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Plan for Flight Testing Intermittent Positive Control

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16. Abstract

Intermittent Positive Control is an automated aircraft collision avoidance system requiring the participation of the aircraft pilots involved. The operational interface between pilots and the IPC system is being evaluated in a series of live flight tests. The Lincoln Laboratory DABS Experimental Facility, augmented to include the IPC function, is the test bed for these evaluation flights. This document described the objectives and methods of the IPC flight testing being conducted by Lincoln Laboratory.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

PLAN FOR FLIGHT TESTING INTERMITTENT POSITIVE CONTROL

1.0 OVERVIEW

1.1 Background

The Federal Aviation Administration (FAA) has generated a plan [Ref. 1] for developing and testing a ground-based collision avoidance system referred to as Intermittent Positive Control (IPC). The baseline IPC concept has been defined and is presented in Refs. 2-4. The development plan specifies two major phases of testing. Phase I includes flight testing using a single experimental Discrete Address Beacon System (DABS) sensor and includes system simulations using the capabilities of the FAA's NAFEC facility and other resources. Phase II encompasses more extensive flight tests using three engineering model DABS sensors to test the operation in a multisensor environment. The flight tests in Phase I will be conducted in a live air traffic environment, utilizing the Discrete Address Beacon System Experimental Facility (DABSEF) at the M. I. T. Lincoln Laboratory in Lexington, Massachusetts. This document presents the plan for conducting Phase I flight tests.

The IPC design has been subjected to analysis and simulation with results reported in Refs. 5 and 6. As with any major system under development, it is desirable to conduct tests in a live environment in order to fully characterize and refine system performance. There is also an additional motivation for conducting IPC flight tests. The baseline concept of IPC relies in part upon the ability of a pilot, assisted by advisory information, to visually acquire a neighboring aircraft, to assess the in-flight situation, and to choose an appropriate course of action. The human responses to various aircraft encounter situations are therefore important elements affecting the operation of IPC. The most realistic method for studying these responses is flight tests.

1.2 IPC Flight Test Program Objectives

There are two categories of IPC flight test program objectives: (1) the objectives concerned with verifying the basic collision avoidance capability of IPC, and (2) the objectives concerned with evaluating the pilot's responses and reactions to various IPC messages and his ability to use the information conveyed in the messages in an effective way. The first objective seeks primarily to assess how well the collision avoidance maneuvers, generated by IPC, provide separation between aircraft when the system is operating with data from a live environment. These objectives are concerned with the mechanical aspects of the IPC system operation and have been termed IPC System Design Validation Objectives. The second category of objectives deals with pilot responses and interactions and is referred to as Pilot Interaction Evaluation Objectives. Specific objectives are presented within these two categories.

1.2.1 IPC System Design Validation Objectives

The most important validation objective is to evaluate, and improve if necessary, the separation assurance capability of the IPC conflict detection and resolution logic. Considerable variation exists in the baseline IPC logic to account for characteristics of the conflict encounter, such as aircraft speed, aircraft ATC status, and aircraft IPC equipment status. Furthermore, the separation assurance capability can be expected to depend on the maneuver status of the aircraft and on other factors such as range from the sensor. Therefore, the objective to evaluate separation assurance capability requires evaluation under all of these conditions.

Validation of the results of the extensive simulation studies of IPC is another objective in this category. Simulation can be used effectively to evaluate proposed modifications to the logic by generating accurately controlled and widely varying conditions. However, in order that conclusions may be drawn from the simulation results, the simulation models must be verified and modified as necessary by analysis of flight test results. Another validation objective is to demonstrate that the IPC system can operate successfully with the surveillance and communication capabilities provided by DABS.

1.2.2 Pilot Interaction Evaluation Objectives

The principle objective is to evaluate how well all of the elements of the IPC system concept work together to provide separation assurance. The ability of the pilot to use the advisory service to his benefit and in a way compatible with the command service is to be assessed. The direct effect of IPC system inaccuracies introduced by surveillance errors, maneuvering aircraft, or delays in displaying IPC messages on the capability of the pilot to use the advisory information is to be evaluated.

Another objective is to characterize the pilot's perception of threat when the various IPC messages appear in order to determine whether the IPC protection volumes should be reduced or expanded. Pilot evaluations of all aspects of the IPC system operation are to be collected and analyzed to reveal any unsatisfactory aspects of system operation that may warrant modification to the baseline concept.

Evaluating the suitability of the baseline pilot response rules is another objective within the pilot interaction evaluation. This objective seeks to determine whether or not the proper balance between mandatory and optional response to messages has been specified in the baseline concept, and whether or not the minimum maneuver rates specified for responding to conflict resolution commands are appropriate.

1.3 Test Method

In order to accomplish both system design validation and pilot interaction evaluation objectives, flight testing is to be comprised of two complementary elements. Since flight testing is at best an inefficient process for obtaining engineering data, it is important to provide an adaptive and flexible test program as part of the system development and refinement process. Every attempt will be made to avoid flight test exploration of issues that are amenable to study by means of analysis or simulation. Rather, flight tests will focus upon gathering data unattainble by other means, and uncovering problems that may have been overlooked during nonoperational evaluations of the concept.

The flight tests described in this document involve general aviation aircraft only. The test aircraft will not be under FAA air traffic control during these tests, and tests will be conducted only when the flight visibility is at least 5 nmi in the test area. Some tests will be performed when the IPC system considers one or more of the test aircraft to be controlled by ATC (i.e., under Instrument Flight Rules [IFR]), but these tests are only scheduled to exercise algorithm logic and are not actually to be carried out under the control of the ATC system.

1.3.1 Validation Tests

The group of flight tests designed to accomplish the System Design Validation Objectives, referred to as validation tests, will involve the use of trained professional pilots to execute contrived near-miss encounters. In this way the variations in pilot behavior will be minimized and the automated system will receive concentrated attention.

Procedures are currently being developed in which near-miss encounters of various types can be generated either from the air or from the ground. With the airborne-generated encounters, the professional pilots operate cooperatively to create a preplanned near-miss encounter. In ground-generated encounters, an observer on the ground issues instructions to effect the near-miss with the aid of a display of aircraft position and tabular flight data. Both air-and ground-generated encounters will be flown during validation tests.

During validation testing, emphasis will be placed upon investigating the minimum separations achieved by the system when the professional pilots respond to IPC commands with nominal maneuver rates. During these flights, the pilots will not use the advisory information to initiate maneuvers of their own choosing, as may be done in the baseline IPC concept. However, data will be recorded that will indicate when each IPC message was displayed so that it can be determined whether or not the algorithms are providing the expected messages at the desired times.

As the validation tests progress, some encounters will be flown in which the pilots will respond to advisory information. Pilot reaction to the complete IPC system operation and their experience when conducting maneuvers of their own choosing will be assessed, not for the purpose of evaluating the operation of the complete IPC system, but to anticipate problems that might be encountered when conducting subject pilot flight tests as presented in Section 1.3.2. Conclusions regarding the pilot interface aspects of IPC will not be determined from validation tests using the professional test pilots because these pilots have extensive experience in flying near-miss encounters and flying in close proximity to other aircraft. Their perception of threat and their ability to visually acquire another aircraft are not regarded as representative of all pilots.

Since a significant amount of experience has been accumulated involving simulation of system behavior under the assumption that the pilot makes no response to PWI information, it is appropriate to select a representative number of encounter situations that have been simulated and then flight test them. The outcome of this action will be an assessment of the ability of the simulations to represent the nominal system behavior, including modeling of system errors, delays, and pilot response.

If unforeseen problems occur during validation testing, it will be possible either to plan additional tests to fully characterize the problems or to submit the problems to analysis and design refinement, as the situation warrants. The test bed implementation of IPC has been established so that experimentation with minor variations of the basic concept is easily accomplished, thereby providing the maximum flexibility to implement solutions to any problems that may be uncovered.

1.3.2 Subject Pilot Tests

The principal requirement for flight tests is that of providing data which characterize typical pilot interaction with the complete services of IPC. It is therefore necessary to subject the system to operations involving many typical general aviation pilots. Subject pilot testing is expected to lead to valuable insight concerning pilot use of advisory functions of the system, in both conflict situations and routine flight operations. To this end it will be necessary to independently explore both the typical pilot's ability to use routine traffic advisory information to avoid causing conflicts, and his ability to resolve existing conflicts in response to conflict advisories and visual acquisition of conflicting aircraft.

Subject pilot use of advisory information will be studied by establishing situations in which a potentially conflicting intruder presents an obstacle to the subject pilot's flight objective. The pilot's ability to utilize the advisory service to safely accomplish his objective will be characterized. The pilot's use of conflict advisories to resolve conflicts will be studied by providing coordinated intercepts, similar to those developed for validation testing.

The consequences of permitting the pilot various degrees of discretion involving the nature of response to IPC commands will also be explored during subject pilot testing.

For reasons of safety and coordination, a professional test pilot will be in command of the subject pilot's aircraft and will have ultimate responsibility for the aircraft, although the subject pilot will fly the aircraft. The subject pilot's aircraft is designated as the drone, whereas the conflicting test aircraft is designated the interceptor. A special VHF communication procedure will allow the test pilot of the interceptor to coordinate with the drone test pilot and the mission ground observer without revealing to the subject pilot the position or intentions of the interceptor. Every effort will be expended to provide as normal as possible a cockpit environment for the subject pilot.

One element that affects the pilot response to IPC information is the display presentation. It is important, therefore, to try to determine to what extent the information display contributes to pilot understanding of the conflict situation. As part of a general pilot debriefing, the role the display presentation has played in the pilot response to the system will be noted. It is not the intent of the flight tests, however, to attempt to provide a human factors assessment of the display design. Therefore, it is necessary that variations in pilot familiarity with the test bed cockpit displays not be a dominant factor in determining response to IPC messages: to this end, each subject pilot will be given a familiarization flight, during which he will gain experience in interpreting the display presentation, as well as in using the flight test procedures in general. At the same time, care will be exercised to avoid preconditioning the pilots to respond to specific IPC commands.

1.4 Schedule

IPC flight testing must provide both short-term design validation and longer-term pilot interaction evaluation data. Thus, there will be a period during which both validation tests and subject pilot tests are flown. Flight test missions involving an average flight of two hours and 12 to 15 IPC encounter events will be supported by DABSEF at the average rate of two missions per week. Allowing some margin for weather cancellations, reruns, system maintenance, and overhead, a reasonable estimate of the required time for a single pass through system validation is 12 to 16 weeks. The first pass at validation of the present system configuration has been underway since mid-April 1975. Beginning in July 1975, subject pilot missions will be scheduled instead of one validation flight per week. Some additional overhead (pilot familiarization flights, briefings, demonstrations, etc.) will accompany the subject pilot testing. The anticipated overall result of merging these operations is included in the schedule of Fig. 1-1.

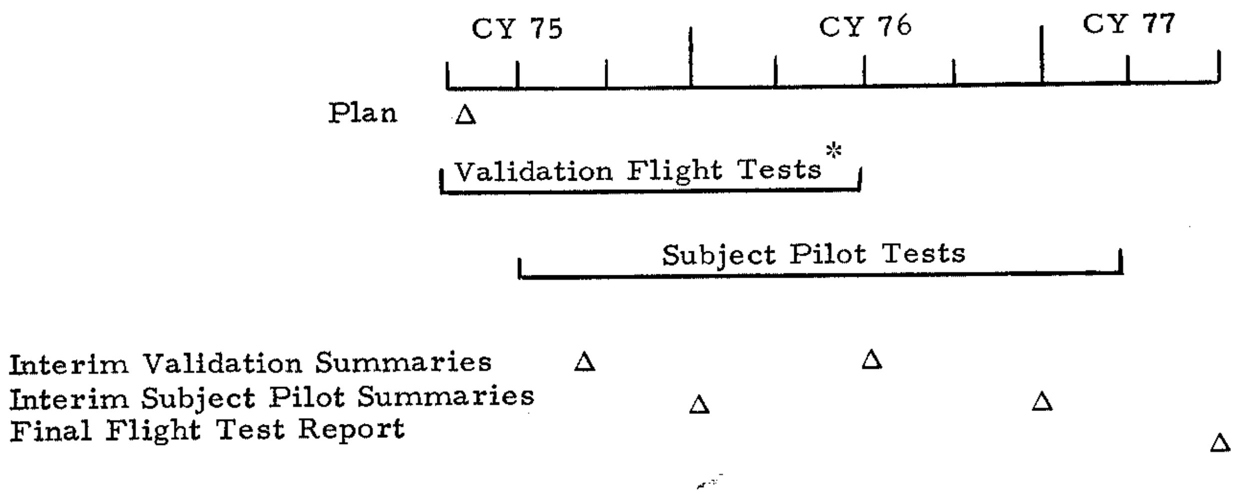

Fig. 1-1. IPC test schedule.

*Additional validation tests will be scheduled, if required, to complete the system development and refinement.

1.5 Products

The Phase I IPC flight testing will result in a representative and permanent data base of realistic encounter situations involving general aviation aircraft pilots. Using this data base as an input, several reports, which summarize various aspects of the IPC system, will result. Algorithm validation results will be the subject of an interim report in summer 1975. Additional validation results will be summarized as obtained. Pilot interaction with the system will be studied separately, resulting in an interim report in late CY 75. Other outputs of the flight test program will include Flight Test Data Summaries after each mission, a Final Report, and Quarterly Progress Reports.

1.6 Summary of This Plan

This document is intended to serve as a guide for testing and evaluating the IPC system. A description of the baseline IPC concept, including methods for pilot interpretation and response to information on the cockpit display, is reviewed in the following section. Priorities and relative emphasis on the choice of flight test encounters are presented in Section 3.0. Particular facilities, unique to Phase I IPC flight tests, are described in Section 4.0. The methods to be used during flight test operations are presented in Section 5.0, and the techniques for data analysis are reviewed in Section 6.0. The appendices contain additional examples and special details.

2.0 IPC OPERATIONAL DESCRIPTION

Intermittent Positive Control (IPC) is an automated ground-based collision avoidance system capable of protecting beacon-equipped aircraft. This section provides a brief description of the operation of IPC from the point of view of the messages displayed to the pilot and the responses expected from the pilot. Reference 2 must be consulted for a complete description of the IPC concept. Reference 3 provides the detailed IPC computer algorithms specified for the flight tests.

For complete IPC service, each aircraft must be equipped with a DABS transponder, which sends three-dimensional position information to the ground. Furthermore, each aircraft must also be equipped with an IPC cockpit display (Fig. 2-1) on which collision avoidance commands and other information appear. The display in Fig. 2-1 will be used during IPC flight tests. This display differs from the IPC display described in Ref. 2, in that the display to be used for flight tests is without an X in the center to indicate "do not continue straight ahead." Because this center X is to be lit each time a command arrow is lit, and because the center X is never lit by itself in the IPC operational concept, the results using this display will be no different from the results using the baseline display.

2.1 IPC Display

Examination of the IPC display used in the test aircraft (Fig. 2-1) is helpful in explaining how a pilot should react to IPC messages. The display includes an outer ring of lights arranged in twelve groups of three lights stacked vertically, each group located at one of the o'clock positions. These are the proximity warning lights that inform the pilot of other aircraft locations, i.e., by identifying the relative bearing (one o'clock, two o'clock, etc.), and the relative altitude. Relative altitude is indicated by a light within a group of three: the top light for aircraft above (500 to 2,000 feet above), the middle light for co-altitude (500 feet above to 500 feet below), and the bottom light for aircraft below (500 to 2,000 feet below). In addition to the proximity warning lights, the display includes a set of "do" arrows and "don't" crosses that present IPC commands to the pilot. A "do" command is displayed by lighting an arrow in the direction to maneuver and lighting the cross in line with that arrow. A "don't" command is displayed by lighting the cross in the direction to indicate no maneuver. The display used in the IPC test aircraft also features three pushbuttons: a YES button that the pilot must push to acknowledge that he will comply with commands, a NO button that is not used, and a TEST button that the pilot may push to see if the display is operating properly (all lights should light).

2.2 IPC Messages

IPC issues four types of messages: ordinary proximity warning indications (PWI(s)), flashing proximity warning indications (flashing PWI(s)),

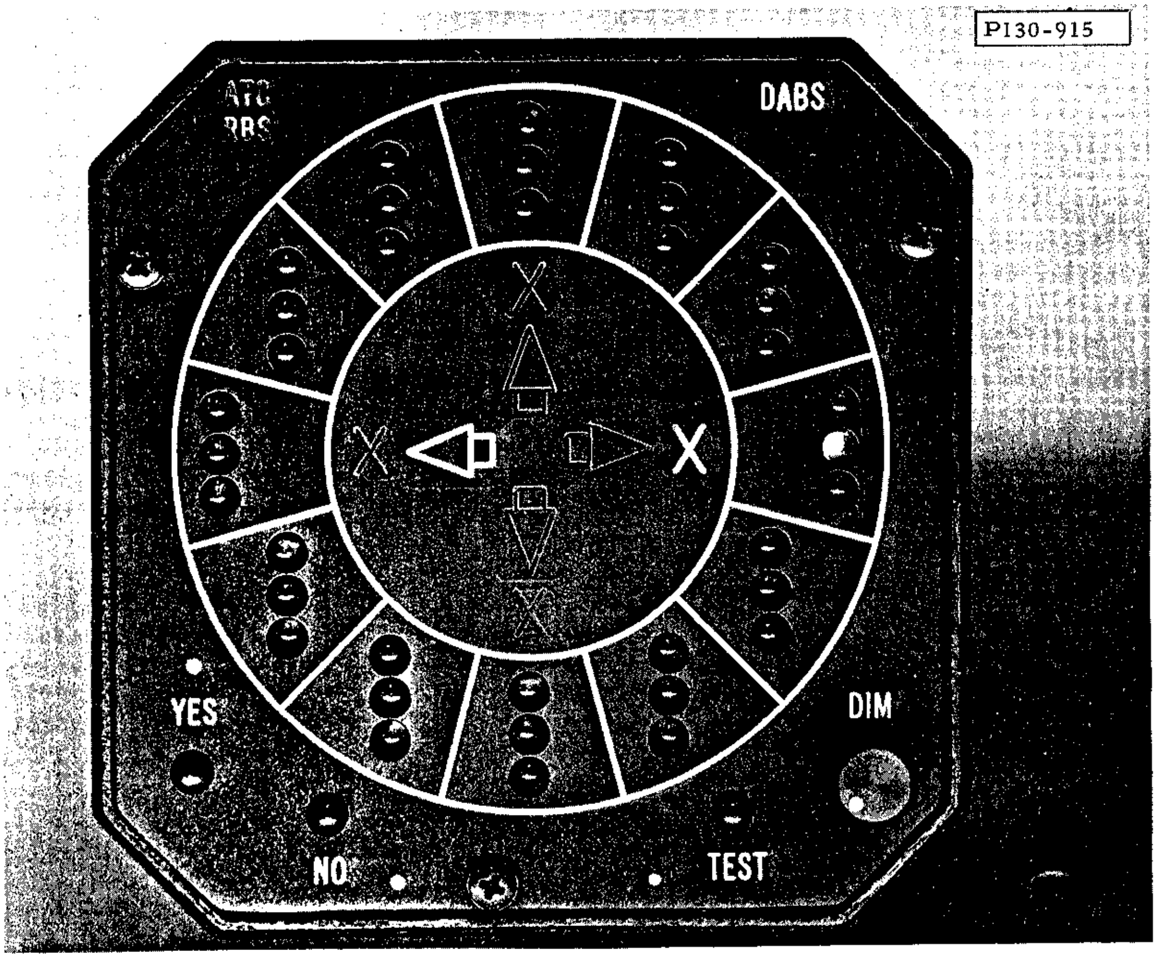

Fig. 2-1. IPC cockpit display.

"do" commands, and "don't" commands. The meaning of these messages to the pilot is next explained. (Note: These message meanings are included to describe normal IPC operation as it is currently envisioned. This section does not completely explain the methods, or utilization rules that subject pilots and IPC test pilots will use during the flight tests. The methods or utilization rules are included in Section 2.4.)

An ordinary PWI informs the pilot of the location of a nearby aircraft that is not currently on a collision course. Location is indicated by lighting the proximity warning light (a steady light) appropriate to the other aircraft's clock position and relative altitude. Aircraft identified by ordinary PWI(s) will be within visual range. Since aircraft identified by ordinary PWI(s) are not collision threats, there is no need for the pilot to consistently scan his IPC display for PWI(s). When the pilot is about to start a new maneuver, however, he may fly into a dangerous situation if other aircraft are nearby. Therefore, prior to making any maneuvers, the pilot should look at the portion of his IPC display that represents the direction of his planned maneuver. If any aircraft is indicated (by an ordinary PWI) as being in that direction, the pilot should visually acquire that aircraft and then proceed in the appropriate manner.

A flashing PWI indicates to the pilot the location of a nearby aircraft that represents a potential collision threat. An audible alarm always accompanies a flashing PWI. Again, the location of the intruding aircraft is indicated by lighting (with a flashing light) the proximity warning light appropriate to the other aircraft's clock position and relative altitude. An audible alarm is sounded when the flashing PWI for a new aircraft is first displayed. Upon receiving a flashing PWI warning, the pilot should visually acquire the other aircraft, assess the situation, and maneuver to avoid a conflict if he believes that a maneuver is desirable or required. The pilot's response to a flashing PWI is optional rather than mandatory. If the pilot does not maneuver and the degree of danger increases, the IPC system will generate a "do" or "don't" command that requires pilot compliance.

