioned earlier, uses a pilot as the recovery officer (RO), which is a ground stationed position. TAC, in contrast, uses electronic warfare officers interchangeably as the airborne remote control operator and the recovery operator, designating his position simply as remote control officer (RCO). This arrangement is indicative of a more loosely structured, flexible crew concept.

One other subtle difference should be recognized. SAC accepts newly assigned EWO's as launch control operators; then, after 250 hours of DC-130 flying experience, considers them for training to the airborne remote control position (Ref 52:7). TAC, on the other hand, has accepted EWO's for training in either operator position without prior experience. TAC's operators are currently starting out as launch control officers, though, with no fixed period or requirements prior to moving to the remote control position.

## Operator Functions

Much has been said so far about how Air Force RPV operators were chosen, but very little has been said about what they actually do. As defined in this study, RPV operators are those individuals who exercise some direct control over the RPV. This definition excludes the airborne radar technician (ART), an NCO whose duty is to obtain radar lock-on and tracking of the RPV during free-flight. Although an integral part of the operator team, he exercises no direct control over the RPV. The three operator roles considered here are that of the launch control officer (LCO), the airborne remote control officer (ARCO) and the recovery officer (RO) (as mentioned earlier, TAC categorizes the latter two positions under one designator, remote control officer (RCO)). In discussing each position, the following areas will be emphasized: tasks accomplished, equipment used, skills required, and scope of decision-making. Prior to detailing each position, however, a typical mission sequence will be developed.

A RPV mission usually begins with a full day of mission planning and team coordination. The team consists of the DC-130 launch ship flight crew, the CH-3 helicopter retrieval crew, and the RPV operators and radar technicians. During the day, the manned vehicle flight routes and the RPV mission profile are established, as well as the precise launch and recovery points. At the end of the day, team briefings are conducted and precise mission coordination is established.

The following day, after extensive ground checks have been completed, the DC-130 aircraft lifts off the runway, normally carrying two RPVs underwing. From the DC-130 mother ship, extensive contact and coordination are maintained with the helicopter retrieval crew, the ground remote operator, and appropriate ground authorities. At a specified time, the launch control officers start the RPV engines and prepares for launch (sometimes, only one of the vehicles is launched). When the DC-130 navigator informs the team that the launch point is reached, the launch control officer initiates the release sequence. The RPV then falls downward, streaking away on its intended path. The airborne remote control officer monitors the RPV's on-board guidance system and at times controls the vehicle manually from his DC-130 control station (if the RPV is a photo reconnaissance type, a camera mounted in its nose automatically photographs areas of interest below). At a predetermined time, vehicle control is passed to a ground remote operator, who steers the RPV to a designated location where the recovery sequence is commanded. The RPV engine shuts down, fuel is dumped, and the parachute system is initiated. During its downward descent, the helicopter moves in and makes a mid-air retrieval to complete the mission.

Launch Control Operator Functions. The launch control officer's functions can be divided into three phases: premission preparation, prelaunch, and launch. Extensive navigation skill is needed for the premission phase. Approximately eight hours are required to accurately plan the vehicle's route from launch through point of recovery, determining the necessary headings, estimated times enroute, and fuel required based on given winds and specified airspeeds. Necessary action points are also determined at this time. This information must be precisely coordinated with the other RPV operators, as well as the DC-130 and helicopter flight crews.

Some knowledge of electronics is also necessary, since most on-board and peripherial equipment is electronically controlled. In order to program the RPV navigational computer, the LCO reports for flight duty several hours prior to the rest of the crew. This mission plan developed earlier is inserted into the computer and cross-checked. Extensive ground and air subsystem checks are also accomplished and coordinated; therefore, a broad knowledge of systems is mandatory. The LCO performs numerous confidence checks to insure that subystems will operate normally inflight, with special attention given to navigation, engine, and remote radio control link subsystems (Ref 31:19).

After the subsytems have been thoroughly checked, the LCO starts the engines and prepares the vehicle for launch. His panel has all the necessary displays and controls to launch the RPV, which is electrically connected to the LCO's direct control panel by an "umbilical cord" (Ref 20:9). As a result of the many variables affecting an RPV mission (such as late DC-130 take-off, radio problems, etc.), the LCO must be able to work under pressure. System checklists have to be run thoroughly and rapidly in order to launch the vehicle at the proper time.

After the vehicle is launched, the LCO's primary duties have ended. He now acts only as an advisor to the airborne remote control officer and performs his normal crew duty of monitoring aircraft flight safety.

In theory, the LCO functions as a technical specialist, acting only in an advisory capacity to the DC-130 aircraft commander, who is ultimately responsible for the RPV mission from take-off until the RPV comes under the control of the recovery officer (Ref 20:10). In reality, he makes real time decisions and is held accountable for his actions. While the scope of his decision-making is limited compared to the other operators, he is still a key member of the RPV team.

Aircraft Remote Control Officer Functions. The airborne remote control officer's duties can be divided into two phases: pre-launch and free-flight. Since much of the premission navigation work is accomplished by the LCO, the ARCO exercises minimum mission planning skills. He does, however, chart the RPV's route and recovery area as well as the DC-130 aircraft's post-launch route. These routes are charted on a 30 inch by 30 inch specially scaled map, which is later attached to his control panel plotting board.

Due to the nature of his equipment, the ARCO must have a fundamental knowledge of electronics and systems. Prior to launch, the ARCO monitors the RPV through the AN/APW-23, a microwave command guidance system (MCGS). His pre-launch responsibilities include checking the AN/APW-23 and the ARN-92 (V) navigation tie-in system for proper operation and completing a number of remote control checks. Prior to launch, he interfaces very closely with the DC-130 navigator, as well as the LCO, to insure that the vehicle will be launched at the proper point.

After launch, the ARCO monitors the RPV flight path and makes necessary corrections via the AN/APW-23 controls. The AN/APW-23 has an eight channel proportional readout system composed of meters and gauges displaying such RPV information as pitch, roll, altitude, airspeed, etc. (Ref 20:11). (The position of these meters and gauges have not been standardized, however, which could potentially cause operator errors resulting in subsequent RPV loss.)

As mentioned earlier, the ARCO has a plotting board to which he attaches his map. Navigation data sent from the RPV drives a plotting pin which tracks the progress of the vehicle along its route. The accuracy of this data is cross-checked through the use of a second plotting pin which is driven by the launch aircraft navigation system (Ref 20:12). It is imperative that the DC-130 navigator accurately update the aircraft position or the ARCO will be unable to precisely control the RPV in relation to its intended flight path.

The ARCO needs some skills in remotely controlling the vehicle. If the automatic programmer malfunctions or adverse winds affect the RPV, the ARCO uses a control stick on the AN/APW-23 to initiate climb or dive maneuvers or lateral corrections to track. The design of the control station is such that the skills needed to control the vehicle are not the same as those skills developed by the traditional aircraft pilot. The ARCO's control stick is positional; that is, the vehicle turns in the direction that the stick is moved at a predetermined rate. With the traditional aircraft rate stick, the pilot's control of the roll rate is a function of stick displacement. The operator's point-of-view is also different. The ARCO's view of the RPV is the plotting pin representation moving across a north/south oriented chart ("outside-looking in" view), whereas the traditional pilot's view is line-of-sight with an "inside-looking out" orientation.

Once control is passed to the recovery officer, the ARCO's primary functions are completed. In theory, his primary role is to act as a technical advisor to the launch aircraft commander, as is the case with the LCO's role (Ref 20:12). In reality, he must make rapid, real time decisions which are critical to mission effectiveness. If the vehicle experiences uncontrollable flight, such as an unexpected dive, the ARCO must be capable of taking immediate action to correct the situation or initiate early recovery. He is certainly a key member of the RPV operating team.

Recovery Officer Functions. Since equipment and skills are very similar to that of the ARCO, a description of the recovery officer's position will be somewhat abbreviated. The recovery officer (RO) mans a TPW-2 ground recovery station which contains the same type of equipment that is located on-board the DC-130 (this stationary ground location limits his line-of-sight control, but certainly aids his navigational accuracy, since a known fixed position is being referenced). Depending on the profile of the RPV, the RO's role may be expanded to include extensive enroute control (high altitude RPV profile), or may be limited to a short recovery sequence (low altitude RPV profile).

Providing the important linkage between the launch aircraft and the recovery helicopter, the RO's responsibilities begin when control of the RPV is received from the ARCO and ends after the parachute sequence is initiated. Towards the end of the free flight phase, the RO makes any last minute alterations to insure that the RPV arrives at the recovery area. Once the designated point is reached, he initiates the deployment of the recovery and engagement parachutes located within the RPV. The vehicle is then ready to be "snatched" by the retrieval helicopter and lowered safety to the ground.

From his ground based location, the RO functions primarily as an independent decision-maker. His decision-making role is complicated by many variables, such as the weather in the recovery area, retrieval helicopter reliability, etc. Therefore, he must possess the ability to make quick, coordinated decisions and take decisive action if necessary to recover the vehicle early or in a different location. His role is vital to the successful completion of the RPV mission

## Summary

Operational experience with RPVs in other than a training role began in the early 1960s with the birth of the reconnaissance RPV. Initial testing relied heavily on non-commissioned officers as operators but as the vehicles became more sophisticated, rated officers assumed the operator role. Electronic warfare officers were selected initially to take advantage of their navigation, electronics, and intelligence background. Later, pilots were trained as ground remote operators to take advantage of their exclusive command authority. At present, both the Strategic Air Command and the Tactical Air Command have operational squadrons of RPVs. Because these operations are airborne in nature (utilizing a DC-130 for launch and an CH-3 helicopter for recovery), rated expertise is considered a desirable operator requirement.

The operator functions are divided into three distinct phases: launch control, airborne remote control, and recovery control, with a single rated officer controlling each phase. Generally, the overall responsibilities and duties of the launch control officer and airborne remote control officer are commensurate with the category of person assigned. The launch control officer requires extensive mission planning skills, knowledge of electronics and systems, and the ability to work under pressure. The airborne remote control officer requires a fundamental knowledge of elecgronics and systems, some skills in remote control, and the ability to make rapid decisions. No longer justified, however, are the reasons for retaining a pilot as the recovery officer. His duties are very similar to those of the airborne remote control officer and, with the repeal of Section 8577 of Title 10, he no longer has exclusive command authority.

With the establishment (and evaluation) of past and present RPV operator criteria, a foundation has been provided for examining the impact of advancing technology on future operator requirements (which follows in the preceding chapter).

## III. Future RPV Operations

Current Air Force RPV operations offer many assets. To carry out their electronic warfare and intelligence missions, these units can be deployed in minimum time to numerous locations throughout the world. In Southeast Asia alone, the Air Force has produced excellent reconnaissance photography in flying more than 2500 RPV combat sorties (Ref 14:26).

Some notable disadvantages are inherent in the present launch and recovery modes, however. By tying the launch mode to the DC-130 platform, the crew is normally limited to two, somewhat short range RPVs, with effective control limited to one vehicle at a time. On occasion, as many as four RPVs have been carried, but size and weight restrictions are definitely imposed when RPVs are mounted under wing on bomb-shackle pylons.

Since the recovery mode is tied to the mid-air retrieval system (MARS), disadvantages also exist. With the helicopter retrieval, the RPV is again restricted in weight. If the helicopter fails to catch the vehicle, back up parachutes will deliver the RPV to the ground. But as much as $20,000 in damage is incurred upon ground impact (Ref 39:26). On every MARS recovery, an average of over $6000 in expendable equipment is used (Ref 44). After experiencing some hard growing pains, this somewhat awkward, retrieval system is attaining a reliability rate of over 95% (Ref 44).

It is estimated that 50% of the RPV operational and maintenance costs are absorbed by the launch aircraft and retrieval helicopter (Ref 41:33). Notable deficiencies, then, are inherent in these costly launch and recovery modes which restrict operations in the number, weight, and range of the RPVs that can be utilized.

Because of the aforementioned deficiencies, Air Force planners started looking to the future with alternatives in mind. One such alternative is offered by the Compass Cope RPV. This high altitude, long endurance vehicle is designed for ground take-off and landing, with a mission control facility (MCF) capable of handling multiple RPVs simultaneously. The projected military missions of this relatively large, long wing span RPV include tactical battlefield support, intelligence collection, and electronic warfare. This RPV program is scheduled for concept validation by the Defense Systems Acquisition and Review Council in December 1975 (refer to Appendices I and J for Cope photos).

A controversial aspect of this and other projected RPV programs involves the qualifications and status of the people who will act as operators. As the Air Force moves towards systems for simultaneously controlling many high performance RPVs from one location, combined with the trend toward ground recovery, man's role is bound to change (Ref 19:29). These technological advances dictate a fresh look at future operator criteria. Therefore, this chapter will examine the impact of emerging technology on future mission planning, enroute, and take-off/landing operations.