A "do" command is issued when a serious collision threat exists that requires immediate resolution. The pilot must maneuver in the direction indicated by the arrow on the IPC display as soon as he sees the arrow. An audible alarm alerts him to this maneuver. He should not wait until he sees the intruding aircraft; however, a flashing PWI will be present to identify the intruding aircraft's location for him. Sometimes the pilot will be required to execute two "do" commands, simultaneously maneuvering horizontally and vertically. The alarm will sound whenever a new "do" command appears. In addition to maneuvering as quickly as possible, the pilot must also press the YES button at the bottom left of the IPC display (Fig. 2-1) to indicate that he will comply with the IPC command.

In IPC, "do" commands are issued only when a conflict has become critical and actions are required immediately to effect a safe passage. This is necessary to reduce the frequency with which IPC must take control of aircraft and to give pilots every opportunity to use the PWI service. As a result, "do" commands will occur infrequently. Because the degree of urgency is high at the time "do" commands are issued, the selection of commands is made to ensure the greatest physical separation between aircraft at the point of closest approach. This may not, in every case, produce evasive maneuvers that suit the preferences of the pilots in permitting them to return to course easily or in permitting them to maintain sight of the other aircraft throughout the encounter. However, because "do" commands are expected to be required infrequently, and because the conflict will be at a critical stage when commands are issued, achievement of safe separation is of much greater concern than providing convenience to the pilots. Furthermore, in many situations in which "do" commands are required, the pilots will not have visually acquired the other aircraft. Again, achieving safe separation is the major consideration.

A "don't" command is issued when a serious collision threat would exist if either aircraft involved were to perform a hazardous maneuver. Therefore, each pilot is instructed not to maneuver in the direction indicated by the lighted cross on the IPC display. The alarm will sound when the don't command appears on the display. The pilot should use the flashing PWI, which always accompanies a "don't" command, to assist him in locating the other aircraft and push the YES button to indicate that he will not maneuver in the prohibited direction. Any other maneuvers are acceptable. Complying with a "don't" command may require rolling out of a turn or stopping a climb or descent.

Notice that flashing PWI(s) and IPC commands are accompanied by an alarm that sounds whenever commands change or a flashing PWI appears for a new aircraft. The pilot must check his IPC display when he hears the alarm and follow the required procedures for complying with the advisories or commands displayed. The pilot must also check his IPC display for the presence of ordinary PWI(s) when he is about to maneuver, since no alarm accompanies these advisories. The safety provided by the ordinary PWI(s) in preventing maneuvers from a dangerous situation is an important feature of the complete IPC system, and to ensure complete safety the pilot must use any ordinary PWI(s) indicating traffic in the direction of a new maneuver to attempt to visually acquire that traffic before he initiates the maneuver.

2.3 IPC Applications

IPC proximity warning and separation services are to be provided to aircraft equipped with DABS transponders and IPC displays. Sufficient lead time (approximately 30 seconds until closest approach for "do" or "don't" commands) is allowed for conflicts between two such aircraft operating VFR so that separation is assured when both aircraft respond to the IPC commands. IPC also provides protection for aircraft under Instrument Flight Rules (IFR)*, i.e., protection from aircraft unequipped to receive IPC

*IPC treats all aircraft (including controlled VFR) that are under the control of an air traffic controller as IFR.

commands (Air Traffic Control Radar Beacon System [ATCRBS] equipped), protection for aircraft involved in multi-aircraft conflicts and for aircraft involved in encounters in which one aircraft does not obey its IPC commands.

In an IFR/VFR encounter, IPC displays a warning to the responsible air traffic controller well before (approximately two minutes) the aircraft would reach closest separation. If no controller action is taken and the aircraft continue to close, a flashing PWI is issued to the VFR aircraft, followed by an IPC command, if necessary. Both of these messages are issued earlier than they usually would be for a VFR/VFR encounter. By responding to the IPC commands, the VFR aircraft should be able to resolve the conflict without the IFR aircraft maneuvering. If the actions of the VFR pilot fail to adequately resolve the conflict and the time until closest approach continues to decrease, the IFR aircraft will also be issued a flashing PWI and an IPC command. Ordinary PWI(s) are transmitted to each aircraft as if they were both VFR.

In an IFR/IFR encounter, IPC serves as a backup system to the ATC system. A controller warning is generated by IPC at a suitable warning time. If no action is taken by the controller to resolve the conflict, flashing PWI(s) are transmitted to each aircraft, followed by IPC commands if the aircraft continue to close. Again, ordinary PWI(s) for transmitted to each aircraft as long as the normal VFR/VFR logic for ordinary PWI(s) is satisfied.

For encounters involving one DABS-equipped aircraft and one aircraft that is not DABS-equipped, the system uses longer look-ahead times so that the conflict can be satisfactorily resolved by issuing commands to only the DABS-equipped aircraft.

For encounters involving two DABS-equipped aircraft, special logic to alter the resolution commands is implemented if one aircraft fails to respond to its command. This logic involves simultaneously issuing commands in both the horizontal and vertical dimensions. An aircraft is considered non-responding if an acknowledgment indicating compliance is not recieved from the pilot within a specified time of the command transmission. In order to resolve conflicts involving more than two aircraft, the IPC decision logic uses the flexibility inherent in the capability to resolve conflicts with horizontal "do" commands and/or vertical "do" commands.

Table 2-1 summarizes the IPC messages displayed and the expected responses to them.

2.4 IPC Pilot Response Rules

A general description of IPC service was provided at the beginning of this section. The specific pilot response rules to be used during these flight tests in complying with IPC advisories and commands are presented next. Several possibilities exist for specifying the proper criteria for stopping an IPC maneuver and the performance required while executing an IPC maneuver. The IPC response rules for most of these flight tests conform to the baseline IPC concept as described in Ref. 2. These baseline rules will be used for

TABLE 2-1

MESSAGE TYPES ISSUED BY THE IPC SYSTEM

MESSAGE TYPE	RESPONSE REQUIRED OF PILOT OR CONTROLLER	METHOD OF PRESENTATION
ORDINARY PWI	NONE. THIS IS AN ADVISORY. THE INDICATED TRAFFIC IS NEARBY BUT REPRESENTS NO CURRENT DANGER. DISPLAY IS TO BE MONITORED PRIOR TO INITIATING ANY MANEUVER.	STEADY ILLUMINATION OF ONE OF 36 POSITION INDICATOR LIGHTS.
FLASHING PWI TO VFR PILOT	OPTIONAL. THIS IS AN ADVISORY. THE INDICATED TRAFFIC WILL PROBABLY COME INTO CONFLICT STATUS IN THE NEAR FUTURE. THE PILOT MAY MAKE ANY MANEUVER NOT PROHIBITED ON HIS DISPLAY TO AVOID THE IMPENDING CONFLICT.	FLASHING ILLUMINATION OF ONE OF THE 36 POSITION INDICATOR LIGHTS. SOUNDING OF ALARM.
FLASHING PWI TO IFR PILOT	NONE. THIS IS AN ADVISORY. BE PREPARED FOR A POSSIBLE COLLISION AVOIDANCE COMMAND.	FLASHING ILLUMINATION OF ONE OF THE 36 POSITION INDICATOR LIGHTS. SOUNDING OF ALARM.
DON'T COMMAND	COMPLY WITH THE COMMAND. ACTIVATE ACKNOWLEDGMENT SWITCH. IF THE DON'T COMMAND DOES NOT PROHIBIT THE AIRCRAFT'S CURRENT MANEUVER, NO CHANGE IS REQUIRED.	FLASHING ILLUMINATION OF THE DON'T TURN RIGHT, DON'T TURN LEFT, DON'T CLIMB, OR DON'T DESCEND CROSS, AND FLASHING ILLUMINATION OF THE APPROPRIATE POSITION INDICATOR LIGHT. SOUNDING OF ALARM.
DO COMMAND	PERFORM INDICATED MANEUVER FOR AS LONG AS THAT MANEUVER REMAINS DISPLAYED. ACTIVATE ACKNOWLEDGMENT SWITCH. MAY PERFORM ANY ADDITIONAL MANEUVER NOT SPECIFICALLY PROHIBITED ON THE DISPLAY.	FLASHING ILLUMINATION OF TWO CROSSES AND ONE ARROW AND FLASHING ILLUMINATION OF APPROPRIATE POSITION INDICATOR. SOUNDING OF ALARM.
CONTROLLER ALERT	MONITOR THIS CONFLICT. IF PROGRESS OF CONFLICT RESOLUTION IS NOT SATISFACTORY, ISSUE COMMANDS TO ANY CONTROLLED AIRCRAFT.	APPROPRIATE DISPLAY ON CONTROLLER'S SCREEN.

most tests unless they are proven deficient. However, alternate rules are included in the following description and will be tested during some designated flights to ascertain their feasibility.

2.4.1 Baseline Pilot Response Rules

The baseline IPC response rules follow. The extent to which these baseline rules are to be preserved in the several types of flight test missions* is indicated.

(1) Response to Ordinary PWI. The presence of ordinary PWI(s) will be checked prior to maneuvering and the pilot will avoid initiating maneuvers that he judges to be unsafe. (This applies to the subject pilot at all times, but the intruder pilot, and the drone test pilot will disregard this usage of ordinary PWI(s) during validation flights when they are maneuvering to create a "turning aircraft conflict.") If either pilot by chance observes ordinary PWI(s) displayed when he is not approaching the the start of a maneuver, he may use the information to visually acquire the other aircraft, but need not do so.

(2) Response to Flashing PWI. The occurrence of flashing PWI(s) is revealed to the pilot by the sounding of an alarm. The pilot will use the flashing PWI location to visually acquire the intruding aircraft. The pilot may make any maneuver that he deems appropriate, or he may not respond at all. Any reaction to a flashing PWI is optional rather than mandatory. All subsequent IPC commands must be obeyed, even if they reverse the direction of a maneuver. (IPC test pilots will fly some validation missions in which they respond to flashing PWI(s), and others in which they will only record the action that they would have taken without actually responding to flashing PWI(s). Subject pilots will always assess the situation and maneuver to avoid a conflict if they feel that a maneuver is desirable or required.)

(3) Response to "Don't" Commands. When a "don't" command is displayed, the pilot must comply, even if it means stopping a maneuver. Any maneuver not specifically prohibited by the display may be performed. (Subject pilots and test pilots will always comply with negative commands.)

(4) Response to "Do" Commands. The pilot will execute the IPC-commanded maneuvers as soon as possible after seeing the command light on, even if the intruding aircraft has not been sighted. Turns will be executed with not less than 25 degrees of bank. Climbs should be performed with the highest rate the pilot is willing to achieve. A zoom climb is permitted if the pilot believes it to be desirable. Descents should be performed

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*See Section 3.0 for definitions of the terms used in subsequent paragraphs.

at not less than 500 feet per minute, and at higher rates if desired. The IPC-commanded maneuver must be continued until the IPC command light goes out.

2.4.2 Alternative Pilot Response Rules

In addition to the baseline rules, the flight tests will investigate alternative response rules that involve pilot discretionary maneuvers. Each pilot is prebriefed to execute maneuvers as he sees fit, i.e., rate of turn, climb rate, and descent rate are at the discretion of each pilot. Performance during maneuvers need not meet the standard minimum requirements previously listed for baseline pilot response rules. For tests investigating pilot discretionary maneuvers (see Section 3.4, Test Series #4), each pilot uses the IPC command only to determine the direction in which to make the maneuver, and the time to begin maneuvering. The exact nature and extent of the pilot's response is determined by his assessment of the resulting conflict resolution.

3.0 FLIGHT TEST PLANNING

The following terms are defined to facilitate the explanation of flight test operations:

Test Pilots - Professional pilots responsible for the conduct and safety of flight tests. Test pilots fly all validation missions and fly with subject pilots during subject pilot missions.

Subject Pilots - General aviation pilots selected to participate in the IPC flight test evaluation.

Interceptor (Intruder) and Drone Aircraft - The two aircraft flown in planned encounters. The general aviation test aircraft, designated drone, will contain either two test pilots or a subject pilot and a test pilot. The interceptor will contain two test pilots and will perform a series of planned near-miss intercepts on the drone.

Intercept or Encounter - A planned near-miss approach bringing the interceptor into conflict with the drone.

Mission - A number of encounters conducted over either a fixed reference point on the ground or while the drone is navigating a planned course. The proposed missions are approximately two hours in duration and involve 12 to 15 planned encounters.

3.1 Mission Types

Three basic types of IPC flight test missions have been identified: training, validation, and subject pilot missions. The training and validation missions will be flown by the test pilots exclusively. The subject pilot missions will be flown by subject pilots accompanied by test pilots.

3.1.1 Training Missions

Training missions are flights conducted by the test pilots to fulfill the following objectives:

(1) To develop a repertoire of near-miss intercept geometries

(2) To drill DABSEF test personnel and air crews in the coordination of intercepts.

The IPC flight test program uses three full-time, instrument-rated, professional pilots. Two pilots have extensive military flight backgrounds and are certified instrument, ground, and flight instructor rated. The training missions will maintain the test pilots' basic flying proficiency. Instrument and night flying proficiency are also desired. There is no plan to conduct encounters under actual IFR conditions. Having the capability to fly IFR flight plans, however, provides flexibility to conduct missions on days when there are VFR conditions on the course to be flown, but IFR conditions at the airport. It is desired to assess night visibility aspects in conjunction with IPC flight test missions. Night training missions will be scheduled to keep the test pilots' night flying capability current.

Training missions will also be conducted to develop a repertoire of near-miss intercept geometries. Several series of intercept profiles are being developed, beginning with straight and level flight, progressing to simple turning maneuvers, and then to climb or descent profiles. These maneuvers are further combined into climbing and descending turning maneuvers. The purpose of these training flights is to familiarize the test pilots and ground personnel with the techniques required to consistently perform near-miss intercepts. The pilots are training to perform the intercepts to within a few hundred feet of the subject aircraft to make the tests as realistic as possible.

3.1.2 Validation Missions

A validation mission is a series of encounters flown by the IPC test pilots to verify simulation results. Validation missions will be scheduled initially to qualify the IPC algorithm and thereafter when changes to the logic are implemented. The objective of the validation missions is to determine whether or not the selected algorithm parameter values provide desired results in operational encounter situations that are consistent with the baseline concept.

A basic purpose of the validation missions is to verify that the IPC system is ready for subject pilots to evaluate. Test pilots will evaluate the algorithm threshold values to determine whether or not they provide adequate warning under operational conditions. The command sequence will be evaluated to determine the timing of the commands and to characterize the evasive maneuvers. The encounter situations, from which marginal results are obtained, will be further scrutinized. Additional tests will be conducted, if necessary, to fully characterize the marginal situation. This situation, the results acheived, and recommendations to improve the IPC logic will be documented. If system refinements result from this process, the revised logic will be subjected to further validation missions as required.

3.1.3 Subject Pilot Missions

Subject pilot missions are flights in which the subject pilots will evaluate the IPC concept. These pilots will be instructed to evaluate the operational characteristics of the PWI and the IPC service during each encounter, and pilot reaction during the encounters will be tape recorded.

The purpose of these missions is to determine pilot reaction to the IPC concept as implemented. Many human factor aspects are being considered in planning the missions. The fact that there is a learning curve associated with mastering and thereby accepting any new technique is an important consideration. Therefore, two types of subject pilot missions will be flown:

(1) Familiarization missions

(2) Data gathering missions.

3.1.3.1 Familiarization Missions

Each subject pilot will fly one mission dedicated to familiarizing the pilot with the cockpit, flight test environment, and the use of the PWI portion of the display for visual acquisition. It is desirable that pilot confusion and disorientation with the flight test environment not contribute to pilot reaction to the IPC service because pilot reactions are an important result of the flight tests. At the same time, it is desirable that the pilots are not overly practiced at responding to IPC commands, since this would yield results that are not representative of IPC performance in an operational environment. Because PWI indications are expected to be relatively common in an operational environment, providing subject pilots with an opportunity to practice the use of PWI service is considered justifiable. Therefore, the familiarization mission will consist of an early portion in which no IPC indications are presented, followed by a portion in which the interceptor will fly near-miss encounters and only ordinary and flashing PWI indications will be presented. The subject pilots will be requested to resolve the conflicts as they normally would in a see and avoid airspace. The objectives of these subject pilot missions are:

(1) To permit the subject pilots to adjust to the cockpit communications, navigation, and general workload involved in flying a briefed flight plan.

(2) To permit the test pilot to evaluate the subject pilot's basic flying skills. This evaluation is necessary to provide the insight to analyze the subject pilot's reaction to the encounter.

(3) To familiarize the subject pilot with the procedure for supplying the desired information during each encounter.

(4) To permit the subject pilot to learn to use the PWI display.

3.1.3.2 Data Gathering Missions

Data gathering missions will be flown with the IPC concept fully implemented and will provide data for assessing IPC performance with subject pilots.

Each feature of the IPC concept will be evaluated. The point at which a pilot locates nearby traffic after being given the PWI service will be observed. Data will be accumulated regarding pilot response time, the type of response to the PWI service, and the pilot's estimation of the threat at the time of the steady and flashing warnings and commands. The latter will be compared to the algorithm's assessment of the situation. Pilot preferences for sequences of positive and negative vertical or horizontal commands (other than those provided by the IPC algorithms) will be recorded.

3.2 Flight Test Parameters

In order to verify IPC's effectiveness as a complete collision avoidance system, its performance in many types of mid-air conflicts must be tested. The flight parameters, which will change from test to test, are shown in Table 3-1. Most of the listed parameters are self-explanatory. Three choices of aircraft airspeed are indicated for testing. Since previous analysis has shown that faster aircraft require special consideration by IPC (especially when a fast aircraft is turning or has just completed a turn when IPC issues commands and advisories), it is desirable to include a fast aircraft in some flight tests. For early tests, 140 knots will be the highest attainable speed. Later, a faster aircraft will be acquired capable of speeds in excess of 200 knots. The encounters listed in this document (see Appendix A) indicate 140 knots as the highest speed tested. Therefore, some of the tests involving a 140-knot aircraft will be repeated using a 200-knot aircraft.

3.3 Encounter Classes

Each encounter of a single mission will usually use a different set of flight parameters. During a number of missions, encounters using identical sets of flight parameters will be tested. All such encounters that use the same set of flight parameters are grouped into one encounter class. A listing of applicable encounter classes appears in Appendix A in tabular form designating representative parameter values to be used for each class of encounters. In this listing of classes there are several characteristics of the encounter that will naturally vary from encounter to encounter, and no effort is made to vary these deliberately. These include range from the DABS sensor (which will vary from 5 to 60 miles), elevation angle of the aircraft with respect to the sensor, orientation of the aircraft track with respect to the sensor radial, effects of wind, and effects of varying visibility.

The list of encounters in Appendix A provides numbers of replications for each individual encounter. These are listed to provide a measure of relative importance of each encounter or encounter class to the total IPC flight test program. The composite listing of encounters represents an a priori estimation of a total flight test program sufficient to evaluate the major aspects of IPC. The list of encounters is not intended to imply that all encounters will be flown solely for the sake of exhausting the list. The flight test program is adaptive and allows for scheduling of new encounters that are shown to be

TABLE 3-1

KEY FLIGHT TEST PARAMETERS

Parameter Number	Parameter	Parameter Values
1	Encounter Equipment Status	DABS/ATCRBS DABS/DABS
2	Encounter Flight Rules Status	VFR/VFR VFR/IFR IFR/IFR
3	Aircraft Air Speed (nominal)	High Speed: 140 or 200+ kts Low Speed: 90 to 100 kts
4	Encounter Response Mode	Both aircraft respond to commands Intruder aircraft non-responding
5	Projected Horizontal Miss Distance (nominal miss, before IPC resolution)	Small: 0 foot Large: 3000 feet
6	Aircraft Horizontal Maneuver Status	Straight or one or both aircraft turning
7	Initial Separation (for turning encounters only)	2 to 3 nmi
8	Aircraft Vertical Maneuver Status	Level, climbing, or diving
9	Track Crossing Angle (angle between aircraft headings)	0, 15, 45, 90, 135, and 180 degrees
10	Pilot Response Rules	Minimum standard response Pilot discretion

necessary by the results of earlier missions. The encounters in Appendix A are grouped into classes in the way that they would be grouped for data analysis. However, individual encounters will be selected for flight by sampling from the encounter classes, rather than by exhausting the encounter classes one by one.

3.4 Test Series

IPC performance will be systematically investigated by consigning the data from each encounter to one broad category designated a test series. The encounter classes listed in Appendix A are arranged into ten test series. Each of the ten test series (Table 3-2) addresses a particular flight environment in which IPC performance must be assessed. Table 3-2 indicates flight test parameters that change and those that are constant during the course of each test series.

Test Series 1 involves straight and level aircraft intercepts at a number of track crossing angles. Only a few tests (2 per encounter class) will be made for head-on encounters, and the plurality of tests (10 per encounter class) will be made for 90-degree crossing intercepts, which represent more interesting tests because the 90-degree case is the most troublesome resolution problem.

A variety of turning geometries will be tested during Test Series 2. These include:

(1) Case 1: Aircraft on parallel tracks heading in the same direction before the turn, with tracks separated by 2 or 3 nautical miles. One aircraft turns 90 degrees, then rolls out to effect a 90-degree crossing intercept.

(2) Case 2: Aircraft in 90-degree crossing geometry before the turn. When aircraft separation is 2 or 3 nautical miles, as specified in Appendix A, one aircraft turns 90 degrees and rolls out to effect a nearly head-on encounter.