## Mission Planning Operations

The mission planning phase, as currently being accomplished, is heavily man-oriented. The launch control operators who handle this task were specifically chosen to take advantage of their navigational background. The planned route is carefully traced on an aerial chart. After determining tracks and distances to each action point, the operators calculate true headings and flight times using established airspeeds and projected weather data. Using a totally manual approach, they take up to eight hours to adequately layout all the details of the RPV flight profile.

To evaluate different approaches to future RPV mission planning, trade studies were conducted by Sperry Univac Defense Systems (Ref 26). Five candidate approaches were examined, which varied from all manual planning and optimization to all automated planning and computer optimization (optimization refers to the development of an efficient plan in which all vehicles required to appear in designated areas are accommodated and all other vehicles are interspersed as permitted to minimize the overall operating time). Criteria used in the study included time required to plan, cost, risk, and adaptability to multi-mission, multi-vehicle operations.

The all manual approach was eliminated because it was too time-consuming and was not compatible with future operations. The other extreme, entire automation, was eliminated on the basis of high cost and risk. It was doubtful whether sufficient data could be incorporated for entirely automatic route selection. Computer aided planning and computer optimization was selected because it represented the best mix between human and automatic capability. Entirely compatible with presently available computerized mission planning capability, this approach employs the man where his intelligence benefits (i.e., route selection), while the computer is used to perform routine tasks such as conflict elimination and operator assignment.

Future operations will involve multiple control of high performance RPVs. The task of translating mission directions into detailed individual flight plans for each vehicle will become very complex when appreciable numbers of RPVs are involved. Therefore, the detailed planning process of manipulating the data will probably be automated, using a human mission planner only when judgement is required, such as in route selection. The operator could be removed from the task entirely. A computer would determine conflict free flight profiles, calculating fuel, speeds, and time over check points. This automated process would give planners the ability to generate mission plans in minutes, with the further capability for changing plans while flight operations are in progress (Ref 25:26).

These mission planning tasks could be performed in a plans section of the mission control facility. The work would consist of responding to operational orders by selecting the number and types of RPVs for each mission and developing detailed computer flight plans which would be converted to flight program data for insertion into the RPVs (Ref 25:47).

Separating the mission planning function from the operator is not a new idea. In the B-52 operations in Southeast Asia, the detailed mission planning tasks were completely divorced from the flight crew functions. Intimate knowledge of each detail of the plan was unnecessary. The crews simply reviewed the mission prior to take-off and then went on their way, having little concern for how each calculation was derived. Computer route selection was also attempted, but this approach did not work well without man's judgement.

Due to the complex scheduling problems of multi-mission, multi-vehicle operations, it will be desirable to divorce the future operators from this task, leaving this work to a mission planner who would rely on computer aided planning and computer optimization. Therefore, future operators will not need extensive mission planning background, which is one of the primary criteria for selecting current operators.

Enroute Operations

The enroute phase, as defined in this study, encompasses all actions from after take-off to descent for landing. A more conventional division would include a terminal phase associated with the RPV mission (recce, strike, etc.) but the emphasis of this study is on the high altitude reconnaissance RPV where the terminal phase of the mission may involve only simple control, such as turning on and off a camera (the terminal phase of a strike mission could require display of sensor data and weapons release, prohibiting multiple vehicle control). Tasks involving TV imagery will be included under the take-off and landing phase, the last section of this chapter.

Systems design philosophy will impact heavily on operator enroute requirements for future RPVs. Research designers feel they now have an opportunity to create new systems from the ground up to fit the operator and the mission, unimpeded by past restrictions that have traditionally constrained manned aircraft designers (Ref 15:63). By locating the remote control facility on the ground, several advantages can be realized. Operators can more easily communicate and share displays. Boredom and fatigue can be reduced by rotating operator crews without having to land an aircraft. Space limitations are not as critical; therefore, more equipment can be located in the ground control facility and specialization can readily take place. Also, on-the-job training can be accomplished more easily. The untrained operator can stand behind the console to monitor experienced operators and perform non-critical tasks.

With remote ground operations, there is little need to preserve an operator's night vision, nor is there need for the specific requirement for 20/20 uncorrected vision (criteria for entry into pilot flight training)(Ref 53:A13-1). Color blindness is a factor, though, since many of the warning indications could be color coded. Operator decision-making can take place in the calm of the ground facility, free from the aircraft noise and vibrations (the lack of motion cues may be somewhat disadvantageous, however). Finally, the physical discomforts of high altitude and high speed are removed, including uncomfortable flight equipment such as helmets, oxygen masks, G-suits, and parachutes.

Remote Control System Design. The RPV console design will most certainly affect future operator requirements. There are three basic console design approaches: the stick, rudder, and throttle approach; the missile approach; and the flight director approach (Ref 40:19).

The stick, rudder and throttle approach follows the basic aircraft cockpit design, with the traditional rate control stick and the inside-out view, using human skill and judgement to the maximum extent possible. The following explanation of control design is given by an RPV control/display study for the Navy:

> "The control stick may direct attitude as a function of displacement from neutral or drive attitude rate as a function of that displacement, these being termed position versus rate controls. Conventional aircraft are generally rate driven in attitude while drone control has been formed with position control. The former provides greater maneuverability and is consistent with pilot experience. The latter provides greater precision and should be easier to use by less qualified personnel" (Ref 28:32).

Conventional instruments are inside-out displays; that is, they present a moving horizon. Through the years, however, a number of studies have indicated that an outside-in mode of presentation might be superior; that is, presenting the same information by allowing the aircraft symbol to move against a stationary horizon (Ref 28:18).

One Navy RPV study favors the stick, rudder, and throttle approach. It concluded that the RPV control problem, including the man-machine interface, is similar to the problem of developing a new cockpit for a manned aircraft; therefore, the experience gained with the flying of manned aircraft and the cues and controls/displays should be used in every way possible (Ref 22 : 2-1). This approach, however, does not recognize some of the previously mentioned advantages of remote ground control.

The missile approach, in contrast to the stick, rudder, and throttle approach, allows for minimum human judgement, relying almost totally on an autonomous, self-contained guidance and control system. All maneuvers are made at a predetermined rate, with no operator capability of determining time urgency of required maneuver (Ref 29:47). This "turn key" approach is inflexible. The amount of redundancy necessary to completely remove the man from the loop could be overwhelming in cost and, if the system should fail, operations are paralyzed.

The flight director approach combines the best features of the previous two approaches. Anticipation, intuition, and decision-making are the responsibility of the operator. Data assimulation and manipulation are the responsibility of the digital computer, and vehicle attitude control is the responsibility of the autopilot (Ref 29:52).

The technology for using digital flight control is available. Simulations being carried out at the Air Force's Aerospace Medical Research Laboratory are utilizing this type of console design (Ref 33). These simulations employ four enroute/return phase operators, as well as one terminal phase operator for special actions. Each enroute/return phase operator monitors and operates a computer terminal station comprised of graphic display (cathode ray tube), alphanumeric key board, light pen, and a mode select function key board (see Appendices K and L). The simulations are executed in real time and permit simultaneous control over many simulated RPVs. The cathode ray tube can display each RPV flight plan, RPV track signature and vector according to reported position, expected times of arrival to action points, velocity and attitude, fuel remaining, lateral distance from flight plan, status of command data link, and various warning conditions. The enroute console is designed to accept handovers from launch activities, monitor progress of several RPVs, exercise control as required, take appropriate action relative to alerts generated by the data processor, and coordinate with and hand over to recovery activities. This approach utilizes program controlled flight and a "control by exception" philosophy, calling on the operator when abnormal conditions arise. The basic scheme draws from successful experience with the Surveyor Lunar Lander and other space programs involving remote control (Ref 25:10).

Taking advantage of man's remote ground location, control system design for RPVs can disregard many of the restrictions that have been imposed on manned aircraft. In viewing future control systems, the flight director approach appears to be the most promising, thereby eliminating many of the pilot skills that would accompany the stick, rudder, and throttle approach and the expense and inflexibility that would accompany the missile approach. With the digital flight director design, systems knowledge, rather than pilot skills, would become an important attribute of future enroute/return operators.

Navigation Capabilities. Navigation systems are available or under development which are adequate for all phases of future RPV missions (Ref 22:3-1). The selection of a system, then, is not as much dependent on availability as with the accuracy needed for specific mission requirements. Increased navigational accuracy would normally be associated with a weapons delivery mission whereas somewhat less accuracy would be associated with a high altitude reconnaissance mission. The type of navigation system selected for use could drive operator requirements to some extent, with the less automated and less redundant system requiring more operator navigation skill.

While a complete analysis of future navigation systems is beyond the scope of this study, it is worthwhile to review some of the more promising ones for RPV use. For comparative analysis, navigation systems can be divided into three general categories: independent position estimating (passive), depending position measuring (active), and multimodal.

Independent position estimating systems, as defined in this study, are systems that are capable of sustained navigation without the aid of remote supporting equipment. Dead reckoning could be a basic form of independent position estimating, using simply an on-board clock and some estimation of track and ground speed.

The inertial navigator is the mainstay of the independent position estimating systems. It provides a self-contained navigation position determination derived by integration of acceleration measurements. Coupled with the doppler radar, a fairly reliable position can be established by inertial means. Inertial systems are ideally suited for mission tasks which do not require extremely accurate positions, such as many high altitude reconnaissance sorties. Advances in digital mechanization and miniaturization, and development of inertial components will provide reasonably low cost inertial systems for the 1980 time period (Ref 22:3-16).

Tercom, another independent type system, provides a navigation position by correlation of an on-board, computer stored, topographical map and a real time map derived from radar measured altitude data. This system attempts to maintain a perfect match between expected terrain variations and those received from the radar. Prior knowledge of the unique elevation profile of the terrain is required; therefore, detailed topographical data must be available. Of course, missions over water and non-descript terrain would not be suitable for Tercom; therefore, its use in future RPVs will probably be very limited.

While independent position estimating systems re generally self-contained and provide intermediate positions, dependent position measuring systems utilize outside sources and establish precise navigational information. They are able to measure position to a degree of accuracy that is unaffected by flight time. One of these dependent position measuring systems, Loran, establishes an average position accuracy good to about 300 feet (Ref 63:13-9). This system, however, does not offer universal coverage, utilizing ground radio facilities whose vulnerability is a measure of concern. Since the system requires long-range reception of radio pulses, its effectiveness can be adversely affected by sunspots, terrestial noise and jamming (Ref 63:13-9).

Omega, a long-range hyperbolic radio navigation system, is designed for world-wide coverage. When fully implemented, the system will have eight transmitting stations with an average separation of 5000 nautical miles and provide an accuracy of between 200 and 300 yards (Ref 22:3-13). It may be subject to the same error sources and vulnerabilities as Loran, however.

Another promising system uses Time of Arrival/Distance Measuring Equipment (TOA/DME) and a tri-lateration method of position determination accurate to about 60 feet (Ref 25:58). The TOA/DME system is dependent upon transponders located at two determined references, one of which could be the mission control facility. Two relays may also be required in high intensity conflicts (Ref 25:58). When a RPV is interrogated, it would return the signal to both ground stations. By determining the total elapsed time from transmission to reception (considering any known delays), the three sides of the triangle can be solved. This system would make use of the existing communications data link and incorporate some anti-jam features.

The most promising dependent position measuring systems for the 1980-1990 time frame may come from navigation satellites. Navstar, a global positioning system, is a multi-service program which will become operational in the mid-1980's. This system will deploy three planes of satellites in circular, 10,000 nautical mile orbits (each plane will contain eight satellites). This deployment will insure that at least six satellites are in continuous view from any location in the earth. Ground control stations will track the satellites, periodically reloading information into their memory. The basic system capability is three dimensions of position, three dimensions of velocity, and very precise time. The expected systems' accuracy (90% of the time) is 24 feet in the horizontal plane and 29 feet in the vertical plane and the velocity determination is expected to be considerably better than one foot per second (Ref 64:10). This system will have anti-jam capability and be unsaturable; that is, it will service any number of users. For the dynamic user in a potentially high jamming environment, the unit cost of on-board equipment is projected to be between $28,000 and $29,500 (Ref 64:8). By offering a common global reference, this system would help integrate the unmanned RPV into the command and control structure of multiple force deployment.

Navigation systems that will involve radar terrain matching, optical map-matching, etc., where some type of ground display is transmitted to the operator for interpretation, will generally result in high cost and high operator skill level. Reading and digesting rapidly changing displays, coupled with the responsibilities of simultaneous RPV monitor and control, would be a formidable task even for experienced pilots and navigators.

Multi-modal systems combine independent position estimating systems and dependent position measuring systems, giving the operator the flexibility of selecting the best mode of operation. Future navigation systems will probably be multi-modal. An independent position estimating mode will be included, preferrably a low cost inertial system, to guide the vehicle between position update. One or more of the dependent position measuring modes will also be integrated into the system, depending on mission requirements.