(3) Case 3: Aircraft on parallel tracks heading in opposite directions before the trun, with tracks separated by 2 nautical miles. One aircraft turns 90 degrees and rolls out to effect a 90-degree crossing intercept.

(4) Case 4: Aircraft in 30-degree merging geometry before the turn. When aircraft separation is 2 or 3 nautical miles, as specified in Appendix A, one aircraft turns 60 degrees toward the other aircraft, then rolls out to effect a 90-degree crossing intercept.

(5) Case 5: Aircraft on parallel tracks heading in the same direction before the turn, with tracks separated by 4 nautical miles. Both

TABLE 3-2

TEST SERIES

Test Series	Variable Parameters	Unchanging Parameters	Number of Encounters
1. VFR/Straight and Level	Track crossing angle Airspeeds Horizontal miss distance	Both aircraft DABS Both aircraft VFR Both straight and level Both respond to IPC Nominal IPC Pilot Procedures Full IPC service	133
2. Turning Aircraft	Geometry of turn Airspeeds Separation before turn Aircraft that turns (drone or <u>intruder</u>)	Horizontal miss distance = 0 Both aircraft DABS Both aircraft VFR Both level Both respond to IPC Nominal IPC Pilot Procedures Full IPC service	105
3. Climbing or Descending Aircraft	Airspeeds, vertical rate Aircraft that climbs or dives (drone or <u>intruder</u>) Altitude separation before maneuver Track crossing angle	Horizontal miss distance = 0 Both aircraft DABS Both aircraft VFR Both straight, one with vertical rate Both respond to IPC Nominal IPC Pilot Procedures Full IPC service	45
4. Maneuvers at Pilot Discretion	Track crossing angle Straight or turning Level or climbing or diving Maneuvering aircraft (drone or <u>intruder</u>) Airspeeds, vertical rate Separation before turn	Horizontal miss distance = 0 Both aircraft DABS Both aircraft VFR Both respond to IPC Discretionary IPC Pilot Procedures Full IPC service	70
5. DABS/ATCRBS	Track Crossing Angle Straight or turning Level or climbing descending Maneuvering aircraft (drone or <u>intruder</u>) Separation before turn	Horizontal miss distance = 0 Drone is DABS equipped Intruder is ATCRBS equipped Both aircraft VFR Airspeed = 100 knots Drone responds to IPC Nominal IPC Pilot Procedures Full IPC service	85

TABLE 3-2
TEST SERIES (cont.)

Test Series	Variable Parameters	Unchanging Parameters	Number of Encounters
6. IFR/IFR	Track crossing angle Straight or turning Level or climbing or descending Maneuvering aircraft (drone or intruder) Separation before turn	Horizontal miss distance = 0 Both aircraft DABS Both aircraft IFR Airspeed = 140 knots Both respond to IPC Nominal IPC Pilot Procedures Full IPC service	35
7. VFR/IFR	Equipment status of intruder (DABS or ATCRBS) Airspeed Track crossing angle Straight or turning Level or climbing or descending Maneuvering aircraft, IFR aircraft (drone or intruder)	Horizontal Miss Distance = 0 Both respond to IPC Nominal IPC Pilot Procedures Full IPC service	95
8. Nonresponding Aircraft	Track crossing angle Straight or turning Level or climbing or descending Maneuvering aircraft (drone or intruder)	Horizontal miss distance = 0 Both aircraft DABS Both aircraft VFR Airspeed = 100 knots Intruder aircraft does not respond to IPC Nominal IPC Pilot Procedures Full IPC service	35
9. Night Tests	Track crossing angle Straight or turning Level or climbing or descending Maneuvering aircraft (drone or intruder) Separation before turn	Horizontal miss distance = 0 Both aircraft DABS Airspeed = 100 knots Both respond to IPC Nominal IPC Pilot Procedures Full IPC Service Both aircraft VFR Tests run at night	35
10. Two Subject Pilots	Track crossing angle Straight or turning Level or climbing or descending Maneuvering aircraft (drone 1 or drone 2) Separation before turn	Horizontal miss distance = 0 Both aircraft DABS Both aircraft VFR Airspeed = 100 knots Both respond to IPC Nominal IPC Pilot Procedures Full IPC service Subject pilots in both aircraft	35

aircraft turn at the same time toward each other, complete a 90-degree turn, and roll out to effect a nearly head-on encounter.

During Test Series 2 and for encounter classes involving turns in later test series, the occurrence of IPC commands may instruct the pilot of the turning aircraft to stop turning ("don't" commands) and/or start another type of maneuver ("do" commands) before he has completed his planned turn. Likewise, the occurrence of flashing PWI(s) may motivate a pilot to stop turning and, if his response rules allow him to react to flashing PWI(s), he may respond accordingly. If a subject pilot notices before he begins to turn that a PWI indicates traffic in the direction of his planned turn, he should try to locate that traffic and should not turn if he sights an aircraft that would become a threat if he were to turn. When a 200-knot aircraft becomes available, it should be used in Test Series 2 as a replacement for the 140-knot interceptor aircraft. When this replacement is made, the specified separation before the turn should be increased by one nautical mile. Only the total number of encounters for this series is listed. Representative encounters from all those listed will be flown.

Test Series 3 involves aircraft performing vertical maneuvers. The aircraft will perform various crossing intercepts in the horizontal plane, separated initially by whichever altitude is specified for that encounter class in Appendix A. One of the aircraft will initiate a climb or a dive with a specified vertical rate at whatever time is necessary to effect a projected zero vertical miss distance when the closest approach occurs in the horizontal plane. The maneuvering aircraft will continue its climb or dive until the aircraft separation is 200 feet, or until the pilot receives and reacts to IPC commands or advisories. As for horizontal maneuvers, the preplanned vertical maneuvers may have to be abandoned whenever IPC commands or advisories occur. All pilots should follow IPC "do" and "don't" commands, and the pilots permitted to do so by their prebriefed response rules should react to flashing PWI(s) whenever they feel the situation warrants it. Furthermore, before he begins a vertical maneuver, if a subject pilot notices that an ordinary PWI indicates traffic in the direction of his planned maneuver, he should try to locate that traffic and should not maneuver if he sights an aircraft that would become a threat if he were to maneuver. When a 200-knot aircraft becomes available, it should be used as a replacement for the 140-knot interceptor aircraft specified in Test Series 3 for some of the encounter classes.

For missions flown to collect data for Test Series 4, pilots will be prebriefed to use pilot discretion in responding to IPC commands, as provided in Section 2.4. Pilots will begin their IPC commanded maneuvers as soon as possible after seeing the IPC command lit, and will maneuver in the commanded direction, but may use whichever turn, climb, or descent rate they feel is necessary. During all other missions, pilots will be prebriefed to maneuver at the required minimum or greater rates and to continue their maneuver until the IPC command light goes off.

Test Series 5 through 8 investigate mid-air encounters in which one aircraft is ATCRBS-equipped (the intruder aircraft), one or both aircraft are IFR (the intruder and/or the drone), or one aircraft (the intruder) does not respond to IPC commands.

Test Series 9 investigates IPC performance at night. A sample of representative encounters will be tested at night, using standard pilot procedure rules and full IPC service.

Test Series 10 investigates IPC performance when subject pilots fly each of the aircraft, each observed by an IPC test pilot occupying the right seat and serving as pilot in command. These flights are planned to investigate the capability of IPC when both pilots use the IPC service as it would be used operationally. This is necessary to evaluate the service when both subject pilots respond at will to the flashing PWI messages.

In addition to these basic test series, flight testing may include investigations of hybrid flight geometries (for example, one aircraft both turning and climbing), and multi-aircraft encounters. In addition, some missions may be scheduled to evaluate the response of subject pilots to a PWI only service in which ordinary and flashing PWI(s) are issued but commands are inhibited.

4.0 FLIGHT TEST FACILITIES

The DABS Experimental Facility (DABSEF), originally constructed to accommodate a large variety of specialized testing of DABS surveillance and link functions, has been augmented to provide an experimental IPC mode of operation. DABSEF is now capable of supporting IPC flight testing, operating similarly to a typical terminal DABS sensor. Although DABSEF is functionally equivalent to a "typical DABS sensor," it should not be confused with a DABS sensor from the point of view of size or complexity.

DABSEF developments have been reported regularly in the DABS Quarterly Technical Summary [Ref. 9]. As far as single sensor IPC operations are concerned, DABSEF performance in its sensor demonstration configuration closely resembles that of the Phase II NAFEC sensors, as described in Ref. 7. Some minor link format variations that apply to DABSEF are explained in detail in Ref. 8.

In this section the DABSEF ground facilities, as depicted in Fig. 4-1, and the DABS/IPC airborne facilities, as depicted in Fig. 4-2, will be described. The sensor calibration procedures pertinent to flight testing will also be summarized.

4.1 Ground Systems

The various devices that comprise the IPC Test Bed are described in this subsection. (See Fig. 4-1.) A core component of the ground system is the Systems Engineering Laboratories SEL-86 computer.

4.1.1 Sensor Demonstration Program

A real-time program (the Sensor Demonstration Program [SDP]) establishes the timing and control for the DABSEF sensor mode. The SDP controls real-time activities on a fixed 10-millisec time frame, during which an ATCRBS/DABS all-call interrogation and one or more DABS discrete interrogations are scheduled. The major elements controlled by the SDP (including various important interfaces) are illustrated in Fig. 4-3.

4.1.2 Cockpit Display Monitors

The IPC program, part of the SDP, generates messages that the DABS Software System (see Fig. 4-3) formats for delivery to the aircraft. When a DABS reply is received as the result of an interrogation that contained IPC/PWI information, the same message is immediately fed to an identical IPC/PWI monitoring display at DABSEF (see Fig. 4-4). This "message release time-interlock" synchronizes cockpit and Cockpit Display Monitor (ground) displays.

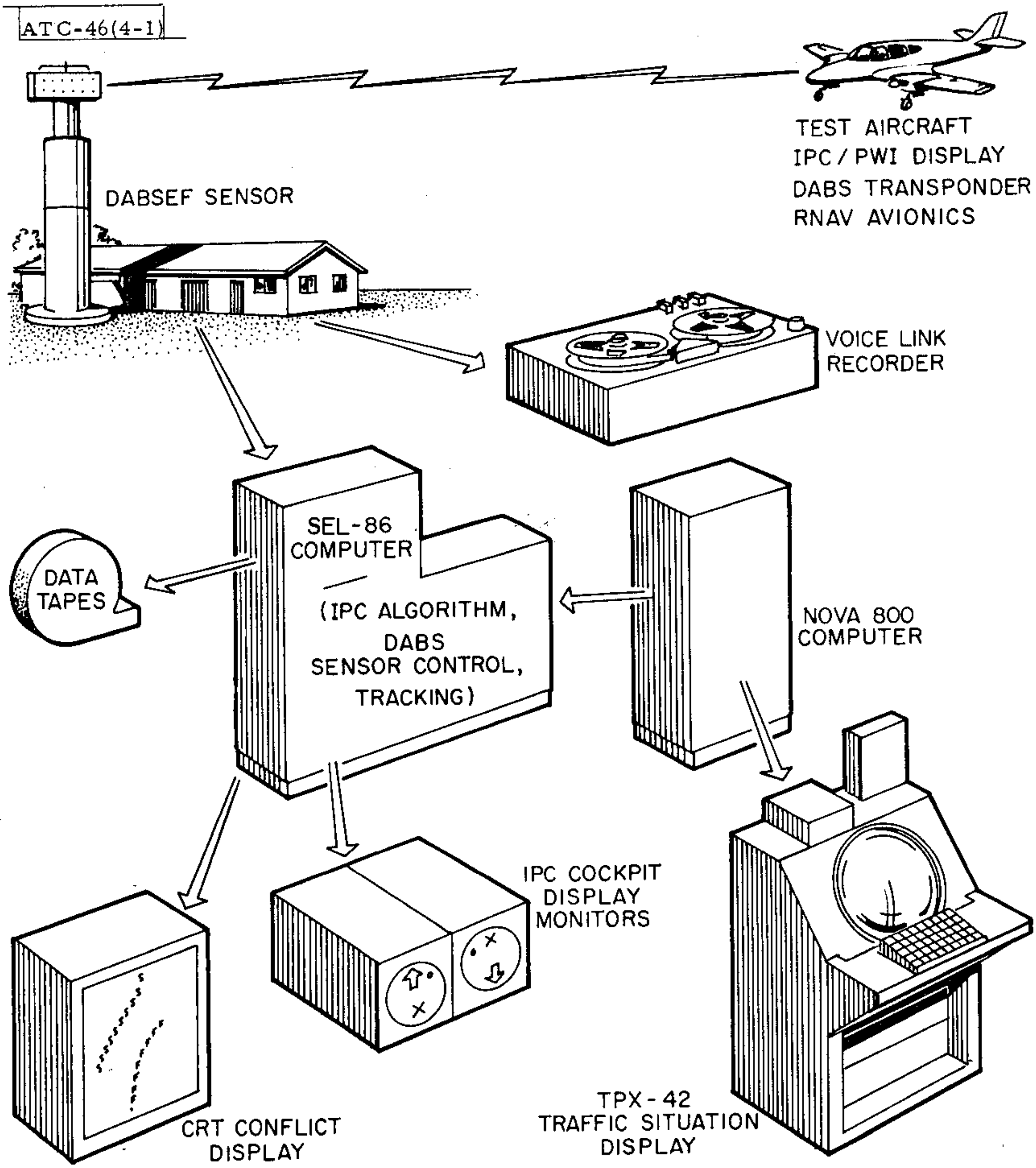


Fig. 4-1. DABSEF IPC flight test bed.

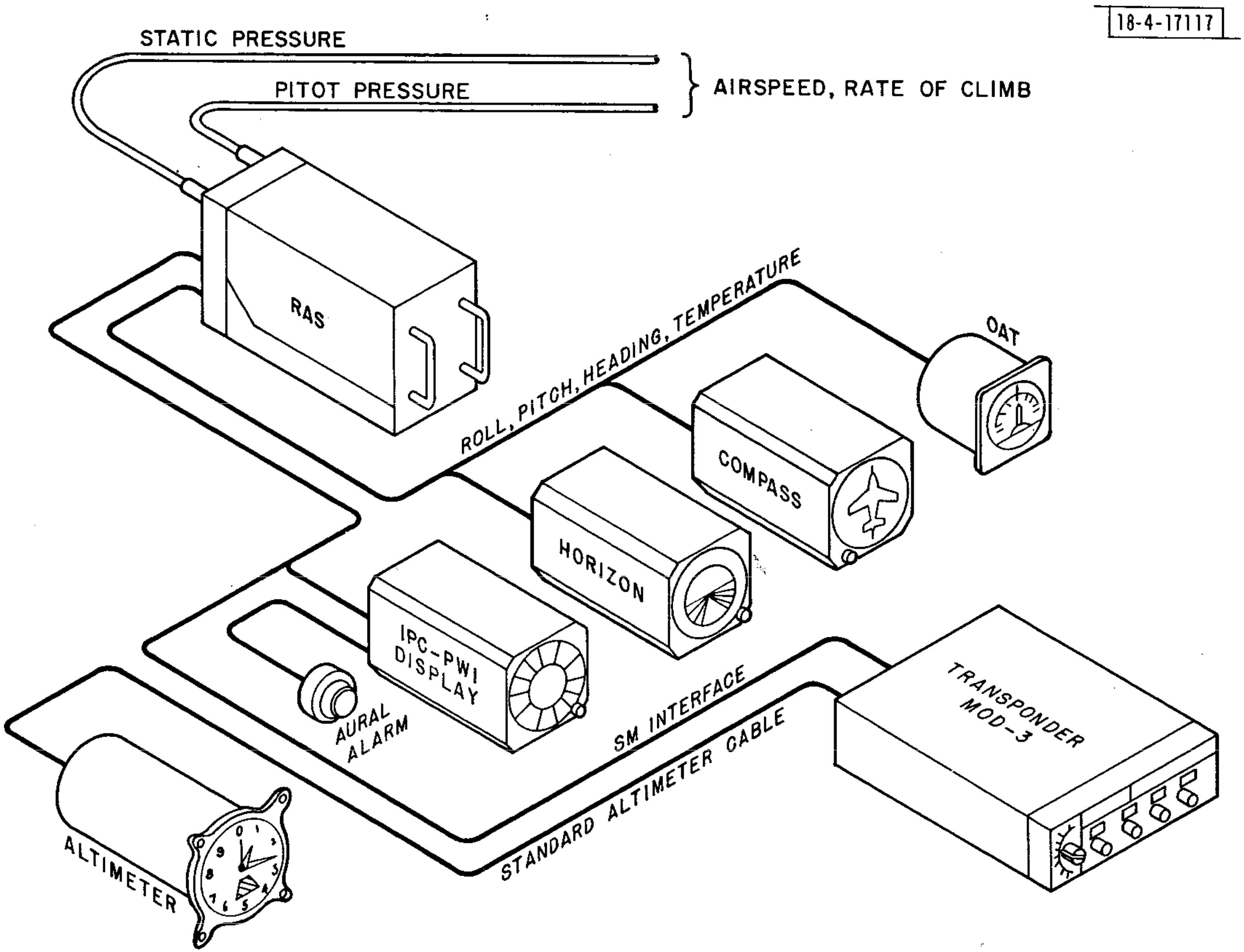
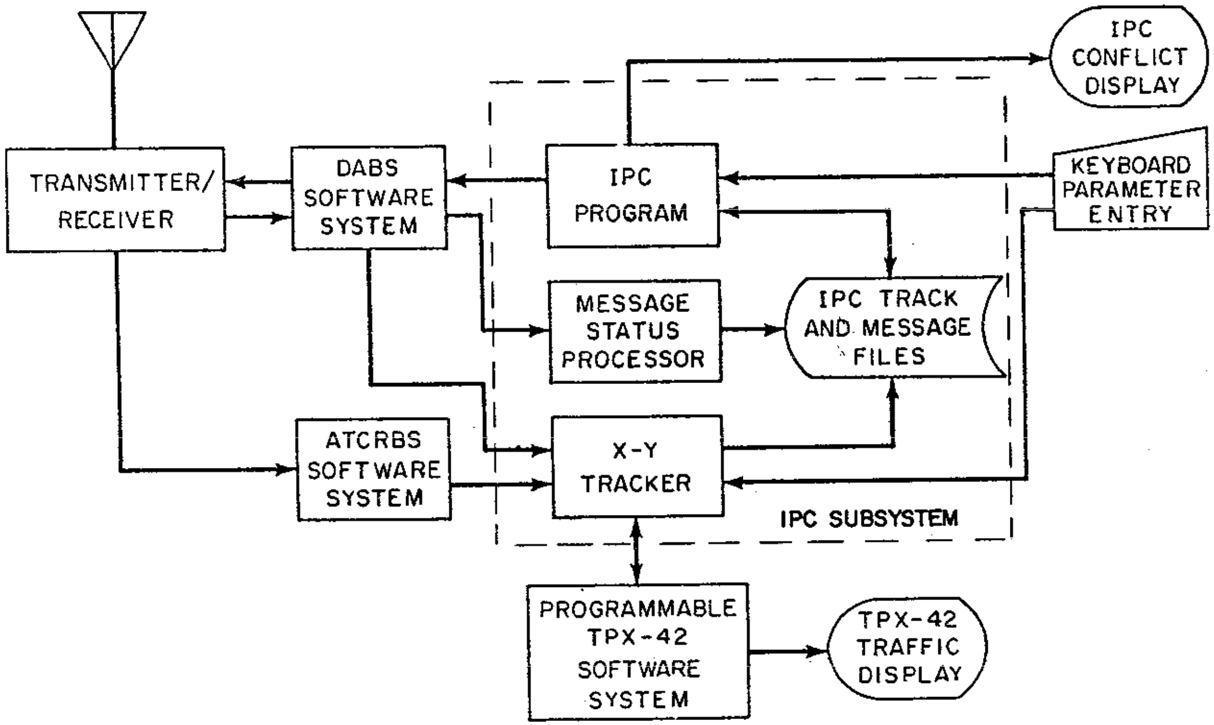


Fig. 4-2. IPC flight test avionics.



ATC-46(4-3)

Fig. 4-3. DABSEF sensor components

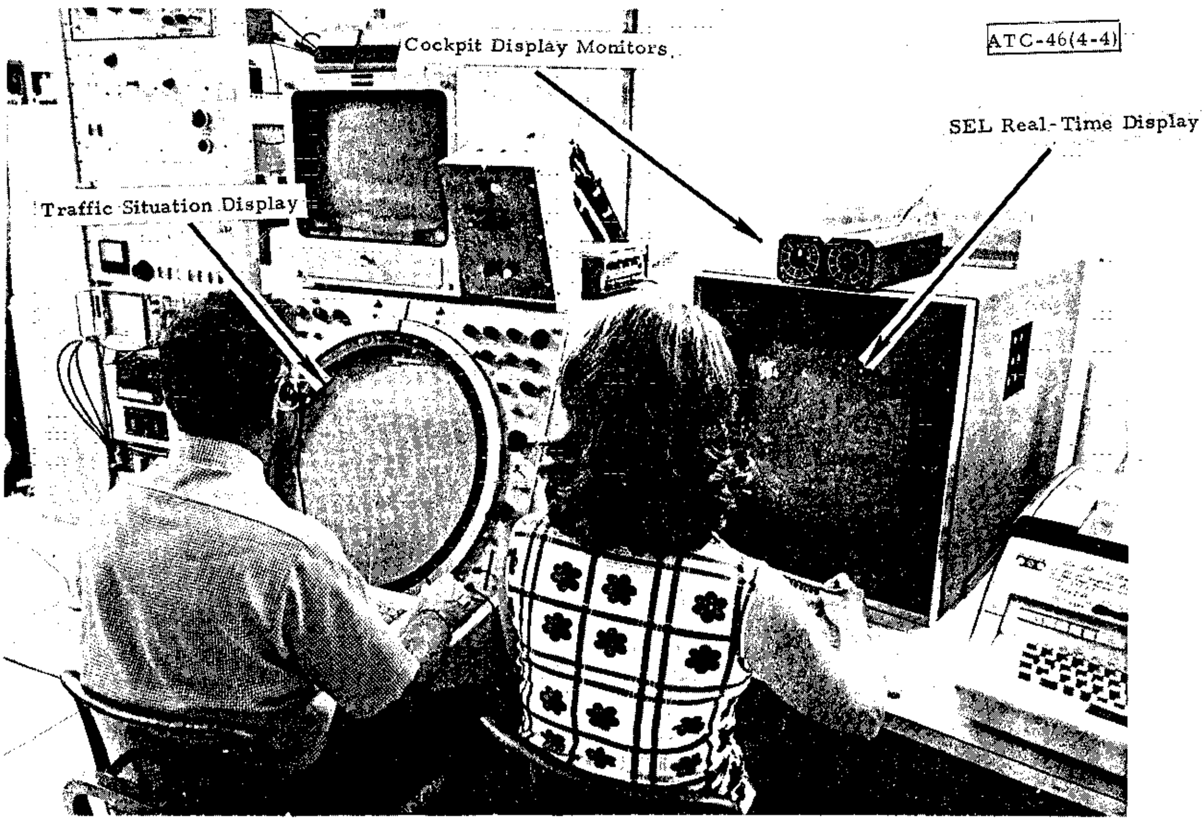


Fig. 4-4. DABSEF control room.

4.1.3 Real-Time Display

The SEL-86 at DABSEF drives a CRT display. This display is illustrated on the right of Fig. 4-4. A graphics program, which replaces the target situation display illustrated on the SEL-CRT in Fig. 4-4, has been installed, with a tabular listing in real-time of all of the important IPC parameters and tracker outputs for the IPC aircraft (see Table 4-1). The real-time display satisfies two requirements: (1) information is provided to allow the ground personnel to assist in initiating the desired intercepts, and (2) it becomes possible for the IPC analyst to observe system performance in real-time.

4.1.4 Situation Display

A 22-inch programmable display (see Fig. 4-4), driven by a Nova-800 computer, is utilized as a "remote controller" situation display*. DABS and ATCRBS target reports, fed from the SEL-86 via the Nova-800 to this display, permit ground personnel to observe the test aircraft flight paths, and to provide test pilots with traffic advisories for ATCRBS-equipped aircraft in the test area. The situation display has an associated keyboard device that allows an operator to enter aircraft tags and to select any of the aircraft for tracking, similar in operation to an ARTS console.†

4.1.5 VHF Communication System

The DABSEF test installation includes two VHF transceivers that are connected via various patch panels to two consoles. In addition, a scanning VHF receiver is used for monitoring various ATC frequencies that may be of interest to the test pilots. The audio outputs of either or both of the VHF transceivers may be tape recorded. Audio mixing on separate consoles is provided for all VHF sources for each of two operators, and a mixer/amplifier is provided to supply VHF output to speakers in the DABSEF console room.

4.1.6 Audio Recording System

A remote controlled 4-channel tape recorder has been configured to provide a time synchronized recording of VHF transmissions and receptions from either of the two VHF transceivers.‡ Two of the audio tracks are used for recording time pulses: one for system starts, and one for multiples of 16 antenna revolutions (scans). During audio playback, a special servocontrol, which counts scan pulses, can be used to orient the tape to begin precisely at any integer multiple of sixteen scans (approximately once each minute). The same autostart that is used during record can thereby be used by a playback

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*This 22-inch display, the OD-58T, and the Nova-800 computer were originally interfaced by the Airborne Instruments Laboratory as components of a programmable TPX-42 beacon system.

†Operator initiated tracking is a TPX-42 program option. All targets are tracked by the DABS sensor, but these tracker outputs are only available in the SEL computer and the SEL CRT.

‡The audio recording is initiated upon startup of the SDP system in the SEL-86.

TABLE 4-1
A REAL-TIME DISPLAY OF IPC DATA

TIME: 10: 43: 16:
ENCOUNTER 6

HISTORY					VARIABLES	THRESHOLDS
SCAN	DAB 601	DAB 613	POSCMD	COMMENTS	RANGE = 1.92	RSPWI = 1.83
420	S	S	0		DOT = -61.2	MDTH = 3040
421	S	S	0		TH = 34.1	TFPWI = 45
422	F	F	-2	CAFLG	TV = -106.1	TCMD = 32
423	R	R	1	RULE A		TIFR = 0
424	R	R	1		ALT = 293	AF = 1000
425	R(ACK)	R	1			AFPWI = 1000
426	R/C	R/C	2		MD = 3440	
427	R/C(ACK)	R/C	3		XANG = 130	
428	L/C	R/C	3	RULE C		
EQUIP	DABS	DABS			OTHER: 601 VS 166	SPWI 12L
FR	VFR	VFR				
HEAD	30	173				
SPEED	112	87				
TURN	0	LEFT				

program on the SEL-86 to provide synchronized audio playback of VHF discussions with presentation of the digital data (see Section 4.1.7). In addition to one channel for VHF commentary, a second channel is reserved for operator comments, which may be inserted during the mission or during playback.

4.1.7 Mission Playback Capabilities

All the elements of the SDP system that operate on the target report data (i.e., beginning with the X-Y tracker) have been duplicated in a nonreal-time simulation program that may be driven from the SDP digital data tapes. A program has been written to read each SDP data record, to note the mission time at which it was recorded, and to delay it until the appropriate time has elapsed before inserting it into the corresponding program buffer. The result has the appearance of a real-time playback of the X-Y tracker, the IPC system, and all the input/output presentations. The mission playback also starts the audio playback for a synchronized presentation and may be utilized for: (1) reconstructing (in real-time) interesting encounters during which pilot reaction commentary was recorded (useful for debriefing pilots), and (2) experiments with variations in the X-Y tracker, the IPC system, and the CRT graphics presentation. In addition, the playback serves as a compact form of demonstration for visitors to DABSEF.

4.2 Aircraft and Avionics

A number of aircraft are being instrumented with DABS transponders and IPC displays for the IPC test program. In addition, various other aircraft with only ATCRBS transponders (thereby requiring no special installations) are to be used to complement the basic tests. In this section the aircraft to be specially instrumented and the avionics involved in the flight test configuration are described.

4.2.1 Aircraft Inventory

Table 4-2 lists the primary aircraft selected for instrumentation in conjunction with flight testing. At this writing the two Cherokee aircraft are fully configured and will serve as the test aircraft for the initial validation testing. The Aircraft State Readout (RAS) equipment (described in Section 4.2.5) has been installed in the Cherokee-180 and the Cessna-172, which will serve as drone aircraft in the first subject pilot tests.

4.2.2 Basic Avionics

Each aircraft is equipped with a full complement of navigation and communication gear, including an ATCRBS transponder, an RNAV computer with digital DME(s), dual VHF transceivers, and an encoding altimeter. Only the test avionics is further described in this document.

TABLE 4-2

IPC TEST AIRCRAFT

Aircraft Type	No. of Engines	Hp.	Cruising Speed (mph)	Service Ceiling (ft)	Test Application
Piper Cherokee-6	1	300	168	16,250	Algorithm validation
Piper Cherokee-180	1	180	143	16,400	Low-wing typical G/A aircraft
Cessna -172	1	150	131	13,100	High-wing typical G/A aircraft
Beech Bonanza	1	285	200	18,300	High-speed G/A interceptor

4.2.3 DABS Transponder

As in the case of the DABSEF ground system, the transponders used for IPC testing are functionally similar to the units described in Reference 7. The transponders, illustrated in Fig. 4-5, are built using commercially available general aviation units. They will support all the functions required for IPC testing in a manner identical to that described in Reference 7.

4.2.4 IPC/PWI Display

The IPC/PWI display faces (purchased from Bendix Avionics Division) were packaged by Lincoln Laboratory with the appropriate drivers and interface logic to connect them to the DABS transponders (see Fig. 4-6). The display operation was discussed in Section 2.0.

4.2.5 Readout of Aircraft States (RAS)

The remainder of the special instrumentation package, depicted in Fig. 4-2, consists of several instruments that sense aircraft speed and attitude parameters and provide, via the RAS equipment, data that may be used in post-flight data analysis to determine the error sources contributing to IPC performance degradation. These instruments provide, on demand by the transponder (i.e., upon request from the ground sensor), samples of pitch angle, roll angle, gyro heading, rate of climb, and outside air temperature. The RAS unit combines samples from each of the indicated devices into a single downlink "Comm-B transaction" for readout at DABSEF. Each time the ground sensor requests a Comm-B downlink from the RAS unit (nominally once per scan) the above process results in a sampling of all the aircraft state devices.

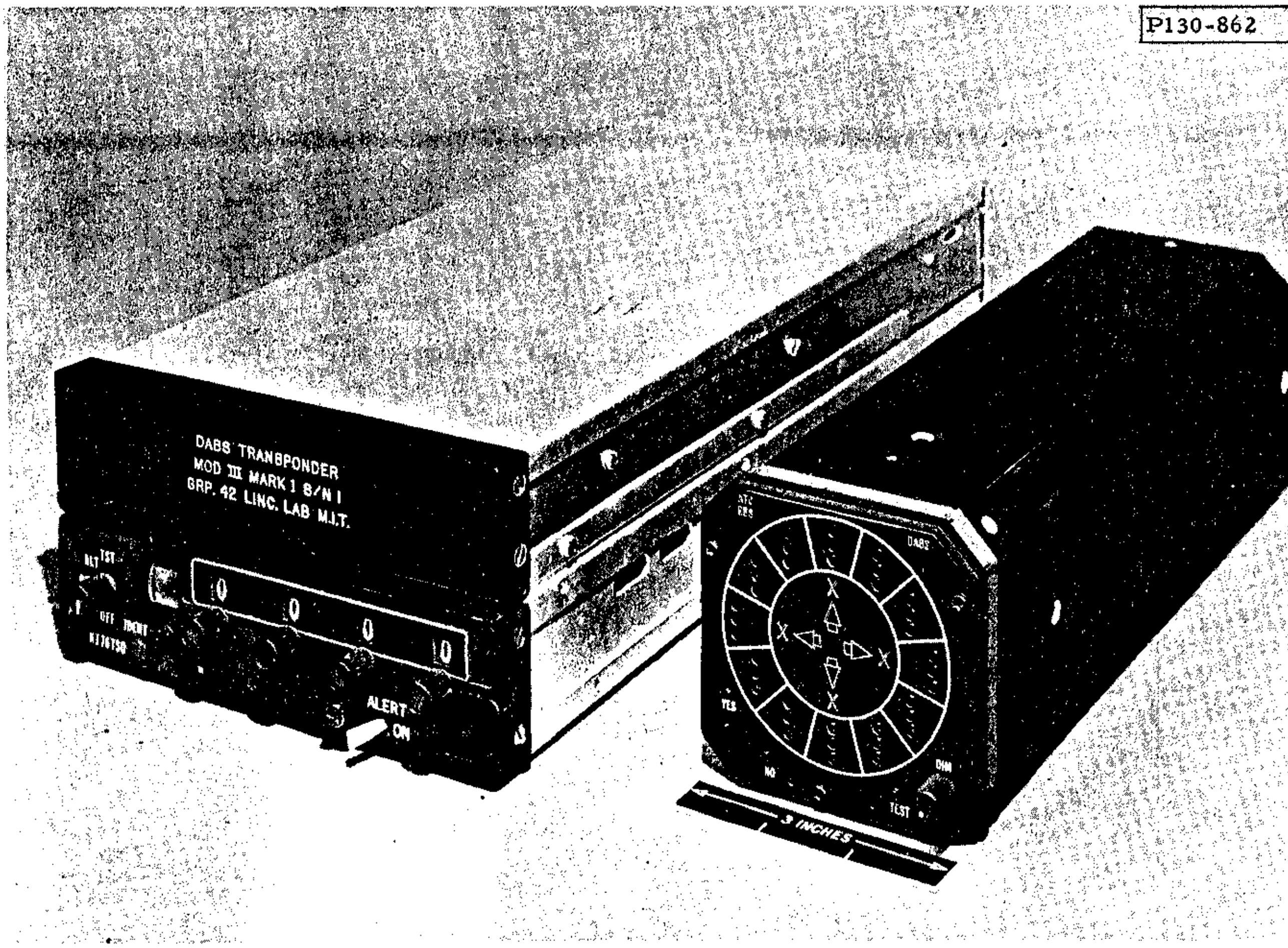


Fig. 4-5. DABS transponder and IPC display.

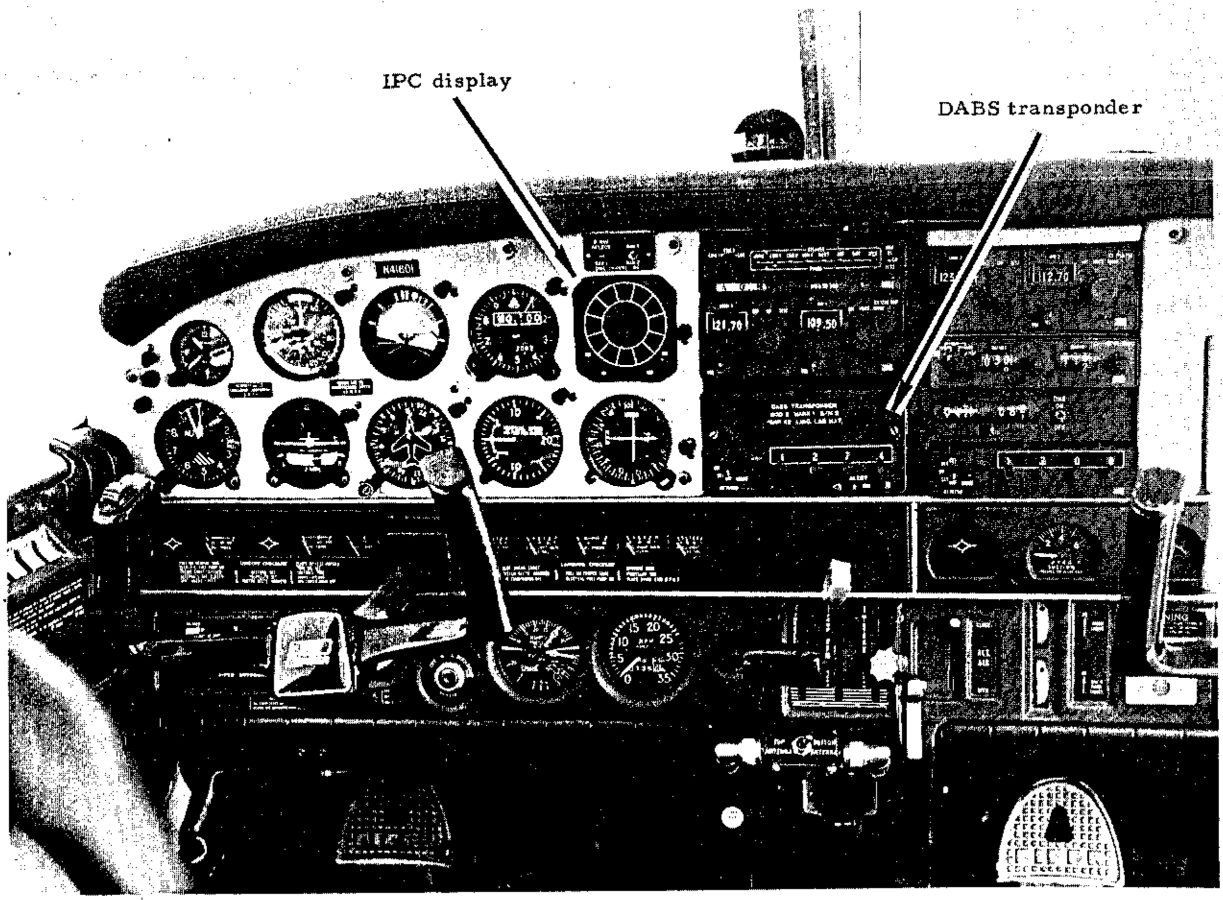


Fig. 4-6. Cherokee-6 instrument panel with avionics installed.

4.3 System Data Validation

The suitability of DABS data for use in conflict avoidance is of interest. Thus a primary concern during flight testing will be the characterization of surveillance errors that may contribute to less than desired IPC performance. In order to obtain an accurate assessment of surveillance errors, a set of special purpose data analysis programs has been assembled as part of the DABS development. During each IPC mission, a large amount of redundant data is accumulated upon which to base a post-flight reconstruction of the actual aircraft position as a function of time. In addition, the RAS unit onboard each aircraft will eventually provide even more redundancy. On the basis of extensive analysis of DABS sensor data for the DABS development program, it was decided that suitable track reconstruction from redundant data would adequately serve the performance assessment requirements of IPC. A report substantiating this decision is forthcoming from the DABS development program.

5.0 FLIGHT TEST OPERATIONS

Flight test operations are the activities performed at DABSEF and in the aircraft to support IPC flight testing. Test flights are performed within a 60-nmi radius of DABSEF.

5.1 Operation Types

Two types of flight test operations have been developed: operations that are conducted over a fixed ground location, and operations that are conducted along a planned course to the north and west of Hanscom Field.

5.1.1 Fixed-Point Operations

Fixed-Point operations include groups of encounters flown by test pilots over a fixed ground location easily recognized from the air and therefore convenient for navigation and maneuver staging. An example of such a location is the Haystack radome (Fig. 5-1), which is approximately 14 nmi northwest of DABSEF. The location has good coverage from the Boston-and Gardner-VOR; it is located 27 DME on the 320-degree radial of BOS and 25.6 DME on the 94.5-degree radial of GDM. An example of a two-hour validation mission involving twelve fixed point encounters is presented in Appendix B.

5.1.2 Planned Course Operations

Operations, which are conducted according to a flight plan over an outlined course, are referred to as planned course operations. The fixed-point operations, although ideal for the test pilot validation flights, do not provide sufficient realism for subject pilot flights. The planned course provides a normal operational cockpit workload in which to assess pilot reaction to the IPC system.

An example of a planned course operation flown over a triangular course follows. The corners of the triangle are Haystack, Gardner-VOR (GDM) and Manchester-VOR (MHT). GDM is 40 miles from DABSEF, and MHT is 25 miles from DABSEF. The drone flight plan (Fig. 5-2) provides the subject pilot with detailed instructions to make a clockwise circuit of the course. The subject pilot is aided by the test pilot to ensure that navigation does not provide excessive cockpit workload. An interceptor flight plan (Fig. 5-3) has been outlined on the course map. Positions of the seven scheduled intercepts are shown. The course is usually flown two times to complete fourteen intercepts in approximately two hours. Other planned courses have been designed (see Appendix C); some are clear of VOR(s) and established airways and use designated waypoints flown using RNAV equipment. Less experienced subject pilots will be aided by a test pilot to maintain the cockpit navigation workload at a reasonable level.