Aerospace Medical Research Laboratory RPV system simulations, which were referred to earlier, are utilizing a multi-modal navigation system. The operators select one of three navigational systems taken from a set of four total. The four, in order of accuracy, are Loran, Inertial, Doppler, and Dead Reckoning. Utilizing these navigation systems, as well as various control devices (i.e., light pen, alphanumeric keyboard, mode/function select keyboard), simulation operators perform such navigational tasks as monitoring and updating RPV lateral position based on minimizing overall cross track error, time phasing certain RPVs so they achieve their computer planned time of arrival to designated action points, and reprogramming RPVs to replace those that are lost due to malfunctions or attrition. Adjusting an RPV time of arrival can involve no more operator action than typing a new ground speed into the system. Inflight replanning simply involves tracing a series of dots (describing a new track) onto the cathode ray tube with a light pen.

Navigation management is enhanced by providing a well organized display of intended and actual RPV track, estimated time of arrival, lateral deviation, ground speeds, and other relevant information (see Appendix L). The operator, using a well integrated display, can avoid such time consuming tasks as matching manually drawn charts against some type of visual display, retrieving navigation data from non-standard, awkward locations, and manually determining estimated time of arrival and lateral deviation.

By designing RPV avionics with an on-board general purpose digital computer, the capacity exists to insert optimized pre-planned flight plans for semi-autonomous operations. Further, by providing a well chosen multi-modal navigation system, avoiding map matching type displays whenever possible, operator navigational background requirements will be reduced. If Navstar even comes close to expectations, navigational skills can be cut significantly. Presenting a well integrated display will further reduce operator navigation skills. These combined factors, then, indicate that a strong navigational background will not be necessary for enroute/return operations.

Other Considerations. The key difference between conventional manned aircraft and a remotely piloted vehicle lies in the communication link between the operator and his aircraft. When inside the vehicle, the pilot can depend upon his complete sensory capacity to bring a full range of information to his immediate awareness. The remote operator, however, must restrict his attention to the objectively displayed information so as to conceptualize the status of the RPV (Ref 28:14). This objectively displayed information is transferred through a communications link, which may be vulnerable to interference and jamming. Under various kinds and levels of limited communications, special operator skills, such as electronic warfare training, may be required to adequately interpret the interruptions in order to perform mission tasks (current RPV communications links have very little anti-jamming protection). Technology, however, may now be able to provide a reasonable degree of anti-jam protection, thereby eliminating any real need for operators to have a sophisticated knowledge of electronic jamming.

The communication data links between the RPV and the control facility will be line-of-sight; therefore, it may be necessary to use some type of relay or additional remote facilities downstream if extended range is desired (due to the curvature of the earth, the line-of-sight of a ground facility to an airborne RPV at 50,000 feet is only about 200 nautical miles). For the Compass Cope operation, an additional vehicle will sometimes be used solely as a communication relay. Because of this possible relay requirement, the data links may be subject to failure or interruption between any of three points: the RPV, the ground facility, or the relay.

Communications between the control facility and the RPV will probably be accomplished through the following three data links: the command link, the telemetry link, and the video link. The command link, as the name implies, is used to transmit commands to the vehicle in order to control its actions. It is a narrow bandwidth, uplink signal that is not particularly susceptible to jamming. The telemetry link, a narrow bandwidth downlink signal, communicates the status of the RPV to the operator. The video link is also a downlink signal, but it utilizes a wide bandwidth which is somewhat more susceptible to jamming. This link transmits video information from on-board sensors to the remote operators.

Aerospace Medical Research Laboratory has incorporated command link jamming into the enroute portion of their RPV simulations (Ref 63:19-7). For RPV Simultion II, it was assumed that jammers were placed every 2.5 miles across a designated area on a line 185 miles long. When a RPV was positioned immediately above a jammer, the probability of getting jammed was usually quite high. These probabilities varied from mission to mission, sometimes being as high as .99. If the command did not get through the first time, however, the ground based computer would automatically cause the command to be rebroadcast every second until it did get through.

If future RPVs have a "weak" communications link, higher operator skills will be required to discriminate different kinds of disturbance in terms of their causes. During crucial phases of the mission, it will be more difficult to protect the up-link command channel from jamming if the RPV is operating in close proximity to enemy jammers. As a result, the operator's control of a vehicle could be disrupted and he would have to discern the degree of this degradation in terms of the disparity between his commands and the feedback he receives (Ref 28:16). Inconsistencies in the flight data readings could be caused by telemetry jamming. For example, if the indicated RPV airspeed suddenly dropped off sharply but the altitude indicator remained constant, telemetry jamming may have occureed. The video link with its wide bandwidth could be very susceptible to jamming. In many ways it is like a home TV signal, which reacts erratically even to small electrical appliance operation. The ultimate in hostile electronic countermeasures (ECM) would be deception jamming, whereby control would actually be taken over by an enemy station.

Such "weak" communication links are not envisioned for future RPV operations. While it is impossible to make such a communication system completely jam-proof, the system can be designed so that it would be too expensive and troublesome for an enemy to attempt such actions (Ref 61: 6). The highly directional nature of these data links make enemy jamming very difficult. A recently completed study by Hughes Aircraft concluded that the RPV jamming threat can be defeated on all links by using the spread spectrum scheme (and associated waveforms), multi-plexing, and error coding (already incorporated in developed hardware), combined with directional antennas and video image processing (Ref 25:10). It is, therefore, postulated that future RPV communications links will be sufficiently protected to negate any strong operator requirement for an electronic warfare background.

Simulation Findings. Aerospace Medical Research Laboratory's RPV System simulations provided the framework to support the analysis of the enroute phase. Therefore, a review of their findings will provide some additional insights. The general objectives of Aerospace Medical Research Laboratory's RPV System Simulation Study II were to perform RPV system design evaluation studies, assess RPV system effectiveness, provide man-machine/environment interface engineering data, and test new technology (Ref 33:1). Some of the specific objectives were as follows: achieve a criterion of ± 1000 feet average cross track (lateral error) enroute for reconnaissance and electronic warfare missions and a criterion of ± 250 feet average cross track error for strike missions; evaluate the effects of several systems parameters, such as the number of RPVs under simulated control, position reporting range error, and position reporting azimuth error (Ref 33:11-13).

The simulation was based on a generalized mission scenario involving vehicle round trip of approximately 400 nautical miles. Launch and recovery phases were assumed to be outside the simulation, as well as the mission planning subsystem. Each RPV was designated one of three mission types: reconnaissance, electronics warfare, or weapons delivery (weapons delivery RPVs were handed off to a terminal operator who performed a very brief simulated TV strike along a 2.4 nautical mile segment of the route).

While the simulation scenario was not exactly a Compass Cope type mission, the equipment used, tasks accomplished, and operator requirements could be very similar, especially for the Recce/EW RPVs. Enroute/return operators were required to perform the following general tasks:

1. Monitor and update RPV position based on minimizing overall lateral deviation.

2. Coordinate all RPV arrivals to the target and recovery areas.

3. Time-phase each strike RPV such that it achieved its assigned flight plan time of arrival to designated decision points.

4. Time-phase RPV recoveries such that all RPV return intervals are as near to 15 seconds as possible and strike RPVs achieve their planned return times.

5. Coordinate hand-backs with other operators.

6. Respond to RPV failure.

7. Manage fuel.

8. Reprogram RPVs (Ref 33:10).

Operator teams for the simulation were obtained from the universities in the Dayton, Ohio area. The students chosen were required to be undergraduates with at least a "B" average. They underwent initial training over a period of six months (approximately two hours a day); then they completed a four month baseline study prior to Simulation Study II.

The results of Simulation Study II were significant in many respects. The study concluded that effective control and time-phasing of multiple RPVs could be accomplished with a digital flight control design. This system, using relatively naive operators, was capable of highly accurate control of RPV arrival times, time-phasing, strike cross-track error (which was near a criterion of ± 250 feet), and electronic warfare and reconnaissance cross-track error (which was within a criterion of ± 1000 feet (Ref 33:21)). Enroute operators could adequately manage 3 to 4 RPVs each, but in no case could operators effectively handle 6 RPVs each and still maintain cross-track error within ± 1000 feet (Ref 33:22). There was also an indication that the system could sustain substantial outages (simulated jamming) of the command and status links and still recover from the loss of communications.

## Summary

While this analysis of future RPV enroute operations was certainly not an all inclusive one, three key areas were examined in some detail as they relate to enroute operator requirements: future remote control system design, future navigational systems, and future communications capacity. If the control system design follows the digital flight director approach, few pilot skills will be necessary for enroute operators. As navigational systems become multi-modal and more accurate, few navigational skills will be required. Also, since communication links being developed are exceedingly difficult to jam, the operator requirement for an extensive background in electronic warfare is diminished.

While it is recognized that the pressures of "real world" operations can not be simulated entirely in the laboratory, simulation studies have shown that relatively inexperienced operators can perform enroute operator tasks. From a ground based station using a digital flight control system, there will be little need to use rated officers as the enroute operators.

Take-off/Landing Operations

In examining future RPV take-off and landing operations, emphasis will be placed on the use of the wheeled type landing gear, which is planned for the Compass Cope RPV. Other launch/recovery systems are also envisioned for future RPVs. For example, a technical report prepared by Hughes Aircraft Company recommended rocket-assisted take-off (RATO) and steerable chute for high rate strike RPV launch and recovery (Ref 25:63). In a study conducted for the Navy by McDonnell Aircraft Company, various RPV launch and recovery methods were evaluated, such as the air cushion landing system (ACLS), skid landing system, rail launch, air launch, parachute airborne recovery, parachute ground recovery, and mattress landing (Ref 22). By using conventional wheeled landing gear, however, expensive support equipment for ground handling can be avoided. Also, much of the technology gained from the manned aircraft take-off and landing system can be used, as well as many of the developed procedures.

Future operator requirements will be influenced by the degree of automation built into the take-off and landing system, as well as console design. The ability to interpret video imagery will have minimal influence on operator requirements. If a manual take-off and landing system is anticipated, experienced pilots will no doubt be considered for operators. If, on the other hand, the operator role becomes that of a coordinator and safety monitor within a highly redundant automatic system, non-rated personnel can be considered for the task. The following sections will examine and develop these observations in some detail.

Progress in Automatic Flight Control/Landing Guidance Systems

Manual Operations. Traditionally, when remote ground recovery has been accomplished manually, experienced pilots have been used as RPV operators. Modified man-rated aircraft are currently being utilized as target drones, operating in training conditions that are not demanding enough to make automatic landing systems economical. The Air Force has converted such manned aircraft as the F-80, F-86, F-104, and F-102 into target drones. The F-102, designated the PQM-102, is one of the latest conversions. For launch and recovery, the PQM-102 uses two experienced pilots as the remote operators. Their control consoles almost duplicate the original instrument configuration in the F-102 fighter interceptor (Ref 4:12).

National Aeronautics and Space Administration's (NASA) Flight Research Center is experimenting with vehicles which they call RPRVs (remotely piloted research vehicles). The RPRVs differ from the military drone in that the responsibilities and tasks of the operators are the same as if they were sitting in the cockpit on-board the research planes (Ref 9:28). As in manned flight testing, the operators have complete charge of performing data gathering maneuvers, evaluating vehicle and systems performance, and determining options for action in emergencies. Highly qualified test pilots are used as operators. One such experimental vehicle is a 3/8-scale version of the F-15, which was recently recovered manually on skids.

Another application of remote take-off and landing utilized a modified Beech Bonanza which was designated the YQU-22B. In Southeast Asia, this vehicle was used in the signal relay role. The ground control operators were fully qualified pilots. To handle take-offs and landings, they manned an open air control station near the runway. A safety pilot was always on-board the airplane, however, to take control if ground direction was erratic (Ref 49). The aforementioned examples of RPV ground recovery operations have not used fully automatic landing systems. Consequently, experienced pilots have been used as the ground control operators.

Automatic Flight Control Systems. Development and test efforts of the last two decades have culminated in demonstrated capability to land manned aircraft automatically. The first experiments in automatic flight and landing systems, occurring in the late 1920s, were clearly motivated to reduce pilot fatigue. The commercial air lines recognized the operational and economic advantage of being able to take off and land in bad weather. Such commercial aircraft as the Boeing 747, Douglas DC-10, and the Lockheed L-1011 possess flight control systems that have been certified for instrument or automatic approach and when the weather ceiling is down to 0 feet and the runway visual range is as low as 700 feet. This landing condition is called Category IIIA (Ref 35:1).