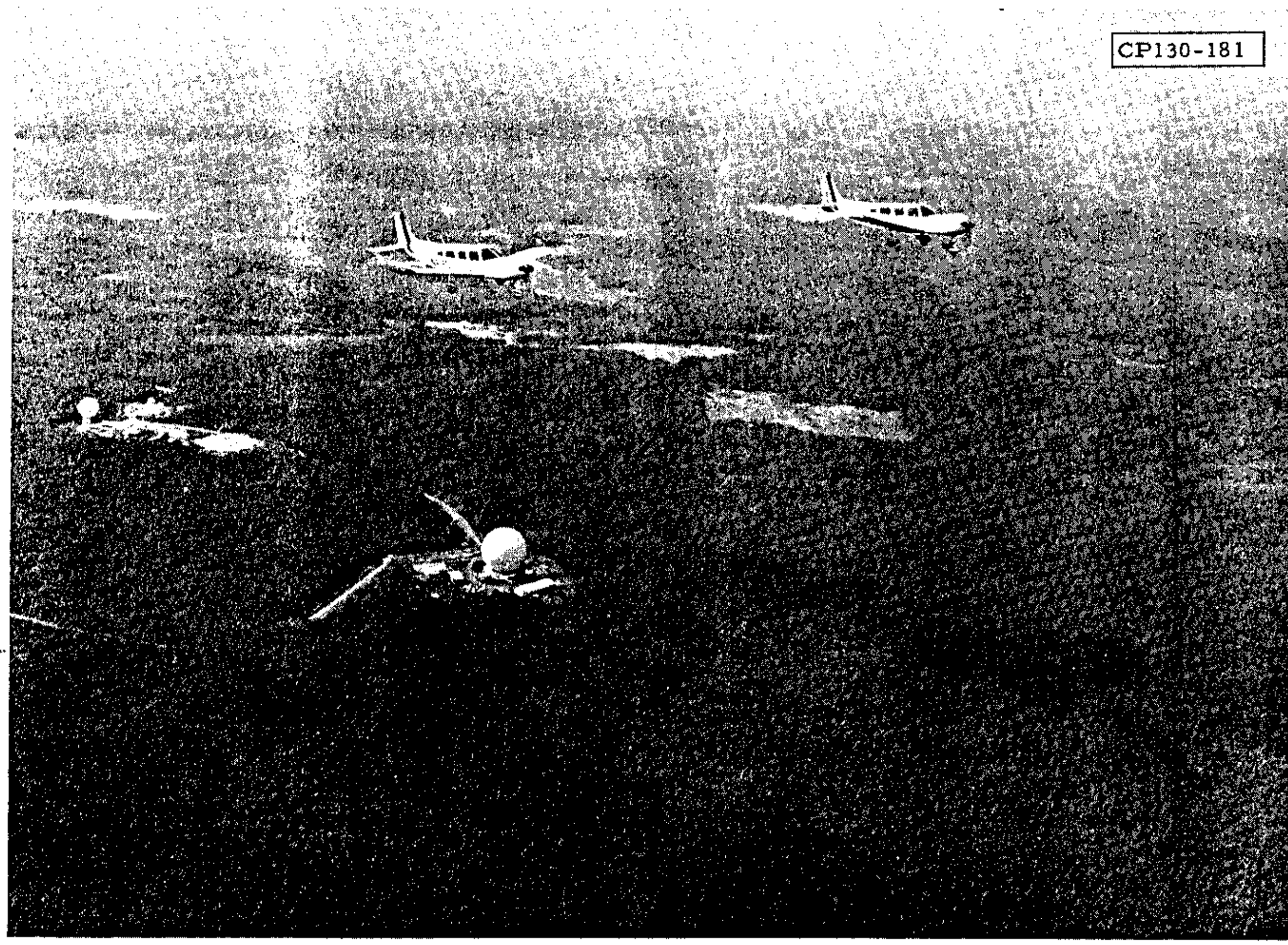
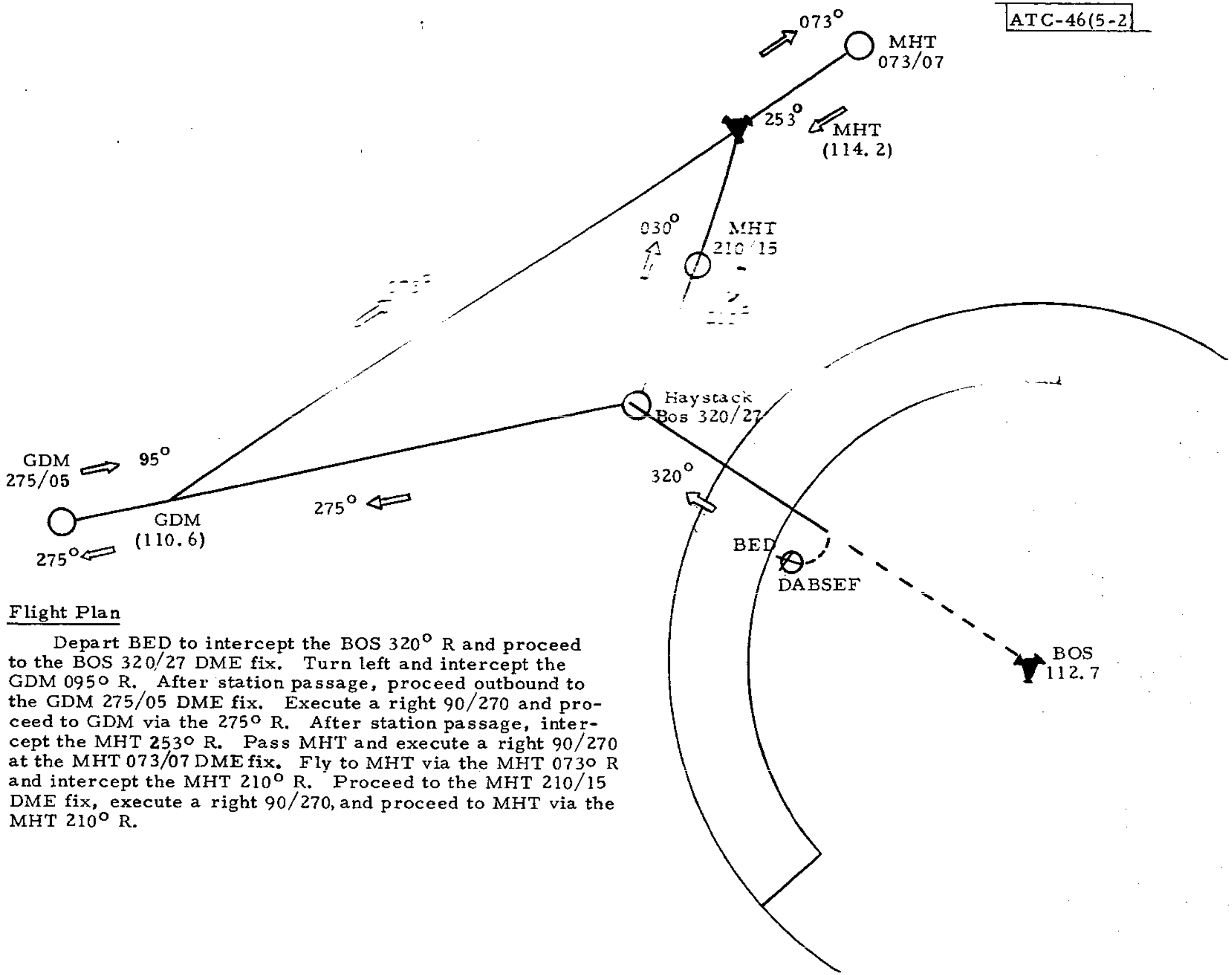


Fig. 5-1. Haystack radome staging point.

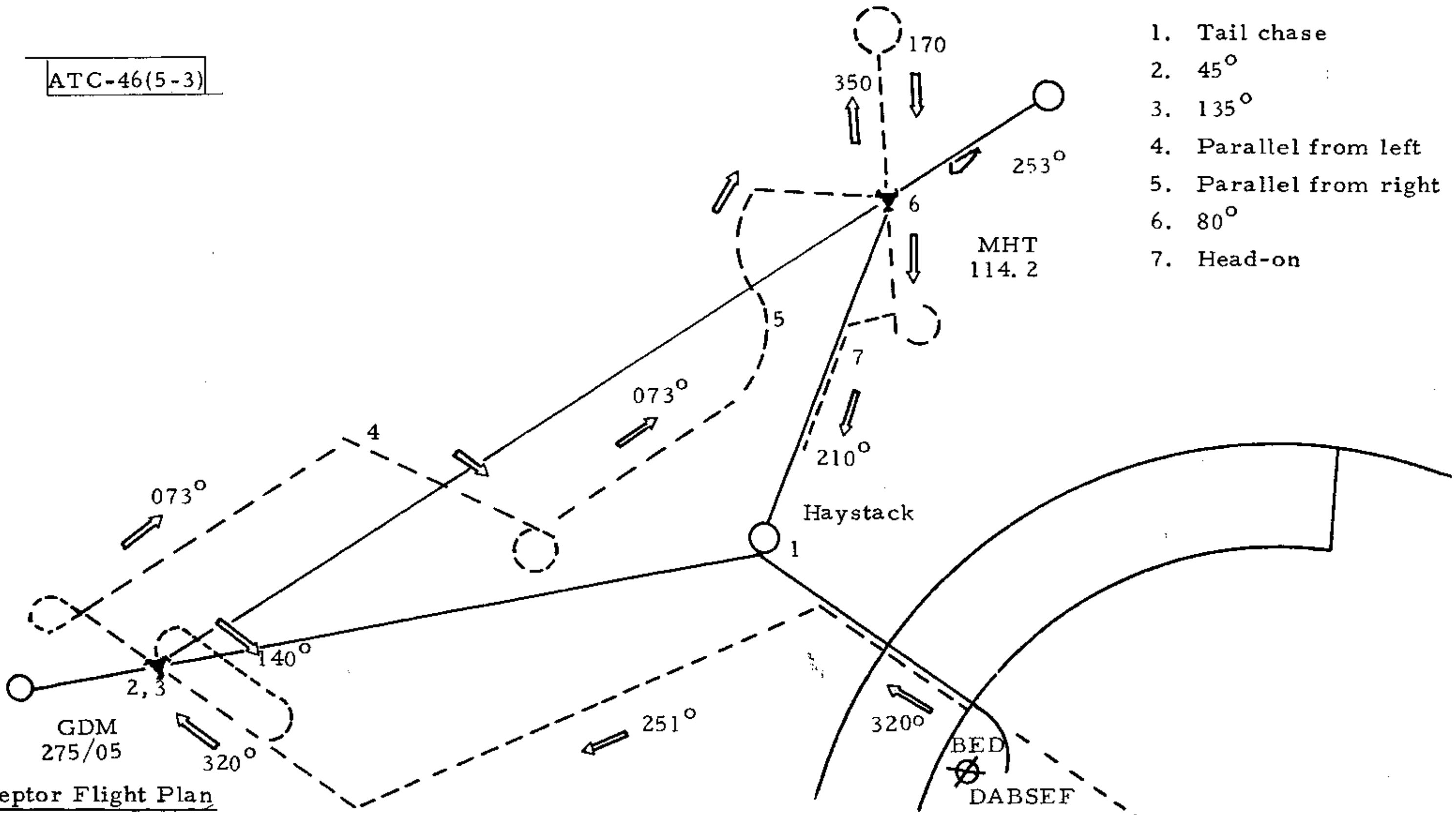


Flight Plan

Depart BED to intercept the BOS 320° R and proceed to the BOS 320/27 DME fix. Turn left and intercept the GDM 095° R. After station passage, proceed outbound to the GDM 275/05 DME fix. Execute a right 90/270 and proceed to GDM via the 275° R. After station passage, intercept the MHT 253° R. Pass MHT and execute a right 90/270 at the MHT 073/07 DME fix. Fly to MHT via the MHT 073° R and intercept the MHT 210° R. Proceed to the MHT 210/15 DME fix, execute a right 90/270, and proceed to MHT via the MHT 210° R.

Fig. 5-2. Drone flight plan.

ATC-46(5-3)



Interceptor Flight Plan

The interceptor (chase) aircraft will depart BED and perform a tail chase (1) intercept on the BOS 320° R. After completion, the chase aircraft will fly a heading of 251° to intercept the GDM 140° R and fly inbound on a 320° heading. Both aircraft will use their DME from GDM to perform a 45° intercept (2) over GDM. At GDM the chase aircraft will turn right and parallel the 140° R until 5 DME. At 5 DME the chase aircraft will turn right and intercept the 140° R inbound to GDM. Over GDM the chase aircraft will generate a 135° intercept (3). At 2 DME past GDM on a 320° heading, a left 270° turn will enable the chase aircraft to parallel the MHT 253° R and perform the two parallel intercepts (4 and 5). At MHT the chase will turn left and intercept the MHT 350° R and fly to the 7 DME fix. A 90/270 turn and interception of the MHT 350° R inbound will enable an 80° intercept (6) over MHT VORTAC. The chase aircraft will continue on the radial until 4 DME and do a left 270° turn and intercept the MHT 210° outbound. This will accomplish the head-on (7) maneuver.

Fig. 5-3. Interceptor flight plan.

5.2 Intercept Control Procedures

All intercepts conducted by the test aircraft are flown in accordance with the safety procedures in Appendix E. A test pilot will be present in the cockpit of each test aircraft during all missions, and two test pilots will be present in each cockpit during validation missions. During subject pilot missions, a test pilot will accompany the subject pilot. All intercepts will be conducted clear of clouds and with a five-mile or greater visibility. The intercept safety is the prime responsibility of the test pilots aboard the interceptor and the drone. Intercept control may rely totally on the pilot's use of RNAV, or it may involve ground assistance.

5.2.1 Pilot Controlled Intercepts

The interceptor aircraft will perform a series of near-miss approaches on the drone to evaluate the IPC system. The drone pilot is given specific altitude, airspeed, and track information to maintain for each leg of the course to be flown.

The drone pilot deviates from the planned course only when executing a conflict escape maneuver. During pilot missions, the subject pilot is not aware of the types of encounters, nor of the locations at which they are to occur; also, the subject pilot is not able to monitor the IPC test dedicated frequency used by the test pilots and DABSEF control. The drone test pilot is in direct communication with the interceptor, which has primary responsibility for the conduct of each intercept and is aware of the details of the drone's flight plan. The drone test pilot will report initiation and completion of all planned heading changes when flying the course. The interceptor pilot will periodically query the drone test pilot regarding the location of his aircraft. Upon request, the drone test pilot responds with the DME reading to the VOR or waypoint being used for navigation, and with ground speed as calculated by the RNAV equipment. The interceptor pilot checks this information with the present position of the interceptor aircraft to determine the corrections necessary for intercept. The interceptor pilot may increase or decrease his airspeed to coordinate the intercept.

The interceptor pilot relies on the ground personnel at DABSEF to provide beacon equipped traffic advisories and also to monitor the subject pilot transmissions and independently check the DME reading and ground speed values given. If the resulting information varies from that calculated by the DABS surveillance system, the ground observer indicates this to the interceptor pilot. The interceptor and drone continue in this manner until the interceptor has sighted the drone. He indicates this to the drone test pilot and to the ground. The interceptor pilot then conducts the planned intercept visually. Intercepts are flown to within a 200-foot vertical separation of the subject aircraft to provide the realism required to evaluate subject pilot reaction. Upon resolution of the conflict, the interceptor flies away and behind the drone to clear all PWI indications. The interceptor then positions itself for the next encounter.

5.2.2 Ground Assisted Intercepts

The ground system has the necessary information to accurately direct the interceptor before the drone is visually acquired. The ground personnel provide vectors to the aircraft using the dedicated VHF frequency. The ground vector assistance is based on the sensor-derived ground track information calculated for each aircraft. In addition, the RAS system provides aircraft heading, airspeed, turn and climb rate information. Various algorithms, using the above information, are being developed to provide reliable vectoring assistance to the test pilots. The vectoring information will be supplied to the ground observers by means of the SEL-CRT.

5.3 Subject Pilot Operations

A series of experiments involving subject pilots selected from the general aviation community has been developed to gradually introduce the IPC concept. Techniques have been prepared to brief subject pilots, conduct subject pilot missions, and debrief subject pilots to establish their reaction to the IPC concept. The subject pilots are placed in operational near-miss situations while rigid safety controls are maintained. All subject pilots selected for the test program will be given a familiarization flight prior to the data-gathering mission. Following the flight, the test pilot who accompanied the subject pilot on the familiarization flight will complete the Pilot Evaluation Form (see Table 5-1).

5.3.1 Subject Pilot Selection

Prospective subject pilots will be expected to provide personal background data of the type on the Pilot History Questionnaire of Table 5-2. Pilots of varying experience levels representing various segments of the general aviation community, including pilots rated as students and instrument rated, will be selected to participate in the test program. The subject pilots selected will be expected to have an active pilot license and a current FAA medical certification. Candidate pilots will be categorized by total flight hours and rating.

5.3.2 Subject Pilot Briefing

Subject pilots will be briefed on their role in the evaluation procedure, and the briefing will be supplemented with handout material. A working model of the IPC display will be demonstrated, and interpretation of the PWI will be discussed. Objectives of the mission will be discussed, but the details of the intercepts to be flown by the interceptor aircraft will not be revealed. The flight plan, the navigation and radio communication procedures, and the safety procedures (outlined in Appendix E) will be discussed.

The subject pilot will be briefed on the type of information he will be expected to supply during the mission. During and after each encounter, he will be asked to answer questions regarding his visual acquisition of the inter-

TABLE 5-1

PILOT EVALUATION

Subject pilot ____________________ Mission no. ______

Test pilot ____________________ Date ____________

Rate on following points (G = good, F = fair, P = poor):

1. Pilot understanding of flight plan G / F / P
2. Use of navigation equipment G / F / P
3. Ability to fly course G / F / P
4. Control of aircraft: Altitude G / F / P
   - Heading G / F / P
   - Straight and level G / F / P
   - Turns G / F / P
   - Overall G / F / P
5. Course reacquistion technique ______________________________
6. Scan and use of flight instruments G / F / P
7. Workload — Frequently overloaded / Occasionally overloaded / Not overloaded
8. Time devoted to scanning for traffic before PWI — More than normal / Normal / Less than normal
9. Time devoted to scanning for traffic after PWI — More / Normal / Less
10. Ability to evaluate conflict situations G / F / P
11. Understanding of IPC/PWI messages G / F / P

TABLE 5-1

PILOT EVALUATION (cont.)

12. Pilot attitude toward test ____________________________

13. How did pilot behavior deviate from what you would expect from him under normal flight conditions?

____

____

14. Did pilot correctly combine his own judgment with IPC/PWI indications?

____

Additional comments: ____________________________________

____

____

TABLE 5-2

PILOT HISTORY QUESTIONNAIRE

No. ______________

Date ______________

Name ______________________________

Address ______________________ City/Town ____________ State ______

Telephone ______________________

Occupation ______________________ Age ____________

Number of years as active pilot ______________________________

Ratings: ☐ Student ☐ Instrument

☐ Private ☐ Instructor (☐ CFI, ☐ CFII)

☐ Commercial ☐ ATR

Flight training: ☐ Military ☐ Civilian ☐ Airline

Aircraft Experience:

Types of aircraft ______________ ________ __________

☐ Single-engine Hours __________

☐ Multi-engine Hours __________

Current pilot experience:

☐ Business ☐ Military

☐ Pleasure ☐ Commercial

Flight time:

Total hours: ______________

Dual __________ Instrument ____________

Solo __________ Night ______________

Cross-country ______

Flight hours during last 60 days ______________________

Time since last cross-country flight __________________ Days

Current FAA medical certification: ☐ Yes ☐ No

Other pertinent information: ______________________________

____

____

ceptor aircraft, his estimation of the threat created, and the maneuver he used to resolve the conflict. The subject pilot will be instructed to indicate his response to these questions for each encounter using the dedicated VHF frequency.

The subject pilot will be instructed to report all traffic by clock position at the time of sighting. He will indicate the type of maneuver he will initiate to resolve the conflict and characterize the encounter, the escape maneuver and the maneuver to regain his original course.

5.3.3 Subject Pilot Communication Procedures

The subject pilot will be instructed in the use of two VHF radios. One radio is used for communications with ATC facilities such as the Bedford Tower, the Boston Center, and the Boston Approach Control; the other radio is used to record the subject pilot's reactions to each encounter via a second DABSEF dedicated frequency.

5.3.4 Example of a Subject Pilot Mission

A specific subject pilot mission will be used an an example to illustrate the operational procedures to be followed:

Sample Mission Objective: This mission is scheduled to allow the subject pilot to evaluate IPC services.

Sample Mission Course: The course the subject pilot will fly is the Haystack, GDM, MHT triangle discussed in Section 5.1.2. The subject pilot is briefed to fly the course two times.

Sample Encounters: Only one interceptor is employed. The encounters to be flown are discussed in Section 5.1.2.

Sample Preflight Procedures: The interceptor and the drone will be taken through their normal preflight procedure. In addition, a ground altimeter crosscheck at field elevation will be made on each aircraft's altimeter. A call by each aircraft on the DABS control frequency will be made to assure that all is ready at DABSEF. The drone departs Hanscom Field for a two-hour mission. The interceptor follows the subject aircraft at a one-minute interval (to keep from prematurely creating PWI indications on the subject aircraft's display).

Sample Flight Procedure: When each aircraft is airborne and on course to Haystack, a test pattern will be requested in each aircraft to check the IPC display lights.

The interceptor will check the position of the drone by calling its test pilot; the drone test pilot will report the distance to Haystack while flying the briefed course. The course and distance will be confirmed by the ground observer, and the interceptor will begin the tail-chase run on the subject aircraft in order that the overtake will occur before Haystack. The subject aircraft will receive a co-altitude six o'clock steady PWI followed by an aural warning and a flashing six o'clock PWI. The subject pilot will report his reaction on the DABS subject pilot frequency and respond to the situation as needed. The interceptor will plan to continue the intercept and pass under the subject aircraft unless the subject pilot maneuvers. Following the completion of the tail-chase encounter, each aircraft will turn left and resume its respective heading to GDM. The 45-degree encounter will occur at GDM. The two aircraft will proceed in a clockwise manner around the course, with the interceptor performing the planned intercepts as specified in Section 5.1.2.

After each encounter during the flight, the subject pilot will answer questions included in Table 5-3 by using the dedicated VHF frequency. These responses will be used to complete the form itself in the post-mission playback.

5.3.5 Subject Pilot Debriefing

Immediately following the mission, data reduction and data analysis routines will be computed on the data collected during each of the encounters. A complete history, by encounter, of the X-Y tracker and IPC algorithm data will be tabulated. Plots of aircraft position, range vs tau, and altitude vs tau will be prepared.

A mission reconstruction program allows each of the encounters to be replayed for post-mission analysis. This reconstruction capability replays each encounter on the various displays: traffic situation display, cockpit monitor displays and on the SEL-CRT display. The SEL-CRT presents a history, by scan, of each encounter. This replay is synchronized with the playback of the tape recording of the VHF radio transactions. The subject pilot's reactions to each encounter are replayed with the encounter geometry being depicted on the traffic situation display. The commands to each aircraft are shown on the cockpit monitors, and the IPC algorithm data appears on the SEL display. The subject pilot is present during this debriefing. Following the reconstruction of each encounter, the subject pilot is asked to expand his initial reaction to the encounter. An encounter questionnaire similar to Table 5-3 will be completed to characterize pilot reaction. A debriefing form similar to Table 5-4 will also be completed to summarize each subject pilot's reaction to the mission.

TABLE 5-3

INFLIGHT ENCOUNTER QUESTIONNAIRE

1. When aircraft was sighted, IPC display indicated:

   NULL / OPWI / FPWI / PCMD

2. When aircraft was sighted, the traffic was:

   ( ) Of immediate concern
   ( ) A factor, but no immediate concern
   ( ) No factor

3. Would you adjust OPWI range?

   Greater / About right / Less

4. Would you adjust FPWI time?

   Earlier / About right / Later

5. Would you adjust CMD time?

   Earlier / About right / Later

6. Did you use FPWI to aid acquisition?
   Did it help?

7. When CMD was received, traffic was:

   ( ) Of immediate concern
   ( ) A factor, but of no immediate concern
   ( ) No factor
   ( ) Not acquired

8. At time of CMD, had you begun an avoidance maneuver? Yes / No

   If you had begun a maneuver, which direction(s) did you choose?

   If you had not begun a maneuver, which direction(s) were you considering choosing?

   (For each part of No. 8, choose one or several:

   Right / Left / Climb / Descent / Slow down / Speed up

TABLE 5-3.

INFLIGHT ENCOUNTER QUESTIONNAIRE (cont.)

9. In your judgment, was the IPC command a safe one?

10. How would you judge duration of CMD?

( ) About right
( ) Turned off too soon, danger still existed
( ) Remained on too long, danger had passed

Test Pilot Check

Control of aircraft before encounter:	Good / Fair / Poor
Control of aircraft during encounter:	Good / Fair / Poor
Workload	Heavy / Moderate / Light

Course reacquisition ______________________________

Comments: ______________________________

____

____

TABLE 5-4.
DEBRIEFING FORM

1. Were you able to anticipate the direction of approach of the intruder? How?

2. Were you able to anticipate the time at which the intruder would cause an encounter? How?

3. PWI/IPC display:
   (a) Was the display readable?
   (b) Was the display in the most desirable location?
   (c) Did you regularly scan the display or wait for the audio alarm?
   (d) Did you ever notice the ordinary PWI before CMD(s) appeared (and the audible alarm sounded)?

   Never / Sometimes / Often / Always

   (e) Did you ever use the ordinary PWI to aid acquisition of

Intruder	Other Aircraft	
( )	( )	Traffic usually already sighted
( )	( )	Did not try to use it
( )	( )	Tried to use it, but often could not locate aircraft
( )	( )	Yes, usually found other aircraft, but PWI not a big help
( )	( )	Yes, and it was very helpful

   (f) In normal VFR flying (other than test) how would you utilize the display?

	VFR	IFR
(1) Include in normal instrument scanning	( )	( )
(2) Check occasionally	( )	( )
(3) Check only when beginning a maneuver	( )	( )
(4) Check only when audio alarm is provided	( )	( )

   (g) Any suggestions relative to the display?

   (h) Were the indications provided by the lights, arrows, and X(s) clear?

   (i) Could you easily hear the alarm over the background noise?

TABLE 5-4.

DEBRIEFING FORM (cont.)

4. Did the IPC system provide reasonable maneuvers?
If no, comment:

5. Was the system too conservative / just right / too late?

	Too conservative	Just right	Too late
PWI	( )	( )	( )
FPWI	( )	( )	( )
IPC command	( )	( )	( )

6. When negative CMD(s) occurred as first command, they were usually

( ) Justified
( ) Too conservative (preferred flashing PWI)
( ) Too risky (preferred positive CMD)

7. Did the system provide a useful service? If yes, what service?

8. Was there sufficient time between a FPWI and a command to resolve the situation yourself?

9. Command indications:

(a) In following the commands were there any contrary to the method you would have used to resolve the situation? Yes ☐ No ☐
If yes, how were they different?

(b) Did commands stay on too long / just right / not long enough?

10. What were some of the reasons you stopped maneuvering?
(one reason for each encounter):

( ) Command light turned off
( ) Had sufficient altitude clearance
( ) Had sufficient horizontal clearance
( ) Saw other pilot maneuvering
( ) Lost sight of intruder
( ) Was getting too far off course
( ) Other:

TABLE 5-4.

DEBRIEFING FORM (cont.)

11. How many times did the system indicate traffic you did not see at all?

PWI	( )
FPWI	( )
Commands	( )

12. Was there any information lacking that would have been more helpful in resolving situations?

13. Test aircraft:

    (a) Were you thoroughly familiar with the test aircraft?
    (b) Did it present a normal workload (including the display features)?

14. General comments:

5.4 Mission Control Room Personnel

The mission control room is located at DABSEF (Fig. 5-4). It is manned during IPC flight test operations by personnel responsible for the conduct of the mission. The personnel include the IPC mission director, the ground safety observer, the system operator, and the IPC system analyst. Personnel on call include a systems software engineer, and a site engineer.

5.4.1 Mission Director

The IPC mission director is responsible for the overall conduct of the flight test missions. He will help plan the missions and therefore be familiar with the specific test objectives. Ready access to other test personnel is provided. Close cooperation with the ground safety observer provides the mission director with test aircraft position data as well as other airborne traffic locations in the test area. Access to the test pilots via the VHF link allows the mission director to control mission operations and provide intercept vectoring assistance.

The mission director monitors the progress of each mission via communications with control room personnel and the test pilots. He monitors the controller situation display, the cockpit IPC display monitors, and an IPC algorithm status display on the SEL-CRT. The mission director has the authority to cancel a mission upon the test pilot's recommendation or because of a software or hardware malfunction.

5.4.2 Ground Safety Observer

The ground safety observer is responsible for monitoring the progress of the test aircraft during a mission. A 22-inch traffic situation CRT, which displays all beacon-equipped aircraft within a 60-nmi radius of DABSEF, is helpful for this purpose. Each beacon-equipped aircraft has its beacon code and ground speed displayed with its position information. If an aircraft is mode-C equipped, its altitude is also displayed. The ground safety observer provides advisories to the test aircraft for any local traffic in the test area. He monitors the planned test aircraft flight paths providing intercept vector information to aid in directing the intercepts.

The ground safety observer maintains radio contact with both test aircraft on a dedicated VHF frequency (see Appendix D). Conversations on this frequency between the ground safety observer and the test pilots are heard on a speaker in the control room. The ground safety observer also monitors, on a VHF scanner, the same ATC frequencies that the test aircraft are monitoring. The ground safety observer will relay any transmissions from Boston Center, Bedford Tower, or Boston approach to the test aircraft. Monitoring the ATC frequencies also permits the ground safety observer to interlace his transmissions with the ATC operational transmissions.

ATC-46(5-4)

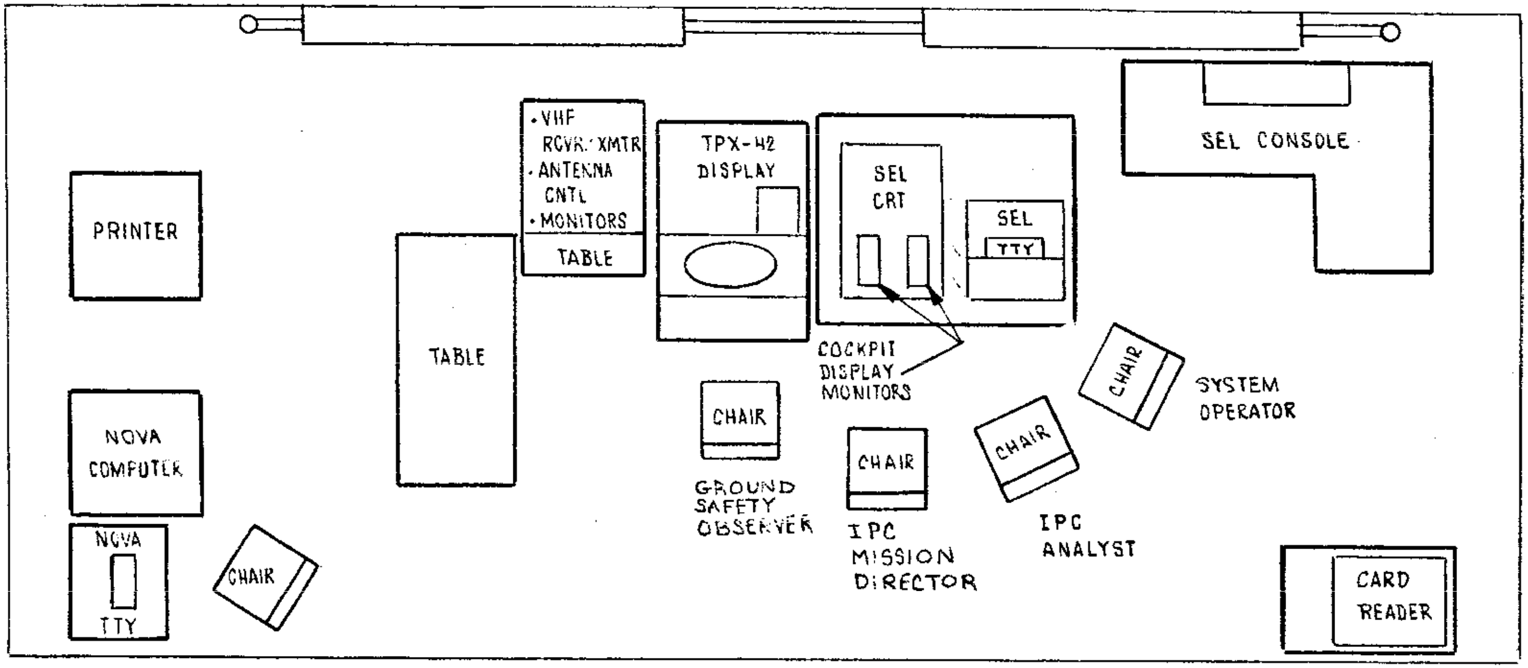


Fig. 5-4. Flight test control room

5.4.3 System Operator

The system operator is responsible for the operation of the experimental DABS sensor software and hardware. He monitors system operation using the SEL control panel, SEL-CRT, the traffic situation display, and cockpit monitor devices. He is responsible for maintaining a log of the encounters flown. He inputs tabs to the computer using a keyboard to indicate the start/end times of the encounters. The start/end times are also recorded in the log.

The system operator has a system engineer and a site engineer available on-call for consultation when problems arise. He will advise the mission director of any expected problems in order to provide the information required to decide whether to delay or postpone the mission.

5.4.4 IPC Analyst

The IPC analyst is responsible for monitoring the performance of the X-Y tracker and the IPC algorithm. The analyst follows the progress of each encounter using the SEL-CRT, the cockpit display monitors, and the traffic situation display. The SEL display contains information on the status of the IPC algorithm. A history, by scan, listing the steady and flashing PWI(s) as well as commands sent to the test aircraft is provided. Data regarding the conflict are presented and updated on each scan. The data include relative range and altitude, horizontal and vertical tau values, and projected horizontal miss distance. The threshold values selected by the algorithm, based on test aircraft flight rules and transponder equipment, are also presented. The flight attitude of each of the test aircraft is indicated. The test aircraft heading, air speed, rate of climb, and turn rate information will be received on comm-B downlink and presented each scan on the SEL-CRT. The IPC system analyst maintains a log for each encounter, reporting any system anomalies he may identify to the test director.

6.0 DATA REDUCTION AND ANALYSIS

Each IPC mission yields a large amount of data that must be edited, reduced, analyzed, and stored for future access. Processing of this data is usually required before questions posed by pilots or other observers may be meaningfully answered in a qualitative manner.

Table 6-1 outlines the data sources, processing techniques, and data reduction analytical "tools" described in this chapter.

TABLE 6-1

DATA REDUCTION ELEMENTS

Data Sources (Section 6.1)	Data Processing Techniques (Section 6.2)	Data Packages (Section 6.3)
Pilot history questionnaire Encounter questionnaire IPC evaluation questionnaire DABSEF log and observer notes DABSEF mission data tape Voice recording Readout of aircraft state (RAS) Cockpit film* *Optional as required.	Automated encounter definition Post-flight smoothing Conflict state definition Special flags Plotting Characterization parameters Playback	Encounter analysis: X-Y plot Altitude-time plot Range-tau plot Altitude-tau plot Data printout Data base analysis: Data base tape Data base plots Documentation: Test memos

6.1 Data Sources

Many of the forms, questionnaires, tapes, etc., used to record pilot and flight data have been mentioned or described in previous chapters. Table 6-2 lists these "sources" and indicates the type of data obtained from each.

6.2 Data Processing Techniques

Several processing routines have been developed for IPC data reduction and analysis; some of these make use of the software developed for general purpose DABSEF data recording and retrieval. This software is part of the DABSEF data collection system and will not be discussed further. Most of the processing routines and techniques discussed below have been developed especially for IPC analysis.

6.2.1 Automated Encounter Definition

Although replies from many aircraft are being processed by the DABSEF sensor at a given time, data output is usually desired for only the DABS-equipped flight test aircraft and any other ATCRBS-equipped aircraft that chance to interact with them during a particular encounter. The IPC data reduction package scans each data tape and records the time intervals in which IPC encounters involving the test aircraft occurred. The identities of any ATCRBS aircraft that interacted during these time intervals are recorded. Surveillance reports are stored for subsequent trajectory analysis.

TABLE 6-2

RAW DATA SOURCES

Data Source	Data Produced
Pilot history questionnaire	Pilot ratings, experience, etc.
Encounter questionnaire	Pilot evaluation of a particular encounter
IPC evaluation questionnaire	Overall pilot evaluation of system
DABSEF log, observer notes	Weather, equipment status, etc.
DABSEF mission data tape	DABS and ATCRBS surveillance data, DABS communication data, IPC algorithm data, readout of aircraft states
Voice recording	Controller and pilot comments during flight

In most cases more conflicts are detected than were intended in test planning because of spurious conflicts caused by the presence of a third aircraft. If desired, operator tabs inserted on the tape can be utilized to inhibit output for the unplanned events and to ensure labeling of events (standardized by mission number and encounter number).

6.2.2 Post-flight Smoothing

Post-flight smoothing involves the use of past and future position reports to estimate more accurately aircraft position, speed, and turn rate. The objective is to be able to precisely plot the trajectory of each aircraft so that IPC performance can be determined accurately and the effect of real-time tracker error can be observed. The processor first chooses all data points accepted by the IPC tracker in real time and which lie within a specified time window centered on the time of interest. A second-order polynomial is then fitted separately to the X and Y coordinates of each point, and the positions, velocities, and accelerations at the time of interest are estimated. Special routines correct for bias in the event that the aircraft is maneuvering.

6.2.3 Conflict State Definition

A set of nine conflict states have been defined (see Table 6-3) to aid in interpreting the events occurring during a conflict. Once each scan, the encounter analysis routines determine the state for each aircraft. Eventually a history of the states entered during the conflict is produced. Thus the overall progress of the conflict may be mapped and performance parameters defined based upon these state occupancies (e.g., how long did State 3 occur before being replaced by a higher state? Did State 8 occur? etc.).

6.2.4 Special Flags

Flags are placed in the conflict detection logic in order to determine whether or not alarms arose by violation of tau or range separation, and whether or not such violations occurred in the horizontal or vertical dimensions. Flags are placed in the command generation logic to determine which rules were used in generating commands.

6.2.5 Plotting Routines

A set of standard plotting routines has been adopted for use with the "Versatec" plotter located at DABSEF. These routines allow symbols or lines to be plotted from an array of input data. The machine produces 8 1/2" by 11" hard copy output. The particular data plots that will be produced are presented in Section 6.4.

6.2.6 Encounter Attributes

A set of parameters has been defined that specifies the attributes of an encounter and characterize IPC performance for that encounter. Table 6-4 displays the parameters that have been initially defined for use in automated analysis of collision avoidance success. These parameters may grow in number as additional flight test experience is acquired.

TABLE 6-3

ALGORITHM STATE DEFINITION

State 1: No IPC/PWI messages
State 2: Ordinary PWI
State 3: Flashing PWI
State 4: Negative command
State 5: Initial positive commands
State 6: Nonresponding commands
State 7: Commands recomputed and not reversed
State 8: Commands recomputed and reversed
State 9: Both responding

Command Being Sent	Positive Command	POSCMD = 3	Horiz Command Reversed	FPWI Being Sent	OPWI Being Sent	State
Yes	Yes	No	-	-	-	5 (for POSCMD = 1) 6 (for POSCMD = 2) 9 (for POSCMD = 4)
Y	Y	Y	N	-	-	7
Y	Y	Y	Y	-	-	8
Y	N	-	-	-	-	4
N	-	-	-	Y	-	3
N	-	-	-	N	Y	2
N	-	-	-	N	N	1

TABLE 6-4

ENCOUNTER ATTRIBUTES

Item	Description	Name
1	Encounter number = mission number + two digits for encounter in mission	ENO
2	Identity of first aircraft	ACID1
3	Identity of second aircraft	ACID2
4,5	Duration of ordinary PWI (State 2) before appearance of higher states, for aircraft 1 and aircraft 2 (secs)	DS1, DS2
6,7	Duration of flashing PWI (State 3) before commands	DF1, DF2
8,9	Duration of negative commands (State 4)	DN1, DN2
10,11	Duration of positive commands (State 5)	DP1, DP2
12	Primary resolution plane equals 1 if horizontal commands were issued first; 2 if vertical first.	PRES
13	Closest point of approach in slant range (obtained by interpolation between data points) (ft)	SCPA
14	Horizontal component of SCPA (ft)	SCPAH
15	Vertical component of SCPA (ft)	SCPAV
16	Closest point of approach in horizontal plane (separation sampled at one-scan intervals) (ft)	CPAH
17	Closest approach in vertical dimension (separation sampled at one-scan intervals) (ft)	CPAV
18	Minimum positive value of horizontal tau (TH) (sampled at one-scan intervals) (sec)	THCPA
19	Minimum positive value of vertical tau (TV) (sampled at one-scan intervals) (sec)	TCCPA
20,21	Total duration of conflict (time in which either OPWI or FPWI was active (sec)	DC1, DC2
22,23	Heading change during POSCMD state (deg)	DH1, DH2
24,25	Altitude change during POSCMD state (ft)	DALT1, DALT2

6.2.7 Playback

The playback package allows the recorded data to be replayed in order to exercise the IPC algorithm, the situation display, and the cockpit display monitors, using as input the same set of surveillance reports that were recorded in real time. Alarm thresholds of the IPC algorithm can be altered for playback if desired, although any changes in IPC commands will not be reflected in the observed aircraft trajectories.

6.3 Data Reduction Procedures and Data Packages

It is convenient to divide the IPC data analysis process into two separate but interrelated areas. The first area, encounter analysis, involves the detailed examination of all data pertaining to a particular encounter, and the computation of various parameters that characterize that encounter. The second area, data base analysis, involves examination of the results of many encounters and usually focuses on one or two parameters at a time.

6.3.1 Encounter Analysis

The first task in the data analysis process is to provide readily interpretable data for use in debriefing. In a sense, the first stage of data analysis is used as an aid to additional data collection. Each encounter is examined by test personnel, and the data often suggests specific questions that should be posed to the pilot concerning his actions or reactions. The data is also used to clarify and interpret pilot comments.

When debriefing is completed, a more comprehensive examination of the conflict will be performed. One objective here is to detect anomalous or previously unrecognized conditions in aircraft flight paths or algorithm states. Inspection of the data may reveal situations in which commands were questionable even though resolution was successful. This process may give rise to new quantitative analysis parameters and techniques that aid in detection or evaluation of previously unknown phenomena.

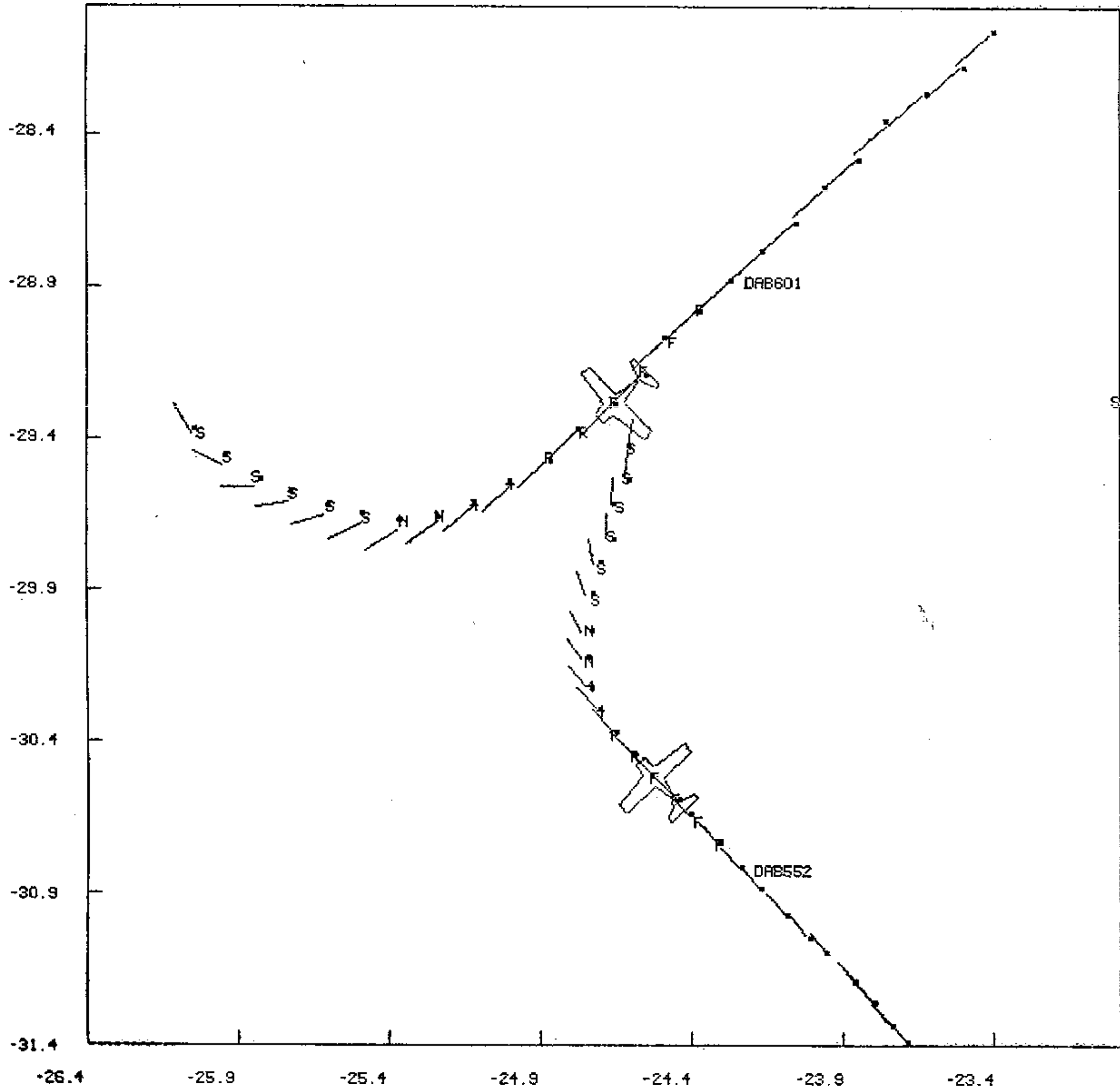
Because several aspects of conflict analysis must rely heavily upon the pattern recognition and interpretation capabilities of the analyst, graphical presentation of the data is useful. Immediately following each IPC flight, several data plots will be generated on the "Versatec" plotter. They will be available for pilot debriefing and then filed for subsequent inspection. The descriptions that follow apply to plots currently in use.