The first U.S. built transport aircraft to be certified for Category IIIA landing conditions was the Boeing 747 fitted with a triple channel autopilot/flight director system (Ref 2:1303). The system operates as follows: With the receiver tuned to the airport instrument landing system (ILS) frequency, the aircraft pilot switches the autopilot system to the "Land" mode. The aircraft then follows the ILS localizer and glide-slope towards the runway with the automatic throttle adjusting power to maintain the correct airspeed and rate of descent. At 53 feet above the ground, as measured by the radar altimeter, the automatic flare device decreases the rate of descent, and the 747 touches down on the runway in a normal landing. Should it be necessary to discontinue the landing, the autopilots cause the aircraft to climb away from the airport on a pre-set heading.

The D-10 uses a PB-100 automatic flight guidance system developed and produced by Bendix (Ref 17:244). This system employs two automatic landing systems, either of which is capable of controlling the aircraft throughout the landing phase. In the event that a malfunction occurs with both systems engaged, the failed system will disconnect or shut down without disturbing the aircraft's flight path while the remaining system completes the landing without any degradation in performance (Ref 17:245).

The Lockheed L-1011 has an integrated autopilot/flight director system which provides automatic control in all three axes (plus automatic thrust control) from take-off to landing (Ref 18:1416). This system utilizes four autopilots during the landing mode in a fail operative state; that is, the system will detect any failure, isolate the failed equipment, and complete the landing unrestricted by visibility condition through completion of landing roll-out.

Flight tests and simulations were conducted by Air Force Flight Dynamics Laboratory (AFFDL) to determine the suitability of automatic take-off and landing for the Compass Cope RPV. The test vehicle used for this program was the USAF/Calspan Total In-Flight Simulator (TIFS), an extensively modified C-131H. Through the use of special control surfaces, servoed throttle, and specially designed analog computers, the TIFS can simulate the flight characteristics of other aircraft, including winds and turbulences (Ref 67:27).

The automatic flight control system used was a derivative of the previously described Lockheed L-1011 flight control system (Ref 34:1). The characteristics of this system and the Teledyne Ryan Compass Cope aerodynamics were modeled in the TIFS computer. With the exception of braking, aircraft taxi, and power application to take-off, the entire take-off, approach, landing, rollout, and missed approach sequence were automated. The automatic flight control system was designed so that the pitch, roll, yaw, and power control were independent which allowed various control mode combinations for remote and automatic RPV control (Ref 67:9). Pilots on board the C-131 had the ability to take command of the aircraft (overriding the remote operator or automatic system) if flight safety was jeopardized.

Automatic take-off and landing systems are being designed to achieve a better accident risk figure than a human pilot or ground controller (the design goal for future airline systems is an overall risk which is less than 1 in $10^{-7}$) (Ref 2:1305). As automatic systems become more and more reliable, pilot skills for future RPV operators will be de-emphasized.

Landing Guidance Systems. The National Microwave Landing System (NMLS) is being developed for both civil and military aviation for the 1980-1990 time frame. This scanning beam landing system will consist of (1) ground equipment to transmit azimuth (localizer) and elevation (glide slope) signals, and (2) airborne equipment that will receive and decode the signals, which can then be processed in an autopilot coupler. After defining the air vehicle position in spherical coordinates (azimuth angle, elevation angle, and range), the airborne system can determine the vehicle's position from the desired approach path and generate appropriate command signals (Ref 68:10). Compared to the standard International Civil Aviation Organization (ICAO) instrument landing system (ILS), NMLS will provide more accurate guidance signals which are less sensitive to weather, terrain, and other aircraft (Ref 35:8). The National Microwave Landing System promises to provide hardware solutions to the potential needs of civilian and military manned aircraft and is also expected to be the eventual standardized solution to RPV automatic landing requirements (Ref 67:20).

Examples of microwave landing systems that have already been developed or are in the development stage are identified under such trade names as C-SCAN, TILS, TLS, and CO-SCAN. They are in use or being tested by the U.S. Navy (for carrier landings), the Swedish Air Force (for the Saab Viggin fighter), the U.S. Army (for helicopters and fixed wing aircraft), and the Canadian Ministry of Transportation (for short take-off and landing programs). Some of these systems have small, relatively light-weight ground units that can be easily transported to selected sites and made operational in a very short time (Ref 62).

RPV automatic take-off and landing tests conducted by AFFDL incorporated the microwave scanning beam design technique. Test and evaluation of the U.S. Army's Tactical Landing System (TLS) was included in the program. This microwave electronic equipment effectively provided the operator and automatic flight control system the following information: localizer, glide-slope, course and fine range, height information, and signals indicating the validity of the information (Ref 62:22).

Using an automatic flight control system coupled with a microwave landing system, future RPV take-offs and landings could some day become a routine task, with the operator assuming the role as systems' monitor and flight coordinator.

The Remote Operator's Role Within an Automatic Landing System. The anticipated world-wide deployment, the unreliability of long range weather forecasts, and the problems encountered in manual runway recovery support the need to include automatic take-off/landing capability for the Compass Cope Vehicle (Ref 35:10). A requirements study conducted by Air Force Flight Dynamics Laboratory detailed the weather conditions and effects that could be encountered in Cope's four prime operating zones (the United States, Southeast Asia, the Middle East, and Europe). After evaluating the effects of fog, rain, wind, dust, snow and thunderstorms, the study concluded that the primary operating mode of the RPV must not be dependent upon having visual contact with the ground (Ref 35:48).

Probably the most compelling reason for using an automatic take-off and landing system is operational safety and reliability. RPV operations represent a potential risk to civilian populations, ground personnel, and crews of manned aircraft operating in the same airspace. Commanders may be very reluctant to accept RPV operations of this nature at their base, particularly when mixed with prime mission aircraft such as the B-1 bomber. By utilizing a highly automated take-off and landing system, safe and reliable operations can be consistently demonstrated. In turn, less pilot control skill will be required by the operator, who will assume the role of coordinator and safety monitor within a highly automated system.

Using an automatic take-off and landing system, the primary responsibility of the ground control operator will be to insure safety of the overall system operation. In addition, his functional requirements will include system initialization, system and flight path monitoring, and back-up manual control (Ref 35:iii). Appropriate coordination will be necessary for take-off and landing initialization. Depending on weather conditions, air traffic, take-off schedules, and other factors, the operator's initialization tasks will include establishment of runway headings, approach and departure path, and RPV altitude.

After initialization of the take-off and landing sequence, all subsequent operations could be performed automatically. The remote operator's role would then be to monitor ground and on-board systems and vehicle flight path, initiating corrective action or manual control if required. System and flight path monitoring is considered necessary to provide the operator with an assessment of overall system performance to assure consistent and safe operations (Ref 35:112).

As systems monitor, the remote operator would have to be aware of the status of the ground systems, flight control system, and communication links, as well as the vehicle engine, fuel, hydraulics, and other sub-systems. A well organized cathode ray tube (CRT) display, augmented with audio or flashing visual signals, could warn the operator of impending failures and provide corrective actions.

With flight path monitoring, the remote operator could determine whether the automatic take-off and landing system is making the proper corrections. Conventional instrumentation could be augmented with a CRT displaying vehicle horizontal and vertical situation relative to the ground and selected flight path. The CRT display, presenting position and trend information in the form of velocity vectors, would aid in monitoring automatic flight control system performance.

Failure or improper operation of the automatic take-off and landing system will require manual operator intervention. This is the most critical task in terms of operator requirements. The control display system should be designed as an integral part of the overall automatic system with independent failure of pitch, roll, yaw, and power control allowing various manual control mode combinations. The operator will have to be prepared to assume manual control of the take-off and landing maneuvers. One back-up control approach would be to duplicate an aircraft cockpit and use a highly trained pilot to maneuver the vehicle in case of automatic failure. Another approach would be to specially train non-rated personnel to control the RPV and determine control-display requirements through an extensive simulation program (Ref 35:112).

Other Considerations

Console Design. Like the enroute phase, the personnel qualification requirements for the take-off and landing phase will be significantly influenced by the ground console design, as well as the degree of automation. A design based on pilot capabilities will be more difficult to operate by non-rated personnel. Initially, it was conceptualized that the Compass Cope Vehicle would employ a totally automatic take-off and landing system, with no manual intervention. Later, it was determined that some manual back-up was necessary to provide an additional degree of flexibility and enhance operational acceptability. With a totally automatic system, the operator would not be able to exercise judgement or handle unanticipated events.

Boeing and Teledyne Ryan, the two prototype contractors for Compass Cope, have been testing different console designs for their take-off and landing systems. The Teledyne Ryan version places strong emphasis on automation with little pure cockpit design. The system is currently being tested at Cape Canaveral, Florida, using experienced pilots as safety monitors and back-up controllers in case of automatic failure.

The runway control station for Boeing's version of Compass Cope is designed on the basis of airborne cockpit technology and instrumentation. The design provides for simultaneous proportional commands via stick, rudder pedal, throttle, rudder trim and toe brake inputs. Although Boeing's system is also designed for automatic take-off and landing, the control system design favors pilot qualifications.

Flight tests and simulations conducted by Air Force Flight Dynamics Laboratory, which were mentioned earlier, employed a two place control/display console designed to be operated by a single person (the additional position was included for an instructor/monitor). Adequate reach and vision envelopes were maintained through the use of a wrap-around design, consisting of five display panels, two control surfaces, and writing areas. To a great extent, this instrument panel and flight control stick also resembled conventional cockpit instrumentation and control (see Appendix M).

A specific console design has not yet been chosen for Compass Cope, but there is little doubt that it will influence the operator qualification requirements.

TV Imagery. RPV studies conducted for the Navy by Decision Science, Inc. considered the operator requirements for video weapons release as similar to those of an operator landing a RPV using a video presentation. In establishing the initial criteria for these studies, the following observation was made:

> "It is reasonable to expect that if the crucial maneuver phase of a strike RPV can be properly executed, this might have an important bearing on the display and control requirements for landing, in principle, at least. Weapons delivery or approach for damage assessment is similar to final approach to a runway (Ref 28:14).

Attention has been given to using remote TV for positioning strike RPVs over designated targets for weapons release. In this RPV role, an operator would have to be highly trained in real-time target discrimination and weapons disposition. RPV altitude and airspeed would have a direct bearing on the operator's ability to accomplish the task. Low altitude and high airspeed, desirable flight characteristics to avoid enemy detection, would decrease the operator's field of view and interpretation time. Because of the difficulty of this task, it is questionable whether TV weapons release will ever be carried out operationally by Air Force RPVs (it might be added, however, that early in the 20th century the manned aircraft itself was viewed as an observation device with only limited weapons delivery capability).

It is envisioned that TV imagery will provide real-time reconnaissance and damage assessment information to the remote control site. It is doubtful, however, whether the RPV operator will act as real-time interpreter of the TV imagery while performing his other duties. This discriminating task will probably be left up to a specialist. According to a study conducted by the Air Force Avionics Laboratory, the combination of multiple sensor displays and real-time operations would impose heavy workload demands on the operator who would have to find, identify, and communicate reconnaissance information in parallel with the rate of sensor inputs (Ref 30:iii).

At the Navy Weapons Center at China Lake, California, target drone take-off and landing operations are conducted by remote TV. However, only one operator, a highly skilled civilian pilot, is qualified to handle this difficult take-off and landing task. From a TV control station inside a van, converted T-38s are launched and recovered with no autopilot except automatic airspeed (Ref 45).

Simulations conducted by Air Force Human Resources Laboratory (AFHRL) at Wright-Patterson Air Force Base evaluated RPV operator performance using TV imagery. The operator task involved tracking ground targets and maintaining fixed horizon and heading on a visual display. The emphasis of this study was on airborne control where conflicting motion cues could result in operator conflict; therefore, its application to this analysis is limited. It is only mentioned here because of the specific subject groups that were compared: rated pilots, rated navigators and non-rated officers. Final results have not yet been completed (Ref 66).

The ability to read and interpret TV imagery will be a necessary skill for future RPV operators, but it appears that its importance has been over-emphasized. If RPVs are to exist in a dense, mixed aircraft environment (such as the traffic pattern), certainly see and avoid capability will be needed to reduce hazards to other air traffic. The remote operator's eyes can be extended to identify conflicting traffic by placing TV cameras in the nose of the air vehicle. This operator identification task will not involve extensive imagery interpretation.

RPVs without see and avoid capability come under rigid Federal Aviation Association (FAA) regulations. Effective 1 July 1975, FAA Handbook 7610.4C requires that RPVs without this capability must be accompanied by a chase plane when operating outside positive control airspace, restricted areas, or warning areas. The chase plane is responsible for relaying potential conflicts to the controlling source and provide changes of headings and altitude to resolve any traffic conflict.

Air Force Flight Dynamics Laboratory's (AFFDL) automatic take-off and landing tests evaluated the useability of an on-board television system as an aid in RPV launch and recovery. It was found that the operators (who were all rated personnel) had very little eye contact with the television, concentrating primarily on the instrument displays until after touchdown. The TV was useful only as a last minute confidence check prior to landing and as an aid in RPV taxi maneuvers (rather than using the TV for taxi purposes, consideration could be given to towing the vehicle into the take-off position and parking area).