6.3.1.1 X-Y Plot

The X-Y plot allows the horizontal positions of the aircraft to be correlated with the conflict state on a scan-by-scan basis. Figure 6-1 is an example of an X-Y plot for an actual encounter. For each scan, the raw position report is indicated by a small square, and the tracker position and velocity estimate are indicated by a line drawn from the current position to

START TIME •11 41 15.939 END TIME •11 42 55.579 711/712 ST SCAN• 788 END SCAN• 804
NPTS FT AC1• 17 NPTS FT AC2• 17 NPTS 702• 50 701/702 TIME FIRST• 3204101. LAST• 3302732.

ENCOUNTER NUMBER 6



PRES • 1
CPAH • 4138.297 CPAV • 166.766

POSCMD• 1 AT SCAN 792 MD• 2330.6
ALT• 200.3 XANG• 90.89

CPA ON SCAN 797 SCPA • 4143.137
SCPAH • 4138.297 SCPAV • 200.207

AC1 TRACK • 1 ID DAB601

AC2 TRACK • 2 ID DAB552

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ
788			0	41.84	1.92	2709	905	199
789	F	F	0	37.56	1.75	2534	1060	199
790	F	F	0	32.70	1.57	2253	1387	199
791	F	F	-2	28.33	1.39	2080	2012	199
792	F	F	1	23.56	1.22	1859	3276	199
793	R	R	1	20.08	1.07	2066	6320	199
794	R	R	4	15.63	0.91	2170	17043	199
795	R	R	4	12.56	0.79	2564	•75915	199
796	R	R	0	11.46	0.70	3100	-26412	199
797	NL	NL	0	15.11	0.65	3596	-20208	199
798	NL	NL	0	120.50	0.69	4186	-20495	200
799	S	S	0	0.00	0.77	4549	0	200
800	S	S	0	0.00	0.88	4789	0	200
801	S	S	0	0.00	1.04	4991	0	200
802	S	S	0	0.00	1.16	4620	0	200
803	S	S	0	0.00	1.32	2985	0	200
804	S	S	0	0.00	1.43	390	0	200

6-22 9 JUNE 75 (IPC 159 • IPC 160) INT DAB601 DRONE DAB552

IPCSUM VERSION 4

23

Fig. 6.1 Example of X-Y plot

the 4-second projection position. A symbol, which indicates the type of message being sent to the aircraft, is printed at the true X-Y position. The meaning of the symbols used is given in Table 6-5. The true positions and headings of the aircraft at the time positive commands are first delivered are indicated by drawing appropriately positioned aircraft symbols for that scan. In the margins of the plot, a scan-by-scan history of messages and critical IPC variables are presented. Certain performance parameters (such as closest approach) are also printed here.

6.3.1.2 Altitude-Time Plot

The altitude-time plot is the vertical complement of the X-Y plot. The tracked and raw altitudes are plotted and symbols that identify the message state are printed.

TABLE 6-5

X-Y CONFLICT PLOTS SYMBOLS

Symbol	Message State
X	No PWI(s) or commands
S	Ordinary PWI
F	Flashing PWI
N	Negative command, POSCMD = 0
R	Turn right, POSCMD = 1
L	Turn left, POSCMD = 1
C	Climb, POSCMD = 1
D	Descend, POSCMD = 1
2	POSCMD = 2 (nonresponding commands)
3	POSCMD = 3 (horizontal command recomputed)
4	POSCMD = 4 (both responding)

6.3.1.3 Range-Tau Plot (See Fig. 6-2)

The range-tau plot allows an observer to follow the progress of the horizontal alarm parameters through range-tau alarm space. Relative range is plotted against horizontal tau (TH) using state symbols similar to those of Table 6-5. The range-tau space can be divided into regions that correspond to the areas in which various alarm flags would be set by the horizontal conflict detection logic.

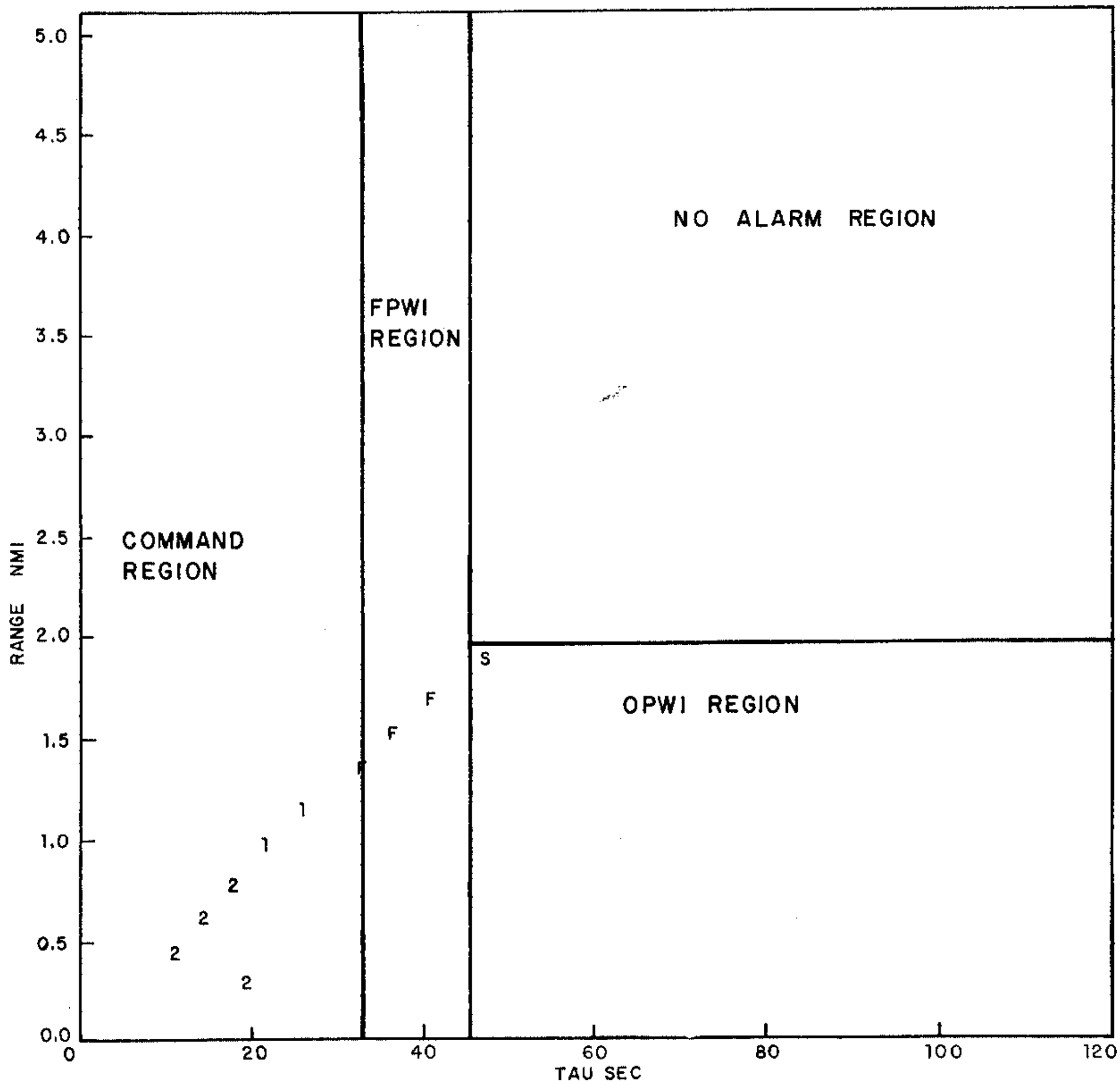


Fig. 6-2. Range-tau plot for VFR/VFR conflict.

6.3.1.4 Altitude Separation-Tau Plot

The altitude separation-tau plot is the vertical complement of the range-tau plot. It allows an observer to follow the alarm dynamics in the vertical dimension.

The previous plots are particularly useful in resolving questions regarding alarms appearing to be late or early, and in determining the affect of maneuvers on the sequence or duration of conflict states.

At the same time the previous plots are being generated, a data print-out will be produced. Included in the printout are the following:

(1) Raw position reports
(2) Tracked and smoothed trajectories
(3) IPC variables that were calculated in real time
(4) IPC variables based on postflight smoothing
(5) DABS communications with the aircraft
(6) Characterization parameters for each encounter
(7) Boundaries of the conflict in space and time.

6.3.2 Data Base Analysis

Once an encounter has been characterized and all quantifiable performance parameters (including answers to certain questions on the debriefing questionnaires) have been recorded, the resulting data is added to a data base, which allows a single analysis program to access data on all encounters. The data base and its accompanying analysis packages are designed to achieve the following objectives:

(1) Reveal trends or characteristics of the system that are not easily discernible without simultaneous consideration of the results of many encounters. For example, portray the sensitivity of IPC performance to encounter attributes such as crossing angle, speeds, etc.

(2) Distinguish, in terms of encounter attributes, between the areas in which IPC performance is acceptable and well understood and areas in which further work is needed.

(3) Allow data to be presented in a manner that tests the validity of intuitive judgments and allow an assessment of particular statements concerning IPC performance.

(4) Allow correlation of pilot reactions with the attributes of the encounter in order to determine the objective conditions giving rise to particular pilot reactions.

(5) Provide data that can be used to calibrate future IPC/PWI simulation.

Histograms or scatter plots will be created for specified encounter parameters. Figure 6-3 is an example of one such plot that portrays the duration of positive commands as a function of crossing angle. Condition tests may be added that filter encounters on the basis of certain attributes (e.g., plot data only for VFR/IFR encounters, etc.). Accompanying statistical analysis routines will provide selected statistical parameters for the specified data (e.g., mean, standard deviation, minima/maxima, etc.). Preliminary experience with such plots, using data generated by the original version of the IPC algorithm, indicates that much can be learned about algorithm performance by pursuing the question of why certain encounters produce scatter points that deviate from others with the same general encounter attributes.

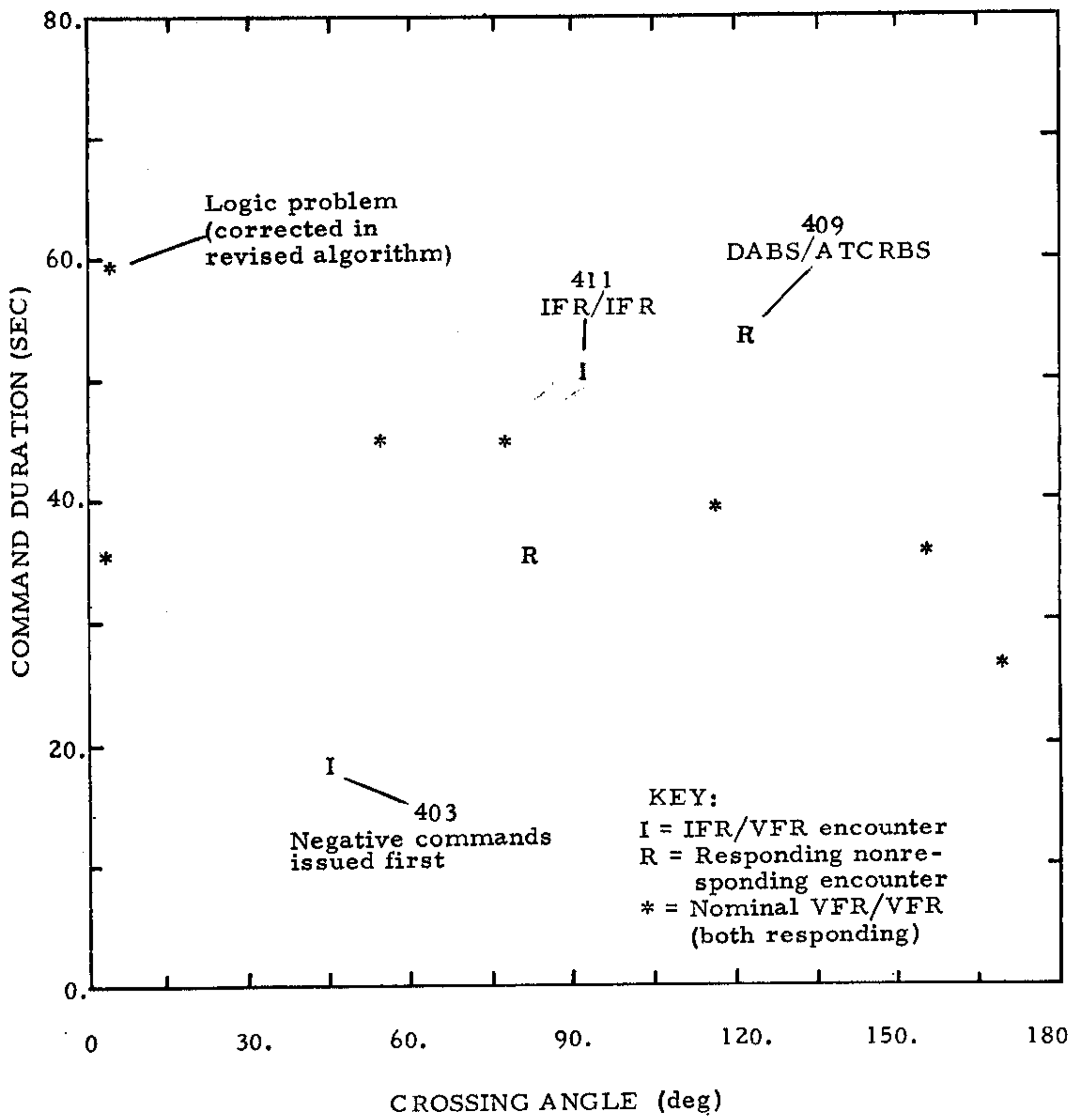


Fig. 6-3. Duration of positive commands plotted against crossing angle for a typical IPC mission.

APPENDIX A

LISTING OF ENCOUNTER CLASSES

Listed in this appendix are all the types of encounters to be run during the IPC flight tests. The track crossing angle will be varied through the following sets of values as indicated for each encounter class:

Set 1: 15-, 45-, 135-, and 180-degree intercepts
Set 2: 15-, 45-, 90-, 135-, and -80-degree intercepts
Set 3: 0-, 15-, 45-, 90-, 135-, and 180-degree intercepts
Set 4: 15-, 90-, and 135-degree intercepts
Set 5: 0-, 90-, and -35-degree intercepts
Set 6: 0-, 15-, 45-, 90-, and 180-degree intercepts

Following is the table of encounter classes to be tested during the IPC flight tests. The identity of the intruder and the drone aircraft can be discerned from the table because the drone aircraft's designation is listed first in the flight rules, the equipment status, the airspeeds and the response mode columns. Therefore, whenever the two designations differ (e.g., DABS/ATCRBS), the first designation applies to the drone and the second to the intruder. Concerning the type of approach, the aircraft (intruder or drone) that is to maneuver is indicated beside the type of maneuver to be performed. For encounters, in which a nonzero horizontal miss distance is tested, a plus sign indicates that the drone aircraft is ahead of the intruder; whereas a minus sign indicates that the drone is behind the intruder. In the type approach column, vertical maneuvers are described by the words "climbs (dives)at X from Y," where X represents the vertical rate to be used in feet per minute, and Y represents the altitude separation in feet at the start of the maneuver. More completely, the designated aircraft will climb or descend at X feet per minute from a separation of Y feet toward the other aircraft. The maneuver will be timed so that the aircraft are projected to reach co-altitude at the same time they reach closest approach in the horizontal plane. Variations in the projected vertical miss will be obtained by varying the initial separation, Y. For some vertical maneuvers (those not included in Test Series 3), the vertical rate X is specified, but not the initial separation Y. For these encounter classes, the initial altitude separation should be outside the vertical alarm region. Similarly, horizontal maneuvers (turns) are described in the type approach column by the words "case N from S," where N indicates which of five turning geometries (see Section 3.4) is to be tested. S represents the initial track separation before the turn for cases 1, 3, and 5, and represents the aircraft separation before the turn for cases 2 and 4.

TABLE A-1

TEST SERIES 1: VFR/STRAIGHT AND LEVEL

Class No.	Encounter Flight Rules	Encounter Equipment Status	Type Approach	Track Crossing Angles	Airspeeds (knots)	Horizontal Miss Distance	Encounter Response Mode	Number Of Encounters
1.1	VFR/VFR	DABS/DABS	Straight Level	90°	100/100	0	R/R	30
.2	"	"	"	Set 1*	"	0	"	17
.3	"	"	"	Set 2*	"	±3000	"	27
.4	"	"	"	Set 3*	140/90	0	"	32
.5	"	"	"	Set 2	"	±3000	"	27
							Total	133

*Track crossing angle set 1 includes 15-, 45-, 135-, and 180-degree intercepts. Set 2 includes all these intercepts and 90-degree intercepts additionally. Set 3 includes all these intercepts and 0-degree intercepts also. For encounter classes 1.2 to 1.5, five encounters should be tested at each intercept angle, except for 180 degrees (2 encounters), and 90 degrees (10 encounters).

TABLE A-2

TEST SERIES 2: TURNING AIRCRAFT

Class No.	Encounter Flight Rules	Encounter Equipment Status	Type Approach*	Track Crossing Angles	Airspeeds (knots)	Horizontal Miss Distance	Encounter Response Mode	Number Of Encounters
2.1	VFR/VFR	DABS/DABS	Drone: Case 1 from 2 Level	90^o	100/100	0	R/R	
.2	"	"	Drone: Case 1 from 3 Level	90^o	"	"	"	
.3	"	"	Drone: Case 2 from 2 Level	180^o	"	"	"	
.4	"	"	Drone: Case 2 from 3 Level	180^o	"	"	"	
.5	"	"	Drone: Case 3 from 2 Level	90^o	"	"	"	
.6	"	"	Drone: Case 4 from 2 Level	90^o	"	"	"	
.7	"	"	Drone: Case 4 from 3 Level	90^o	"	"	"	
.8	"	"	Intruder: Case 1 from 3 Level	90^o	"	"	"	
.9	"	"	Intruder: Case 2 from 2 Level	180^o	"	"	"	
.10	"	"	Intruder: Case 3 from 2 Level	90^o	"	"	"	

Turning case 1 is aircraft on initially parallel tracks, which are separated by N nmi ("Case 1 from N"), one aircraft turning 90 degrees toward the other. Turning case 2 is aircraft initially in 90-degree crossing geometry, where one aircraft turns 90 degrees toward the other; turn starts when aircraft are separated by M nmi ("Case 2 from M"). Case 3 is the same as case 1, except initial tracks are antiparallel, separated by N nmi. Case 4 is aircraft initially in 30-degree merging geometry; one aircraft turns 60 degrees toward the other; turn starts when aircraft are separated by M nmi ("Case 4 from M"). Case 5 is the same as case 1, except both aircraft turn 90 degrees toward each other.

TABLE A-2

TEST SERIES 2: TURNING AIRCRAFT (cont.)