Video interpretation will not be a major requirement for future RPV operators. TV will be used primarily to provide landing confidence checks and identify conflicting traffic.

Simulation Findings. Simulations conducted by AFFDL and AFAMRL provided the framework to support the analysis of the take-off/landing phase.

Therefore, a review of some of the tentative findings will provide some additional insights.

Flight tests and simulations conducted by AFFDL evaluated the remote operator's ability to establish initial conditions for the automatic take-off and landing, to monitor the automatic system and vehicle performance, and to exercise remote control in the event of automatic system failure. The test subjects were obtained from the potential user commands. They were all Air Force officers, ranging in rank from captain to lieutenant colonel. With the exception of one electronic warfare officer with civilian pilot experience, all subjects were qualified military pilots.

The automatic take-off system was tested in ground simulation prior to the flight tests. After a short system break-in period, the operator tasks became almost routine (Ref 47).

During the test flights, operators had to cope with simulated adverse weather such as limited visibility and cross-winds. Also, automatic landing system failures were introduced which required operator detection and manual intervention. The operator would monitor the automatic system and approach performance and assume control when a programmed failure occurred. It was determined that simulataneous manual control of pitch, roll, and yaw during landing was a very difficult task, even for experienced pilots. When a triple axis failure occurred, very intensive activity was required during the final moments of the landing. Tentative results indicate that operators experiencing a failure of this nature were successful in manual landing only about 50% of the time. Operators incurred a much higher success rate when experiencing single and dual axis failures (Ref 48). It appears that the landing phase is more appropriately a two man task when manual back-up is required.

Quantitative data from these simulations and flight tests have not yet been published, but the results will no doubt have a strong impact on future operator requirements.

A parallel simulation was conducted by Air Force Aerospace Medical Research Laboratory (AFAMRL). This simulation examined operator performance following failure of a RPV automatic landing system on a baseline console with two axis control (pitch and roll). Four control-display configurations were used to evaluate the two basic control modes: pitch attitude and flight path angle.

Ten subjects were initially tested. The group included six naive subjects (students from a nearby university), two KC-135 pilots, and two engineers with extensive civilian pilot experience. Training was conducted until the subjects reached a criterion of six successful instrument landings under each of four display-control configurations. The training periods ran thirty minutes a day, five days a week. The six students required between two and two and one-half months to complete the training while the two Air Force pilots and two engineers required only about six days. Once the minimum criteria were met, however, all subjects obtained about the same performance level in the experimental phase (Ref 42).

The operator tasks were not as comprehensive as the tasks accomplished by the subjects in the Flight Dynamics Laboratory tests. Nonetheless, it appears that naive subjects can be trained to perform some manual landing tasks. The results of this simulation, which have not yet been fully analyzed, should also have some bearing on future operator criteria.

Summary

Future take-off and landing operator requirements will be influenced by the degree of manual control utilized, as well as console design, with very little emphasis on video interpretation. A review of some of the manual take-off and landing operations revealed that only qualified pilots were being used as operators (on pilot type consoles). However, advances in flight control systems and microwave landing systems make RPV automatic take-off and landing a viable option. This is especially true for the Compass Cope RPV, which will require an all weather capability.

Within an automated take-off and landing system, the primary responsibility of the operator will be to insure safety of the overall system operation. His functional role will be primarily systems oriented (i.e., system initializer, systems and flight path monitor), but the critical task of back-up manual controller could require extensive pilot background if control systems and displays follow conventional cockpit design. His ability to interpret video displays will not be a major requirement, however.

Simulations conducted by AFAMRL indicate that after extensive training, naive subjects can exercise effective back-up control after automatic system failure. Flight tests conducted by AFFDL, however, indicate that manual back-up is a difficult task even for experienced pilots.

The evaluation of the impact of advancing technology on future RPV operator criteria suggests a movement away from specialized requirements such as navigation, pilot and electronic warfare skills. Emerging as an important requirement for future operators is the ability to understand and operate integrated systems. In order to enlarge this evaluation,

a composite nucleus of knowledge opinion was gathered on future operator criteria. The subsequent chapter presents an analysis of this subject data.

# IV. Operator Selection Criteria

## The Interview Group

Through a structured, systematic interview approach, a comprehensive nucleus of knowledgeable opinion was analyzed to assist in establishing baseline RPV operator criteria. An array of open-ended and closed-formed questions were directed to a select interview group consisting primarily of three major sub-groups: Air Force RPV operators from the two operational squadrons at Davis-Monthan AFB; engineers and managers from the Air Force RPV System Program Office at Wright-Patterson AFB; and psychologists and engineers directing RPV simulations at the Air Force Laboratories at Wright-Patterson AFB.

The qualifications of the people responding were impressive. Over 73% of the group had two or more years of RPV experience, with over 23% having more than 6 years experience (nearly 10% of the group had over ten years of RPV experience). Over 40% of the people responding were formally educated beyond the single bachelor degree level.

Of the fifty-two people actively participating, 22 were non-rated personnel. The remaining 30 rated personnel consisted of 21 navigators and 9 pilots. Within the three major sub-groups, 22 inputs came from the operational units at Davis-Monthan AFB, 16 inputs came from the Systems Program Office, and 10 inputs came from the Air Force Labs (a complete summary of demographic data is listed in Appendix C).

## The Interview Questions

Over 50 people actively participated in the interview by completing an interview form containing key questions regarding future RPV operator criteria. Open-ended questions were asked initially to stimulate thought and establish a broad perspective of future operator criteria. At the end of the interview form, a check-off selection sheet was provided to aid the interviewee in crystallizing his thought patterns. The respondents were asked to indicate preferences for different categories of operators (i.e., officer/enlisted, rated/non-rated, engineer/non-engineer) for both the enroute phase and the launch/recovery phase of the RPV mission profile. In addition, if "officer" was selected, the interviewee could further indicate a rank preference. If "rated" was selected, a more specific grouping within the rated field could be indicated. The respondents were also encouraged to add any additional comments or preferences in this section (the interview form is displayed in Appendix D). A summary analysis of the respondents' opinions follows.

<u>Open-ended Response Analysis</u>

As mentioned previously, open-ended questions were asked initially to gain a broad perspective of future operator criteria. The initial question was very general, asking the interviewee to explain the kind of background that would be best suited for future RPV operators. Reactions to the questions were mixed. Several respondents felt that operator criteria would be dependent on the type of mission, with the rated pilot favored for the strike profile. Such hard to define traits as quick reactions, cool headedness, good hand/eye coordination, visual perception, desire, willingness to accept responsibility and sound judgement were mentioned as desirable. Several respondents suggested placement tests to single out RPV operators. One respondent suggested that the size of the operations would strongly influence operator selection criteria, with a large force warranting a special training program, such as the program used to train pilots and navigators. Many of the respondents listed control/display design as a key influence of operator criteria.

The subsequent open-ended questions referred to a mission profile such as envisioned by Compass Cope, with one question dealing with how the operator crew positions should be divided. About one half of the group favored some form of mission phase division, such as a take-off/landing phase and an enroute phase. The advantages of specialization were cited as reasons for such divisions. Most of the remaining group preferred an operator/monitor, operator/assistant, or single operator approach. Those favoring an operator/monitor approach suggested an enlisted person in a passive role as monitor. Those favoring the operator/assistant approach suggested a junior operator in an upgrading status as the assistant. Tactical Air Command's respondents appeared to overwhelmingly favor the one operator approach.

When asked to choose one category of person to handle the total operation (i.e., launch, enroute, recovery), over half of the respondents listed some category of rated officer, with pilot mentioned most frequently.

The final open-ended question asked the respondents to assume that RPVs become highly automated and sophisticated, and then express an opinion on whether RPV operations would require greater skill or less skill on the part of the operators. Over half of the group felt unequivocally that greater skill would be required. Others expressed the opinion that the type of skills would simply shift, with increased emphasis on systems' understanding and technical skill and decreased emphasis on motor and piloting skills.

## Closed Form Response Analysis

Enroute Phase. For the enroute phase of the RPV mission, 60% of the interview group specifically indicated a preference for using an officer as the RPV operator (73% of the rated personnel and 40% of the non-rated personnel indicated this preference). Less than 6% of the group specifically indicated an enlisted person for this job. Most respondents indicated no preference when offered a choice of rank between lieutenant and captain or captain and major, with no respondent specifically choosing a major.

Less than half (45%) of the group indicated that the enroute operator should be a rated person (60% of the rated personnel and 24% of the non-rated personnel indicated this preference). When asked to specify a rated category, most respondents indicated no preference, and when asked to evaluate flying hours desirable, those responding were about equally split between under 1000 and over 1000 hours.

Twenty-five percent of those responding specified an engineering background as desirable (22% of the rated personnel and 29% of the non-rated personnel stated this preference).

Of some general interest also was the differences in the responses of the three sub-groups; Operations, System Program Office, and the Laboratories. The people responding from Operations and the System Program Office were strongly in favor of an officer for the enroute phase (73% and 62%, respectively), while only 20% of the people responding from the Labs made this preference. With regard to using a rated operator for the enroute phase, only the Operations people favored this category (68%). Thirty-one percent of the System Program Office people and 11% of the Lab people specified a rated person. No major sub-group indicated a preference for an engineering background (13% of the Operations personnel, 25% of the System Program Office personnel and 33% of the Lab personnel) (Appendix F contains a more extensive break-out of the enroute phase response analysis).

Launch/Recovery Phase. For the launch/recovery phase of the RPV mission, 79% of the group indicated that an officer should assume the role as operator (87% of rated personnel and 68% of the non-rated personnel indicated this preference). Less than 2% specifically indicated an enlisted person for this job. Again, not one respondent specifically indicated that a major should be selected, with most of the group indicating no preference between lieutenant and captain or captain and major.

Over half (55%) of the group indicated that the launch/recovery operator should be a rated person (70% of the rated personnel and 33% of the non-rated personnel indicated this preference). Less than 12% specifically indicated a non-rated person for this job. Most respondents indicated no preference when asked to specify a rated category; however, when a category was specified, a pilot was most frequently mentioned. When asked to evaluate the flying hours desirable, those responding were again about equally split between over 1000 and under 1000 hours.

Thirty-four percent of those responding specified an engineering background as desirable (26% of the rated personnel and 43% of the non-rated personnel stated this preference).

Some controversy of opinion was revealed when the three sub-groups were compared. While the three sub-groups favored using an officer for the RPV take-off and landing phase (82% of the Operations personnel, 86% of the System Program Office personnel, and 60% of the Laboratory personnel), only the Operations people overwhelmingly preferred a rated person (73%). Of the respondents, 44% from the System Program Office and 33% from the Labs preferred a rated operator. Again, no sub-group indicated a preference for an engineering background (33% of the Operations people, 38% of the System Program Office people, and 44% of the Lab people)(Appendix F contains a more complete break-out of the launch/recovery response analysis).

Summary

While no attempt was m... to establish statistical significance from the opinions rendered, an exhaustive attempt was made to interview a relatively large, highly diversified group. The nucleus of the information gathered from an experienced RPV community should not be ignored. Planners could look at the opinions of the various sub-groups to consider with other technical information developed earlier. From the analyzed data in total, the following baseline operator criteria was derived:

ENROUTE PHASE

officer (junior grade)
rated or non-rated
engineering background--not significant factor

LAUNCH/RECOVERY PHASE

officer (junior grade)
ra..d
engineering background--not significant factor

The analysis of subjective opinion, as well as the evaluation of advancing technology, indicate that it is feasible to use non-rated personnel for some if not all future RPV operator positions. The desirability of using such people, however, will be dependent (to a great extent) on differential operator costs, which are investigated in the following chapter.

# V. Differential Operator Costs

Remotely piloted vehicles could become a significant force in our future Air Force inventory, but their long term viability will hinge on demonstrated cost advantages over manned aircraft. According to Col Ward H. Hemenway, RPV System Program Office Commander, "the high cost item in systems acquisition and operation is manpower."

Although it might well be desirable to use only rated officers as RPV controllers, it should be recognized that such people are expensive assets. They have been trained for other flying assignments. It is, therefore, well to question whether other personnel might perform adequately if provided with appropriate displays and controls pertinent to their background and capacity. Some compromise in mission performance might even be justified if the savings are great enough.

## The Consideration of Sunk Costs

Why not use qualified rated officers! Isn't there an excess of these people available in the Air Force? At the present time, there is a temporary overage of rated officers, but this excess should not exist by 1980 (Ref 57). Some of these flying officers are being used in the rated supplement program. This is a stockpiling concept where rated officers are assigned to non-rated duties with the understanding that they will return to the flying ranks in the event of a contingency. Supplement jobs do not specify rated officer requirements; therefore, the flight training schools do not have to intentionally produce rated officers for these positions. On the other hand, if a flying Air Force Specialty Code (AFSC) is identified with particular jobs (such as RPV operators), flight training schools incur an obligation to train personnel to fill these slots and consequently the cost of this training would bear directly upon the operation. In the short run, of course, if "excess" rated personnel are used as operators, the cost of initial flight training can be considered a sunk cost (i.e., a past cost that is unavoidable because it cannot be changed no matter what action is taken). If, however, RPV operations can be considered a viable, long term concept, reliance on temporary excesses in the rated ranks to fill operator assignments is not feasible.

If it is assumed that rated skills are needed for future RPV operators, an alternative would be to use flying personnel who have been indefinitely disqualified from flying for medical reasons (Category 03 status). This, of course, would be contingent upon some minimum medical fitness being attainable. Many of the grounded officers could have such medical problems as ear blockage at high altitude or back problems that occur when strapped into an ejection seat. In relation to ground RPV operations, these problems are irrelevant. According to the Flight Status Branch at Randolph AFB, there are 882 pilots and 689 navigators in Category 03 status (Ref 51). Through the years these figures have been fairly stable. Previous operator training can be considered a sunk cost if this resource pool is used for future operators. Of course, a thorough investigation of this resource pool would have to be undertaken before any decisions could be made.

Differential Costs and Assumptions

Rated Operators. The differential costs (costs that are different) of using various categories of operators should be recognized. The life cycle cost (LCC) impact of using rated officers instead of non-rated officers could be significant, especially if large force levels are envisioned.

Possibly the most relevant and identifiable costs associated with using rated officers are initial flight training costs and aviation incentive payments. Flight training costs for rated officers, as determined by Headquarters, Air Training Command (based on fiscal year 1975 estimates) are listed in Table I.

TABLE I

Flight Training Costs

| | |
|---|---|
| Pilot | $176,000 |
| Navigator | 55,098 |
| Electronic Warfare Officer | 78,927 |

These dollar figures are average costs per student to complete initial flight training based on 1800 pilot graduates, 800 navigator graduates and 160 electronic warfare officer graduates (Ref 46). The electronic warfare officer costs include basic navigation training.

Of course, training more or less people than a standard number would have some impact on the average cost per student; that is, training fifty fewer pilots may not result in exactly 50 times $176,000 in savings. Therefore, only variable costs within a relevant range of trainees will be used for comparison. Table II contains estimates of variable training costs provided by Headquarters, Air Training Command:

TABLE II

Variable Training Costs

| | |
|---|---|
| Pilot | $106,000 |
| Navigator | 39,000 |
| Electronic Warfare Officer | 50,000 (includes variable navigation training) |

In the long run, these training costs are relevant if fully qualified rated officers are identified for RPV operator duties. While it might be argued that the rated pool could be increased bv exerting extensive controls on the outflow of pilots and navigators (through retirement delays, resignation denials, etc.), major policy changes of this nature are generally reserved for wartime emergencies.

If, for example, the future Compass Cope operations identified the need for fifty pilots as RPV operators, the flight training programs would have to increase their output to support this operation. This would amount to a one time increase in the rated pool, which could then restabilize. At some point in time, however, the outflow from this (enlarged) pool would also increase somewhat (due to additional retirements, resignations, etc.). Therefore, the rated pool itself would experience some decay through the years (which would require additional replenishment). No attempt will be made to include any downstream flight training costs in the comparisons, but an example of the possible impact of this additional cost is exhibited in Appendix H.

Aviation incentive payments are another key differential cost (entitlement status for these payments is described in Air Force Regulation

60-1). The flight incentive pay per year, based on years of service, is listed in Table III.

TABLE III

Flight Incentive Pay

| Years in Service | Incentive pay/year |
|---|---|
| under 2 | $1200 |
| over 2 | 1500 |
| over 3 | 1800 |
| over 4 | 1980 |
| over 6 | 2940 |

Since the life cycle of the Compass Cope Operation is projected to be ten years (Ref 32:9-6), the application of a 10% discount rate (to these incentive payments) will be included in the cost comparisons to reflect the time value of money. A 10% rate is considered to be the most representative overall rate at the present time (Ref 55:10). The annual present value tables contained in Air Force Regulation 178-1 will be utilized in the operator cost comparisons (the use of monthly tables would have the effect of increasing rated costs somewhat).

Other costs associated with using rated officers are not as well defined but are noteworthy nonetheless. For example, the cost of providing support aircraft for flying proficiency could be considered (support aircraft are currently provided for pilot operators), but future RPV duties will most likely not require any active participation in flying. Maintaining flight records and providing special medical support (i.e., flight surgeons, etc.) are additional costs that are incurred in completing secondary aviation requirements, such as basic survival and water survival programs. For the purposes of this analysis, however, only basic flight training costs and aviation incentive payments will be explicitly identified as additional costs of rated operators.

Non-Rated Operators. Any additional cost that would be incurred in training non-rated operators is not well defined. Due to the high degree of automation and control/display design envisioned, one contractor planning group believes that there would be little, if any, difference in training costs between rated and non-rated officers. Another point of view is that flight training background will enable the rated officer to become operator qualified much faster (and at less cost) than the non-rated officer (a significant transfer of learning could be a valid assumption, especially if the operator role becomes highly active during an automatic landing system failure).

If additional RPV training is necessary to qualify non-rated officers, the amount and cost of such training is highly speculative. RPV training simulations on hand at AFAMRL could be used to develop qualitative data in this area. However, for purposes of estimating non-rated training costs, suppose the baseline criteria for training rated officers is three months at a cost of $15,000 per operator (estimate developed after conferences with contracting planning groups and review of existing costs of such programs as Titan II missile operator training, navigator bombardier training, etc.). Hypothetically, if the training cost doubled for non-rated officers to become qualified RPV operators (using the aforementioned estimates), the differential cost for maintaining non-rated operators (over a ten year life cycle) can be estimated (refer to Appendix G for computations). It will be assumed that there is no difference in training times to reach a specified level of proficiency for the various rated categories.

## Operator Cost Comparisons

Differential operator cost comparisons can be illustrated using fiscal year 1975 estimates of flight training variable costs and aviation incentive payments. Junior officers (rated and non-rated) with service time of six years appear to be a representative group for comparison. Differential costs will be determined with aviation pay discounted, using force levels of twenty-five (FL-25) and fifty (FL-50) operators. Since aviation incentive pay is the same between rated groups of equal service time, only the variable flight training costs will be used to differentiate the various rated categories (cost comparisons of operators of different rank could be of some significance but will not be dealt with in this analysis). Assumptions stated earlier will apply to these differential comparisons, which are intended only to help illuminate any significant cost differences (refer to Table IV).

The operator cost comparison tables provide decision-makers another aid in determining entry RPV operator criteria. Considering force levels of fifty operators, manpower savings with a present value of over four million dollars can be realized by using non-rated officers instead of pilots. When all operator groups are compared, there appears to be a clear cost advantage in using both non-rated officers and Category 03 personnel (whose initial flight training can be regarded as a sunk cost).

TABLE IV

Differential Operator Costs - 10 Year Life Cycle
(FY 75 Dollars)

| | Pilot | EWO | Navigator | Non-Rated | Category (03) |
|---|---|---|---|---|---|
| 1. Aviation incentive payment/year | 2,940 | 2,940 | 2,940 | - | - |
| 2. Discount factor (10 yr/10%) | 6.447 | 6.447 | 6.447 | - | - |
| 3. Total incentive payments (1x2) | 18,954 | 18,954 | 18,954 | - | - |
| 4. Variable flight training costs | 106,000 | 50,000 | 39,000 | - | Sunk cost |
| 5. Cost Differential/operator (3&4) | 124,954 | 68,954 | 57,954 | - | - |
| 6. Total Cost Differential (FL-25) | 3,123,850 | 1,723,850 | 1,448,850 | * 868,125 | 0 |
| 7. Total Cost Differential (FL-50) | 6,247,700 | 3,447,700 | 2,897,700 | *1,736,250 | 0 |

*Estimated cost of additional training
(see Appendix G for computations)

## Summary

Rated officers are expensive resources. It is appropriate to consider whether non-rated officers might perform adequately as ground RPV operators if provided with appropriate displays and controls. If rated officers are identified for RPV operator jobs, however, flight training schools incur an obligation to train personnel to fill these slots.

Consequently, the cost of this training should bear directly upon the RPV operation (one means of by-passing this cost, however, is to use Category 03 personnel). Aviation incentive payments are another differential cost associated with using rated personnel.

Additional costs incurred in training non-rated personnel are not well defined and, in fact, may not exist (it would no doubt be beneficial to examine this area through training simulations). One contractor planning group estimated that it may require a much longer time to train non-rated officers, while another planning group indicated that there would be no significant difference in training rated and non-rated operators. Even if initial training costs are $15,000 more for non-rated officers, a significant cost advantage is still evident over rated groups. When differential operator costs are weighed, it becomes very desirable to consider non-rated officers as future RPV operators.

# VI. Conclusions and Recommendations

The primary objective of this research was to examine criteria for Air Force RPV operators to determine both the feasibility and desirability of using other than rated officers as future RPV operators. The research methodology involved an analytical approach in which several sub-objectives were established. Past and present RPV operator criteria were identified initially, followed by an evaluation of the impact of advancing technology on future operator requirements. In order to broaden this evaluation, a nucleus of knowledgeable opinion on future operator criteria was gathered and analyzed. As a final element of this investigation, differential operator costs were estimated. Although special emphasis was placed on the future Compass Cope operation, the analysis was intended to have application to other RPV operations as well.

## Conclusions

1. An examination of past and present operator criteria indicates that there are valid reasons for using rated officers as current RPV operators. In the initial testing of reconnaissance RPVs (early 1960s), enlisted personnel were used as operators, but, as the vehicles became more sophisticated, electronic warfare officers assumed the role as operators to take advantage of their navigation, electronics, and intelligence background. Later, pilots were trained as recovery operators to take advantage of their exclusive command authority. By law, only pilots could command flying units (prior to December 1974); therefore, it was beneficial to have pilot operators (to act in the dual capacity as site commanders). Since rated officers have prior experience working

in an airborne environment (and current operators are not ground based), rated expertise is a desirable operator requirement. Some background in electronics is also necessary. In addition, since the current mission planning phase is a manual operator task, it is essential that RPV operators have a navigational background.

2. An analysis of emerging technology indicates that rated skills will not be necessary for future enroute operators, but a pilot background may be desirable for the take-off and landing phase. Future operators will not need extensive navigator training to support mission planning efforts. Computer aided planning and computer optimization appears to be the most effective means of handling future mission planning operations. The complex task of translating mission direction into detailed individual flight plans for high performances, multiple RPVs will be assigned to a mission planning specialist, with the operator removed from the task entirely.

Operator requirements for the enroute phase are dependent upon three key factors: remote control system design, navigation capability, and communications capacity. Taking advantage of man's remote ground location, control system design can be free from many of the constraints of manned aircraft. Using a digital flight director approach, few pilot skills will be needed by enroute operators. Semi-autonomous operation can be realized by designing RPV avionics with an on-board digital computer. Future navigation systems such as Navstar have such impressive capabilities that operator navigation skills can be reduced significantly. Future communication links will be sufficiently protected to negate any strong need for an electronic warfare background.

Future take-off and landing operator requirements will be influenced by the degree of manual control utilized, as well as console design, with very little emphasis on video interpretation. If a manual approach is anticipated, qualified pilots should be used as operators. However, advances in flight control systems and microwave landing systems make automatic take-off and landing a viable option, especially for the Compass Cope vehicle. Within an automatic take-off and landing system, the primary responsibility of the operator will be to insure safety of the overall operation, with essentially systems oriented functional tasks. Video imagery interpretation will probably be limited to identifying conflicting traffic and providing landing cross-checks. The critical task of manual back-up control (following automatic system failure) may require a pilot background, however, especially if control systems and displays follow conventional cockpit design.

3. Opinion of an experienced RPV community generally confirms the criteria for future RPV operators derived from the analysis of emerging technology. A knowledgeable interview group identified junior officers as the primary resource pool, utilizing either rated or non-rated operators for the enroute phase and rated operators (with pilots most frequently recognized) for the launch and recovery phase.

4. An investigation of differential operator costs indicates that significant savings can be realized by using non-rated officers as future RPV operators. Differential costs of rated and non-rated operators (force levels of twenty-five and fifty) were compared over a ten year life cycle. Initial flight training costs and aviation incentive payments were identified as the most prominent differential cost associated with using rated operators. The differential cost associated

with using non-rated operators was not well defined. However, it was recognized that a non-rated officer, lacking a flying background, might incur additional training costs to become RPV operator qualified. Through the use of non-rated operators, it is suggested that millions of dollars in manpower savings can be realized.

5. Non-rated officers are attractive candidates as future RPV operators. While only rated officers are currently used as RPV operators, an analysis of knowledgeable opinion, as well as an evaluation of advancing technology, indicated that it is feasible to use non-rated officers for some, if not all, future operator positions. After differential operator costs were identified, the desirability of using non-rated personnel became evident.

Recommendations

1. The Strategic Air Command should begin using electronic warfare officers interchangeably as airborne remote control operators and recovery operators. The operator roles for these two positions are very similar. In addition, with the repeal of Section 8577 of Title 10, exclusive pilot command authority no longer applies (pilot skills can probably be more appropriately used in other Air Force operations; this would also eliminate the present need for support aircraft). This operator policy, if implemented, should result in additional flexibility and costs savings for the Air Force.

2. Air Force Aerospace Medical Research Laboratory and Air Force Flight Dynamics Laboratory should assess the effectiveness of different categories of operators in their RPV system simulations. In their assessment, an evaluation of training time to specified levels of

proficiency should be emphasized. By evaluating this area in simulation, less speculation will be required in determining differential training costs.

3. Future ground based RPV operations, such as envisioned by the Compass Cope Project, should identify junior, non-rated officers as enroute operators. Since system knowledge, rather then rated skills per se, has emerged as the key attribute of future enroute operators, the selected non-rated personnel should possess the ability to understand and operate integrated systems (therefore, some screening process may be required).

4. Junior rated pilots should be identified initially as take-off/landing operators with consideration given to cross training non-rated enroute operators in the long run (there is still some uncertainty about the operator's role in the event of automatic landing failure). Category 03 (medically disqualified) rated personnel should be recognized as a potential "sunk cost" source of rated skills. By using non-rated and Category 03 personnel as future RPV operators, significant manpower savings can be realized.

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# APPENDIX A

## Acronyms

1. ACLS Air Cushion Landing System
2. AFM Air Force Manual
3. AFR Air Force Regulation
4. ALS Automatic Landing System
5. AMRL Aerospace Medical Research Laboratory
6. ARCO Airborne Remote Control Officer
7. ART Airborne Radar Technician
8. CRT Cathode Ray Tube
9. ECM Electronic Counter Measures
10. EWO Electronic Warfare Officer
11. FAA Federal Aviation Association
12. FDL Flight Dynamics Laboratory
13. HRL Human Resource Laboratory
14. ICAO International Civil Aviation Organization
15. ILS Instrument Landing System
16. LCC Life Cycle Cost
17. LCO Launch Control Officer
18. LORAN Long Range Navigation
19. MARS Mid-Air Retreival System
20. MCF Mission Control Facility
21. MCGS Microwave Command Guidance System
22. NASA National Aeronautics and Space Administration
23. NCO Non-commissioned Officer
24. NMLS National Microwave Landing System
25. RATO Rocket-assisted Take-off
26. RCO Remote Control Officer

27. RO Recovery Officer

28. RPRV Remotely Piloted Research Vehicle

29. RPV Remotely Piloted Vehicle

30. SAC Strategic Air Command

31. SPC System Program Office

32. TAC Tactical Air Command

33. TERCOM Terrain Contour Matching

34. TIFS Total Inflight Simulation

35. TILS Tactical Instrument Landing System

36. TLS Tactical Landing System

37. TOA/DME Time of Arrival/Distance Measuring Equipment

38. TV Television

# APPENDIX B

## Key Technological Impact References

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# APPENDIX C

## Demographic Data Symbols

TITLE/ORGANIZATIONAL SYMBOLS

| | |
|---|---|
| ALS | Automatic Landing System |
| AMRL | Aerospace Medical Research Laboratory |
| FDL | Flight Dynamics Laboratory |
| HALE | High Altitude Long Endurance |
| HRL | Human Resource Laboratory |
| SPO | RPV System Program Office |
| TR | Teledyne Ryan Corporation |
| TS | 6514th Test Squadron |
| TFW | 355th Tactical Fighter Wing |
| SRS | 350th Strategic Reconnaissance Squadron |
| SRW | 100th Strategic Reconnaissance Wing |

RANK SYMBOLS

| | |
|---|---|
| Civ | Civilian |
| 0-2 | 1st Lieutenant |
| 0-3 | Captain |
| 0-4 | Major |
| 0-5 | Lieutenant Colonel |
| 0-6 | Colonel |
| E-5 | Staff Sergeant |
| E-6 | Technical Sergeant |

EDUCATION SYMBOLS

| | |
|---|---|
| BA | Bachelor of Arts Degree |
| BS | Bachelor of Science Degree |
| HS | High School |
| MA | Master of Arts Degree |
| MS | Master of Science Degree |
| PH D | Doctorate Degree |
| + | (additional education beyond level listed) |

## Demographic Data Summary

| Respondent Number | (Non-rated Respondents) TITLE | Organization | Rank | Education | RPV Experience (years) |
|---|---|---|---|---|---|
| 1 | Flight Test Program Manager | TS | 0-3 | MS | 6 |
| 2 | Squadron Program Manager | TS | 0-3 | BS+ | 9 |
| 3 | Aeronautical Engineer | AMRL | Civ | BS | - |
| 4 | Test Director | TR | Civ | BS+ | 25 |
| 5 | Engineering Psychologist | SPO | Civ | BS | 2 |
| 6 | General Engineer | SPO | Civ | BS | 4 |
| 7 | Engineering Psychologist | AMRL | Civ | MA+ | 2-1/2 |
| 8 | Research Psychologist | HRL | Civ | MA+ | - |
| 9 | Industrial Engineer (ALS) | FDL | Civ | BS | - |
| 10 | Director, Development Systems | SPO | 0-5 | BS+ | 6 |
| 11 | Systems Test Manager | SPO | 0-4 | BS | 3 |
| 12 | Chief, Hale Systems Group | SPO | 0-5 | BS+ | 2 |
| 13 | Director of Training | SPO | 0-4 | MA | 7 |
| 14 | Systems Test Manager | SPO | 0-3 | BS | 9-1/2 |
| 15 | Lead Systems Engineer | SPO | 0-4 | BS+ | 3 |
| 16 | Research Engineer | AMRL | 0-3 | PH D | - |
| 17 | Crew Systems Engineer (ALS) | FDL | 0-2 | MS | - |
| 18 | Systems Engineer (ALS) | SPO | 0-3 | MS | 3 |
| 19 | Systems Engineer | SPO | 0-3 | BS | 2 |
| 20 | Former Launch Operator | SPO | E-7 | HS | 13 |
| 21 | Airborne Radar Technician | SRS | E-5 | HS | 3-1/2 |
| 22 | Airborne Radar Technician | SRS | E-5 | HS | 4 |

| Respondent Number | (Rated Respondents) TITLE | Organization | Rank | Education | RPV Experience (years) |
|---|---|---|---|---|---|
| 23 | Program Manager | TR | Civ | BA | 11 |
| 24 | Deputy Director | SPO | 0-6 | BS+ | 3 |
| 25 | Pilot Factors Engineer (ALS) | FDL | Civ | HS+ | - |
| 26 | Flight Test Director (ALS) | FDL | Civ | BS | 1 |
| 27 | Chief, Tactical Operations | FT[illegible] | 0-4 | MA | 1 |
| 28 | Director, Operation Systems | SPO | 0-[illegible] | MA | 12 |
| 29 | Development Group Leader | FDL | 0-[illegible] | BS | 17 |
| 30 | Systems Program Manager | SPO | 0-4 | BS | 6 |
| 31 | Program Manager | SPO | 0-4 | BS+ | 7 |
| 32 | DC-130 Pilot (ALS) | TDS | 0-3 | MA | 2 |
| 33 | Launch Control Officer (ALS) | TDS | 0-5 | BS | 3 |
| 34 | Wing Tactics Officer | TFW | 0-3 | BS | 3-1/2 |
| 35 | Remote Control Officer | TDS | 0-3 | BS | 2 |
| 36 | Remote Control Officer | TDS | 0-3 | BS | 4 |
| 37 | Remote Control Officer | TDS | 0-3 | BS | 3-1/2 |
| 38 | Remote Control Officer | TDS | 0-3 | BS | 3-1/2 |
| 39 | Remote Control Officer | TDS | 0-3 | BS | 5 |
| 40 | Launch Control Officer | TDS | 0-3 | BS | 4 |
| 41 | Launch Control Officer | TDS | 0-3 | BS | 1 |
| 42 | Recovery Officer | SRS | 0-3 | BA | 1 |
| 43 | Recovery Officer | SRS | 0-4 | HS+ | 2 |
| 44 | Recovery Officer | SRS | 0-3 | BS | 2-1/2 |
| 45 | Launch Control Officer | SRS | 0-[illegible] | BS | 4 |
| 46 | Launch Control Officer | SRS | 0-4 | HS+ | 2 |
| 47 | Launch Control Officer | SRS | 0-4 | BA | 1-1/2 |
| 48 | Launch Control Officer | SRS | 0-3 | MA | 4 |
| 49 | Wing Systems Development Officer | SRW | 0-4 | MS | 3-1/2 |
| 50 | Airborne Remote Control Officer | SRS | 0-5 | HS | 4 |
| 51 | Launch Control Officer | SRS | 0-3 | BA | 3 |
| 52 | Deputy, Development Systems | SPO | 0-5 | MS | 3-1/2 |

# APPENDIX D

## Interview Questions

Name ______________________________

Rank ______________________________

Title ______________________________

Education ______________________________

RPV Experience ______________________________

Rated/Non-rated ______________________________

1. What kind of background do you feel would be best suited for future RPV operators? (i.e., rank, flying experience, education, special skills)

2. Looking at the ground launch ground recovery type RPV (such as envisioned by Compass Cope), how should the crew positions be divided?

3. What category of person should handle each position?

4. If you had to choose one category of person to handle the total operation (i.e., launch, enroute, other actions, recovery), who would you choose?

5. Assuming future RPV's become highly automated and sophisticated, do you feel this will require greater skill or less skill on the part of the operators?

6. Launch/Recovery Phase (circle one)

   a. Officer/Enlisted/Either

      If Officer:

      (1) Capt/Lt/Either

      (2) Maj/Capt/Either

   b. Rated/Non-rated/Either

      If Rated:

      (1) Pilot/EWO/Either

      (2) Pilot/Nav/Either

      (3) EWO/Nav/Either

(4) Under 1000 hrs/Over 1000 hrs

c. Engineer/Non-engineer/Either

7. Enroute Phase (circle one)

a. Officer/Enlisted/Either

If Officer:

(1) Capt/Lt/Either

(2) Maj/Capt/Either

b. Rated/Non-rated/Either

If Rated:

(1) Pilot/EWO/Either

(2) Pilot/Nav/Either

(3) EWO/Nav/Either

(4) Under 1000 hrs/Over 1000 hrs

c. Engineer/Non-engineer/Either

# APPENDIX E

## Rated/Non-rated Opinions to Closed-form Questions

| QUESTION 6 (LAUNCH/RECOVERY PHASE) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| OPERATOR CRITERIA | | Non-rated | | | | Rated | | | |
| | | Total Inputs | 1 | 2 | 3 | Total Inputs | 1 | 2 | 3 |
| a | (1) officer (2) enlisted (3) either | 22 | 15 | | 7 | 30 | 26 | 1 | 3 |
| 1. | (1) captain (2) lieutenant (3) either | 15 | | | 15 | 19 | 1 | 1 | 17 |
| 2. | (1) major (2) captain (3) either | 11 | | 1 | 10 | 13 | | 1 | 11 |
| b | (1) rated (2) non-rated (3) either | 21 | 7 | 3 | 11 | 30 | 21 | 3 | 6 |
| 1. | (1) pilot (2) EWO (3) either | 10 | 3 | | 7 | 20 | 7 | 1 | 2 |
| 2. | (1) pilot (2) navigator (3) either | 8 | 1 | | 7 | 8 | 1 | 1 | 6 |
| 3. | (1) EWO (2) navigator (3) either | 6 | 1 | | 5 | 9 | 1 | 1 | 7 |
| 4. | (1) <1000 fly hours (2) > 1000 fly hours | 11 | 6 | 5 | | 21 | 9 | 12 | |
| c | (1) engineer (2) non-engineer (3) either | 21 | 9 | | 12 | 23 | 6 | 3 | 14 |

| QUESTION 7 (ENROUTE PHASE) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| OPERATOR CRITERIA | | Non-rated | | | | Rated | | | |
| | | Total Inputs | 1 | 2 | 3 | Total Inputs | 1 | 2 | 3 |
| a | (1) officer (2) enlisted (3) either | 22 | 9 | 2 | 11 | 30 | 22 | 1 | 7 |
| 1. | (1) captain (2) lieutenant (3) either | 12 | | | 12 | 17 | 1 | 1 | 15 |
| 2. | (1) major (2) captain (3) either | 10 | | 1 | 9 | 14 | | 1 | 13 |
| b | (1) rated (2) non-rated (3) either | 21 | 5 | 7 | 9 | 30 | 18 | 3 | 9 |
| 1. | (1) pilot (2) EWO (3) either | 7 | 1 | 1 | 5 | 14 | 2 | | 12 |
| 2. | (1) pilot (2) navigator (3) either | 8 | 1 | 1 | 6 | 8 | | | 8 |
| 3. | (1) EWO (2) navigator (3) either | 6 | 1 | | 5 | 14 | 4 | 1 | 9 |
| 4. | (1) < 1000 fly hours (2) > 1000 fly hours | 9 | 6 | 3 | | 20 | 8 | 12 | |
| c | (1) engineer (2) non-engineer (3) either | 21 | 6 | 1 | 14 | 23 | 5 | 4 | 14 |

APPENDIX F

Various Sub-group Opinions to Closed-form Questions

| QUESTION 6 (LAUNCH/RECOVERY PHASE) | | OPERATIONS | | | | SPO | | | | LABS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OPERATOR CRITERIA | Total Inputs | 1 | 2 | 3 | Total Inputs | 1 | 2 | 3 | Total Inputs | 1 | 2 | 3 |
| a | (1) officer (2) enlisted (3) either | 22 | 18 | | 4 | 16 | 14 | | 2 | 10 | 16 | 1 | 3 |
| b | (1) rated (2) non-rated (3) either | 22 | 16 | 2 | 4 | 16 | 7 | 2 | 7 | 9 | 3 | 2 | 4 |
| c | (1) engineer (2) non-engineer (3) either | 15 | 3 | 1 | 11 | 16 | 6 | 1 | 9 | 9 | 4 | 1 | 4 |

| QUESTION 7 (ENROUTE PHASE) | | OPERATIONS | | | | SPO | | | | LABS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OPERATOR CRITERIA | Total Inputs | 1 | 2 | 3 | Total Inputs | 1 | 2 | 3 | Total Inputs | 1 | 2 | 3 |
| a | (1) officer (2) enlisted (3) either | 22 | 16 | | 6 | 16 | 10 | 1 | 5 | 10 | 2 | 2 | 6 |
| b | (1) rated (2) non-rated (3) either | 22 | 15 | 1 | 6 | 16 | 5 | 5 | 6 | 9 | 1 | 4 | 4 |
| c | (1) engineer (2) non-engineer (3) either | 15 | 2 | 2 | 11 | 16 | 4 | 1 | 11 | 9 | 3 | 2 | 4 |

# APPENDIX G

## Differential Training Costs for Non-rated Operators

(Over a Ten Year Life Cycle)

(Hypothetical case based on the assumption that an additional $15,000 training cost/operator is incurred by using non-rated personnel, who are replaced every four years.)

| | force level (25) | force level (50) |
|---|---|---|
| 1. Additional training cost/operator (estimate) | $15,000 | $15,000 |
| 2. Number of operators | 25 | 50 |
| 3. Additional training cost (initial contingent) (1x2) | $375,000 | $750,000 |
| 4. Additional future training cost (fourth year replacement group) | $375,000 | $750,000 |
| 5. Present value factor (10%/4 years) | .717 | .717 |
| 6. Present additional training cost (first replacement group) (4x5) | $268,875 | $537,750 |
| 7. Additional future training cost (eighth year replacement group) | $375,000 | $750,000 |
| 8. Present value factor (10%/8 years) | .489 | .489 |
| 9. Present additional training cost (second replacement group) (7x8) | $183,375 | $366,750 |
| 10. Present additional cost of training non-rated operators (3+6+9) | $827,250 | $1,654,500 |

# APPENDIX H

## Additional Rated Pilot Costs

(That might be incurred through decay of the pilot resource pool)

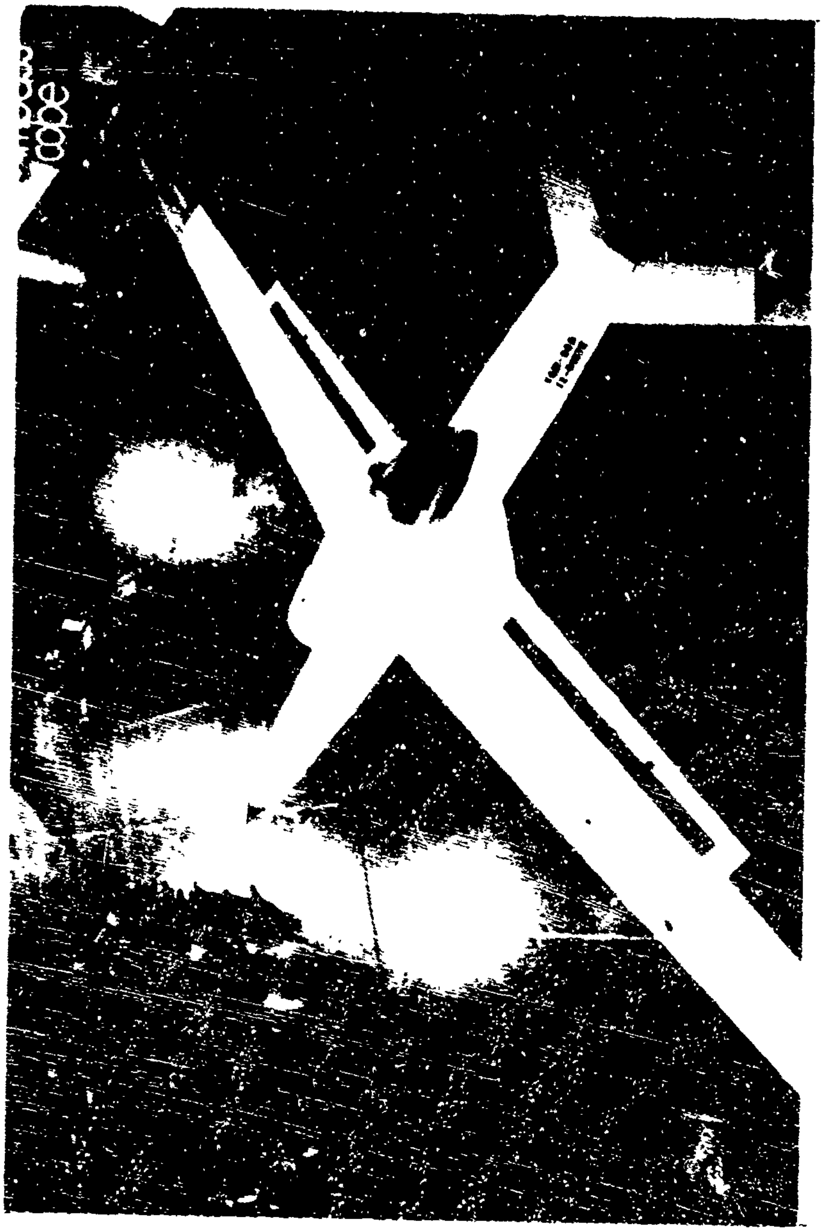
For simplicity, a 4% attrition rate/year (for ten years) will be assumed for this example using an additional 25 and 50 pilots, respectively. That would amount to training 1 additional pilot/year (at a variable cost of $106,000/year) or 2 additional pilots/year (at a variable cost of $212,000/year). It is recognized, however, that little, if any, attrition may occur from these groups until after the initial five or six year period.

| | (FL-25) | (FL-50) |
|---|---|---|
| | $106,000 | $212,000 |
| discount factor (10 yr/10%) | 6.447 | 6.447 |
| | $683,382 | $1,366,764 |

# APPENDIX I

Compass Cope (Boeing)
(photo provided by Richard Johnson, Boeing Aerospace Company)

# APPENDIX J




Compass Cope (Ryan)
(photo provided by Robert Boone, Teledyne Ryan Aeronautical)

# APPENDIX K

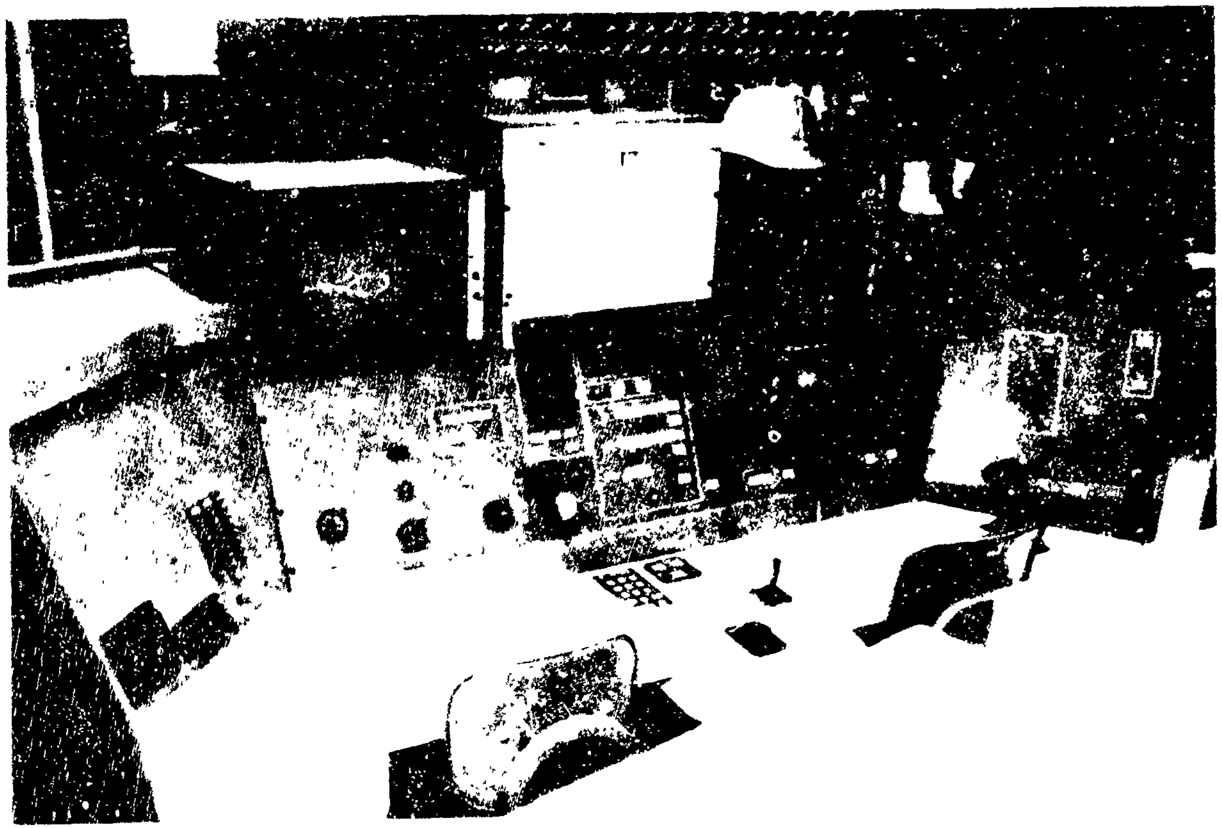
AMRL RPV Simulation Operators
(photo provided by Robert Mills, Air Force AMRL)

# APPENDIX L

Future Enroute Control Station Design
(photo provided by Robert Mills, Air Force AMRL)

# APPENDIX M

FDL Landing Control Station Design
(photo provided by Paul Tafce, Air Force FDL)



# Vita

Robert Gene Kiggans was born 14 April 1943 in Wellsville, Ohio. After graduating from Wellsville High School in 1961, he attended The Citadel where he received the degree of Bachelor of Science and a commission in the USAF. After receiving his navigation wings in 1966, he was assigned to the Strategic Air Command, where he gained operational experience in all active B-52 models (with several Southeast Asia deployments). He was assigned to the Standardization-Evaluation Division with SAC Bomb Wings at Homestead AFB, Wright-Patterson AFB, and Mather AFB. In addition, he worked as a systems engineer with Electronic Data Systems. In 1974, he was selected to attend the Air Force Institute of Technology for a Master's Degree in Systems Management.

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| | |
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| Drones | Pilots |
| Compass Cope | Crews |
| Man Machine Interface | |

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The primary objective of this research was to examine criteria for Air Force RPV operators to determine both the feasibility and desirability of using other than rated officers as future RPV operators. The research methodology involved an analytical approach in which several subobjectives were established. Past and present operator criteria were identified initially, followed by an evaluation of the impact of emerging technology

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on future operator requirements. In order to enlarge this evaluation, the opinion of an experienced RPV community on future operator criteria was sampled. Differential operator costs were estimated as a final element of the investigation. Although special emphasis was placed on the future Compass Cope operations, the analysis was intended to have application to other RPV operations as well.