Class No.	Encounter Flight Rules	Encounter Equipment Status	Type Approach	Track Crossing Angles	Airspeeds (knots)	Horizontal Miss Distance	Encounter Response Mode	Number Of Encounters
2.11	VFR/VFR	DABS/DABS	Intruder: Case 4 from 2 Level	90^o	100/100	0	R/R	
.12	"	"	Both turn: Case 5 from 4 Level	180^o	"	"	"	
.13	"	"	Drone: Case 1 from 2 Level	90^o	140/90	"	"	
.14	"	"	Drone: Case 1 from 3 Level	90^o	"	"	"	
.15	"	"	Drone: Case 2 from 2 Level	180^o	"	"	"	
.16	"	"	Drone: Case 3 from 2 Level	90^o	"	"	"	
.17	"	"	Intruder: Case 1 from 2 Level	90^o	"	"	"	
.18	"	"	Drone: Case 1 from 2 Level	90^o	90/140	"	"	
.19	"	"	Intruder: Case 1 from 3 Level	90^o	"	"	"	
.20	"	"	Intruder: Case 2 from 2 Level	180^o	"	"	"	
.21	"	"	Intruder: Case 3 from 2 Level	90^o	"	"	"	
							Total	105

TABLE A-3

TEST SERIES 3: CLIMBING OR DESCENDING AIRCRAFT

Class No.	Encounter Flight Rules	Encounter Equipment Status	Type Approach	Track Crossing Angles	Airspeeds (Knots)	Horizontal Miss Distance	Encounter Response Mode	Encounters
3.1	VFR/VFR	DABS/DABS	Straight; drone climbs at 500 ft/min from 500 ft	Set 6*	100/100	0	R/R	5
.2	"	"	Straight; drone dives at 1000 ft/min from 1000 ft	"	"	"	"	5
.3	"	"	Straight; drone climbs at 800 ft/min from 1000 ft	"	"	"	"	5
.4	"	"	Straight; drone dives at 2000 ft/min from 1100 ft	"	"	"	"	5
.5	"	"	Straight; drone climbs at 800 ft/min from 1500 ft	"	"	"	"	5
.6	"	"	Straight; drone dives at 2000 ft/min from 2500 ft	"	"	"	"	5
.7	"	"	Straight; intruder climbs at 1000 ft/min from 800 ft	"	"	"	"	5
.8	"	"	Straight; drone dives at 2000 ft/min from 1100 ft	"	140/90	"	"	5
.9	"	"	Straight; intruder dives at 1500 ft/min from 1200 ft	"	90/140	"	"	5
							Total	45

*Set 6 contains one encounter each at 0°, 15°, 45°, 90°, and 180°.

TABLE A-4

TEST SERIES 4: MANEUVERS AT PILOT DISCRETION

Class No.	Encounter Flight Rules	Encounter Equipment Status	Type Approach	Track Crossing Angles	Airspeeds (knots)	Horizontal Miss Distance	Encounter Response Mode	Number Of Encounters
4.1	VFR/VFR	DABS/DABS	Straight Level	Set 4*	100/100	0	R/R	20
.2	"	"	Straight Level	Set 5*	140/ 90	"	"	20
.3	"	"	Drone: Case 1 from 2 Level	Set 6*	100/100	"	"	5
.4	"	"	Intruder: Case 1 from 3 Level	"	"	"	"	5
.5	"	"	Drone: Case 1 from 3 Level	"	140/ 90	"	"	5
.6	"	"	Straight; drone dives at 500 ft/min	"	100/100	"	"	5
.7	"	"	Straight; intruder climbs at 500 ft/min	"	"	"	"	5
.8	"	"	Straight; intruder climbs at 1000 ft/min	"	90/140	"	"	5
							Total	70

*Track crossing angle set 4 includes 15-, 90-, and 135-degree intercepts. Set 5 includes 0-, 90-, and 135-degree intercepts. Five encounters will be tested at each intercept angle, except for 90 degrees, where 10 encounters will be tested. Set 6 includes 0-, 15-, 45-, 90-, and 180-degree intercepts.

TABLE A-5

TEST SERIES 5: DABS/ATCRBS

Class No.	Encounter Flight Rules	Encounter Equipment Status	Type Approach	Track Crossing Angles	Airspeeds (knots)	Horizontal Miss Distance	Encounter Response Mode	Number Of Encounters
5.1	VFR/VFR	DABS/ATCRBS	Straight Level	Set 3*	100/100	0	R/NR	30
.2	"	"	"	Set 6*	140/ 90	"	"	5
.3	"	"	"	"	90/140	"	"	10
.4	"	"	Drone: Case 1 from 2 Level	"	100/100	"	"	5
.5	"	"	Drone: Case 1 from 3 Level	"	100/100	"	"	5
.6	"	"	Intruder: Case 1 from 2 Level	"	100/100	"	"	5
.7	"	"	Intruder: Case 1 from 3 Level	"	100/100	"	"	5
.8	"	"	Straight; drone climbs at 500 ft/min from 500 ft	"	100/100	"	"	5
.9	"	"	Straight; drone dives at 1000 ft/min from 1000 ft	"	100/100	"	"	5
.10	"	"	Straight; intruder climbs at 500 ft/min from 500 ft	"	100/100	"	"	5
.11	"		Straight; intruder dives at 1000 ft/min from 1000 ft	"	100/100	"	"	5
							Total	85

*Track crossing angle set 3 includes 0-, 15-, 45-, 90-, 135-, and 180-degree intercepts. Set 6 includes 0-, 15-, 45-, 90-, and 180-degree intercepts.

TABLE A-6

TEST SERIES 6: IFR/IFR

Class No.	Encounter Flight Rules	Encounter Equipment Status	Type Approach	Track Crossing Angles	Airspeeds (knots)	Horizontal Miss Distance	Encounter Response Mode	Number Of Encounters
9.1	IFR/IFR	DABS/DABS	Straight Level	Set 4*	140/140	0	R/R	15
.2	"	"	Drone: Case 1 from 2 Level	90°	"	"	"	5
.3	"	"	Intruder: Case 1 from 3 Level	"	"	"	"	5
.4	"	"	Intruder climbing at 1000 ft/min: Straight	"	"	"	"	5
.5	"	"	Drone descending at 1000 ft/min: Straight	"	"	"	"	5
							Total	35

*Track crossing angle set 4 includes 15-, 90-, and 135-degree intercepts. For test series 9, each intercept angle should be tested five times.

TABLE A-7

TEST SERIES 7: VFR/IFR

Class No.	Encounter Flight Rules	Ecnounter Equipment Status	Type Approach	Track Crossing Angles	Airspeeds (knots)	Horizontal Miss Distance	Encounter Response Mode	Number Of Encounters
10.1	VFR/IFR	DABS/DABS	Straight Level	Set 5*	90/140	0	R/R	15
.2	"	"	"	"	140/90	"	"	15
.3	"	"	Intruder: Case 1 from 3 Level	90°	90/140	"	"	5
.4	"	"	Intruder climbs at 1000 ft/min: Straight	90°	"	"	"	5
.5	IFR/VFR	"	Straight Level	Set 5	140/90	"	"	15
.6	"	"	Drone: Case 1 from 3 Level	90°	"	"	"	5
.7	"	"	Drone dives at 1000 ft/min: Straight	90°	"	"	"	5
.8	"	DABS/ATCRBS	Straight Level	Set 5	"	"	R/NR	15
.9	"	"	"	"	90/140	"	"	15
							Total	95

*Track crossing angle set 5 includes 0-, 90-, and 135-degree intercepts. For test series 10, each intercept angle should be tested five times.

TABLE A-8

TEST SERIES 8: NONRESPONDING AIRCRAFT

Class No.	Encounter Flight Rules	Encounter Equipment Status	Type Approach	Track Crossing Angles	Airspeeds (knots)	Horizontal Miss Distance	Encounter Response Mode	Number Of Encounters
11.1	VFR/VFR	DABS/DABS	Straight Level	Set 4*	100/100	0	R/NR	15
.2	"	"	Intruder: Case 1 from 2: Level	90°	"	"	"	5
.3	"	"	Drone: Case 1 from 2 Level	"	"	"	"	5
.4	"	"	Intruder climbs at 500 ft/min: Straight	"	"	"	"	5
.5	"	"	Drone dives at 500 ft/min: Straight	"	"	"	"	5
							Total	35

*Track crossing angle set 4 includes 0-, 90-, and 135-degree intercepts. For test series 10, each intercept angle should be tested five times.

Test Series 9: <u>Night Tests</u>

The same encounters as those described in Test Series 8 will be flown, but at normal range from the DABSEF at night. Total number of encounters: 35.

Test Series 10: <u>Two Subject Pilots</u>

The same encounters as those described in Test Series 8 will be flown, but at normal range from the DABSEF. Subject pilots, each under the observation of an IPC test pilot, will fly both aircraft. Whenever Test Series 8 indicates "intruder aircraft," Test Series 10 replaces that phrase with "one of the drone aircraft." Total number of encounters: 35.

APPENDIX B

TYPICAL HAYSTACK MISSION

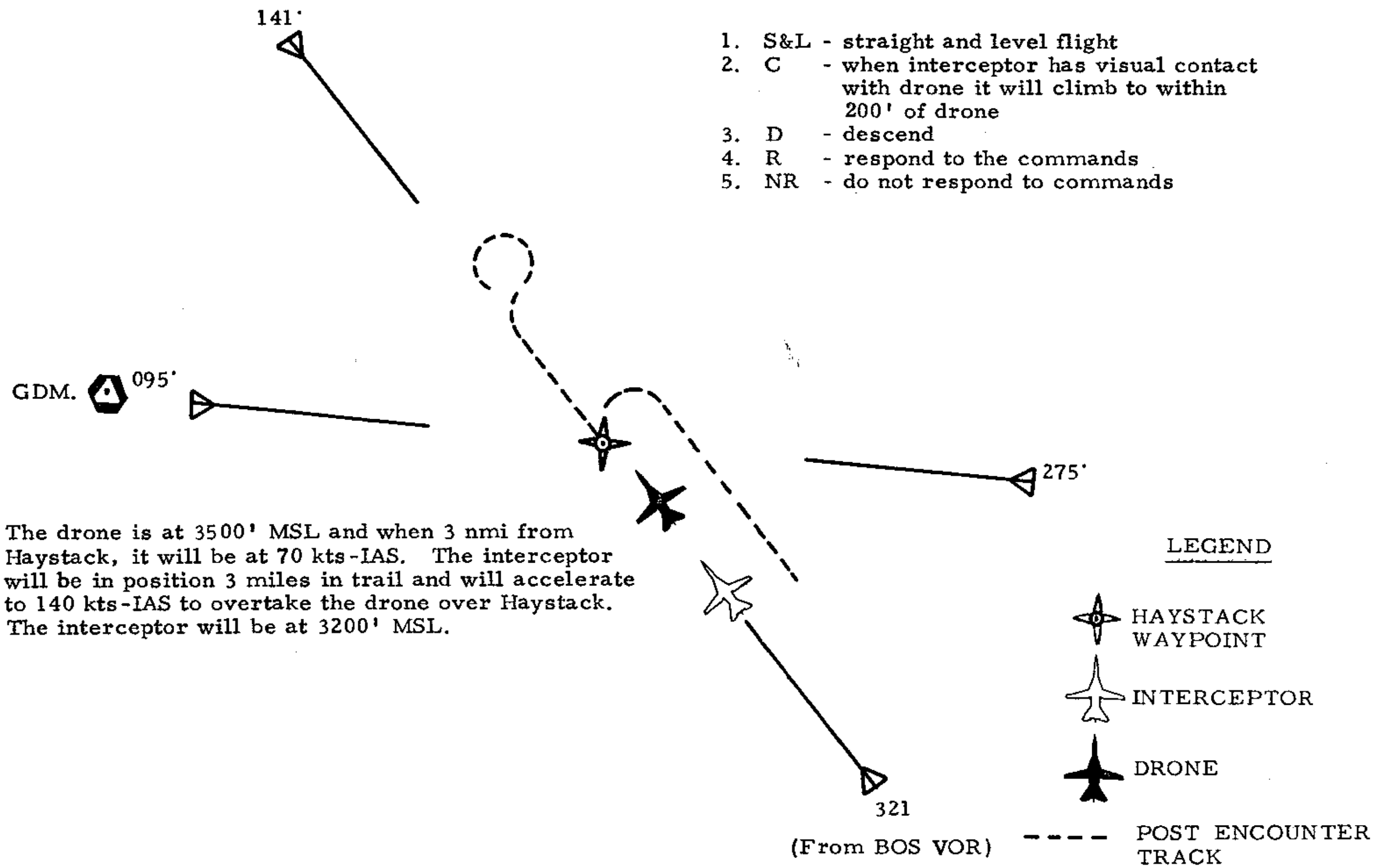
This appendix describes a typical Haystack mission including twelve encounters. The radials for the interceptor and drone are specified for each of the crossing angles. The parameter values for each encounter are at the top of each sheet. The operational aspects of this mission are given in Section 5. 1. 1, Fixed-Point Operations.

Note that the notational convention for the slash line differs in this Appendix from that introduced in Appendix A. In this Appendix all items, which appear before the slash line, refer to the interceptor; whereas those items following the slash line refer to the drone.

Interceptor/Drone — Production Encounters — Encounter 1

Flight Rules	Equipment	Type Approach	X-Angle (deg)	Airspeeds (kts-IAS)	Proj. Miss (nmi)	Initial Alt. Dif(ft)	Responding
VFR/VFR	DABS/ DABS	S&L/S&L	(Tail)	140/70	0	200	[4]R/R

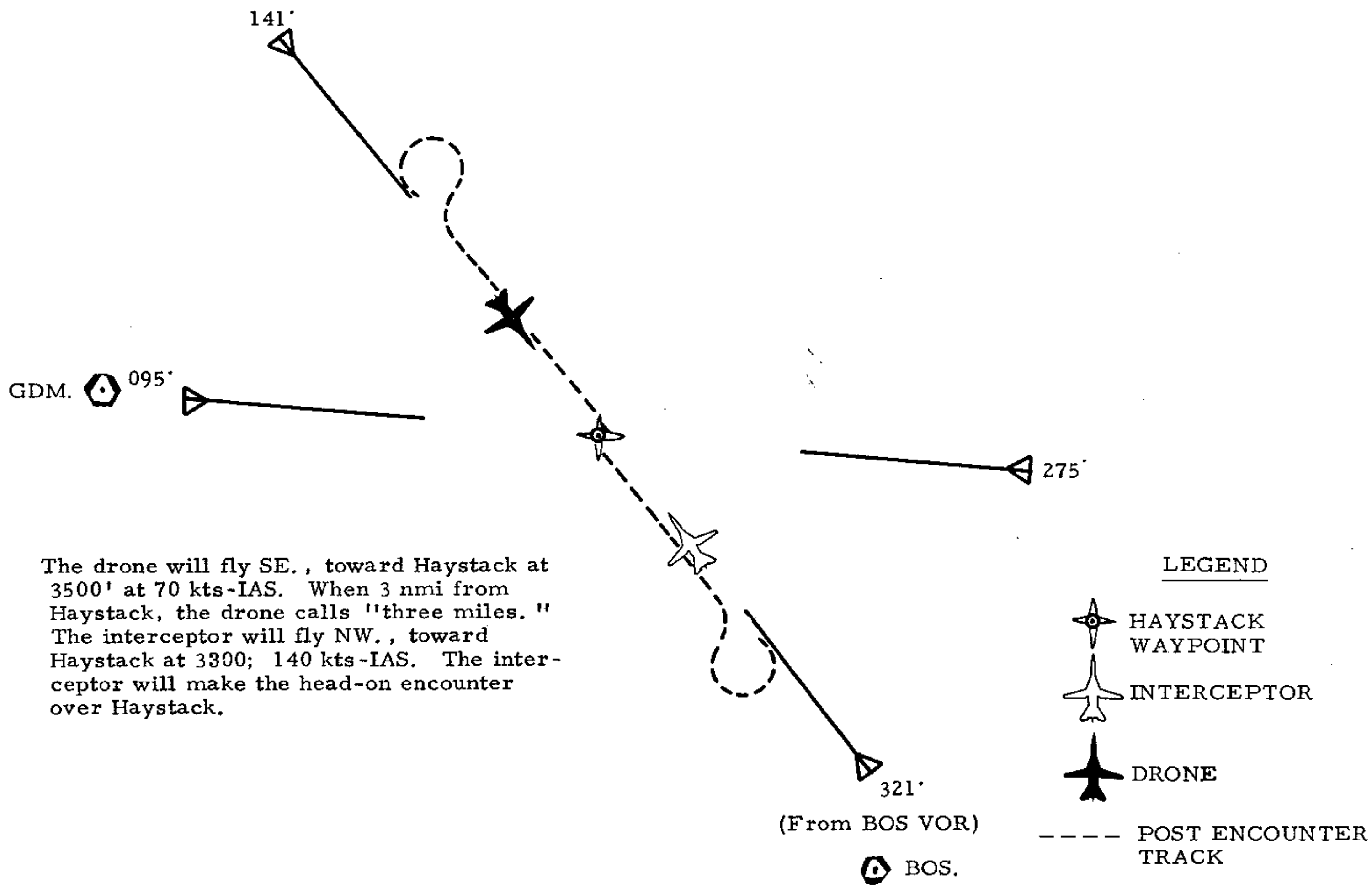
1. S&L - straight and level flight
2. C - when interceptor has visual contact with drone it will climb to within 200' of drone
3. D - descend
4. R - respond to the commands
5. NR - do not respond to commands



The drone is at 3500' MSL and when 3 nmi from Haystack, it will be at 70 kts-IAS. The interceptor will be in position 3 miles in trail and will accelerate to 140 kts-IAS to overtake the drone over Haystack. The interceptor will be at 3200' MSL.

Interceptor/Drone | Production Encounters | Encounter 2

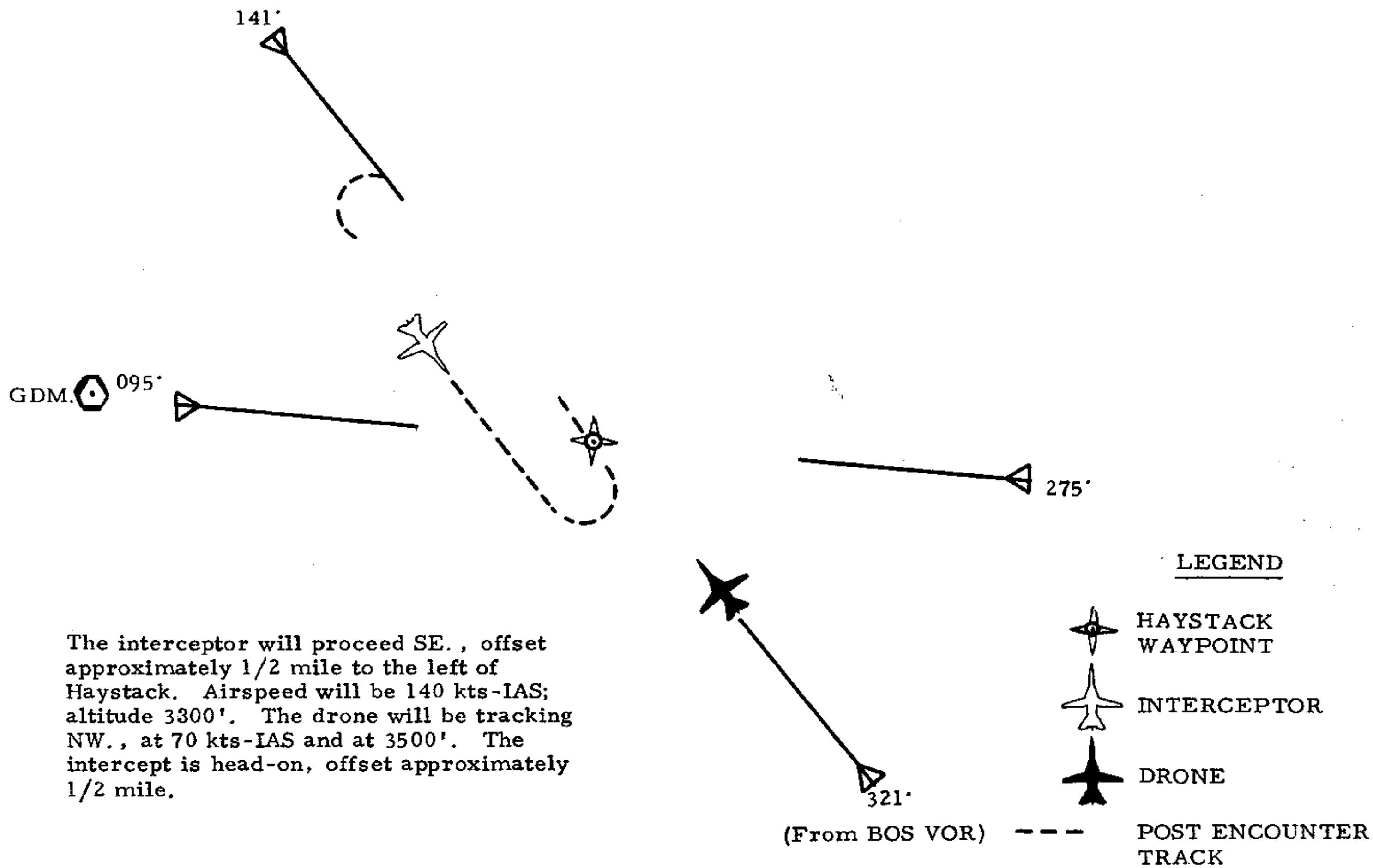
Flight Rules	Equipment	Type Approach	X-Angle (deg)	Airspeeds (kts-IAS)	Proj. Miss (nmi)	Initial Alt. Dif(ft)	Responding
VFR/VFR	DABS/DABS	S&L/S&L	180 Head-on	140/70	0	200	R/R



The drone will fly SE., toward Haystack at 3500' at 70 kts-IAS. When 3 nmi from Haystack, the drone calls "three miles." The interceptor will fly NW., toward Haystack at 3300; 140 kts-IAS. The interceptor will make the head-on encounter over Haystack.

Interceptor/Drone | Production Encounters | Encounter 3

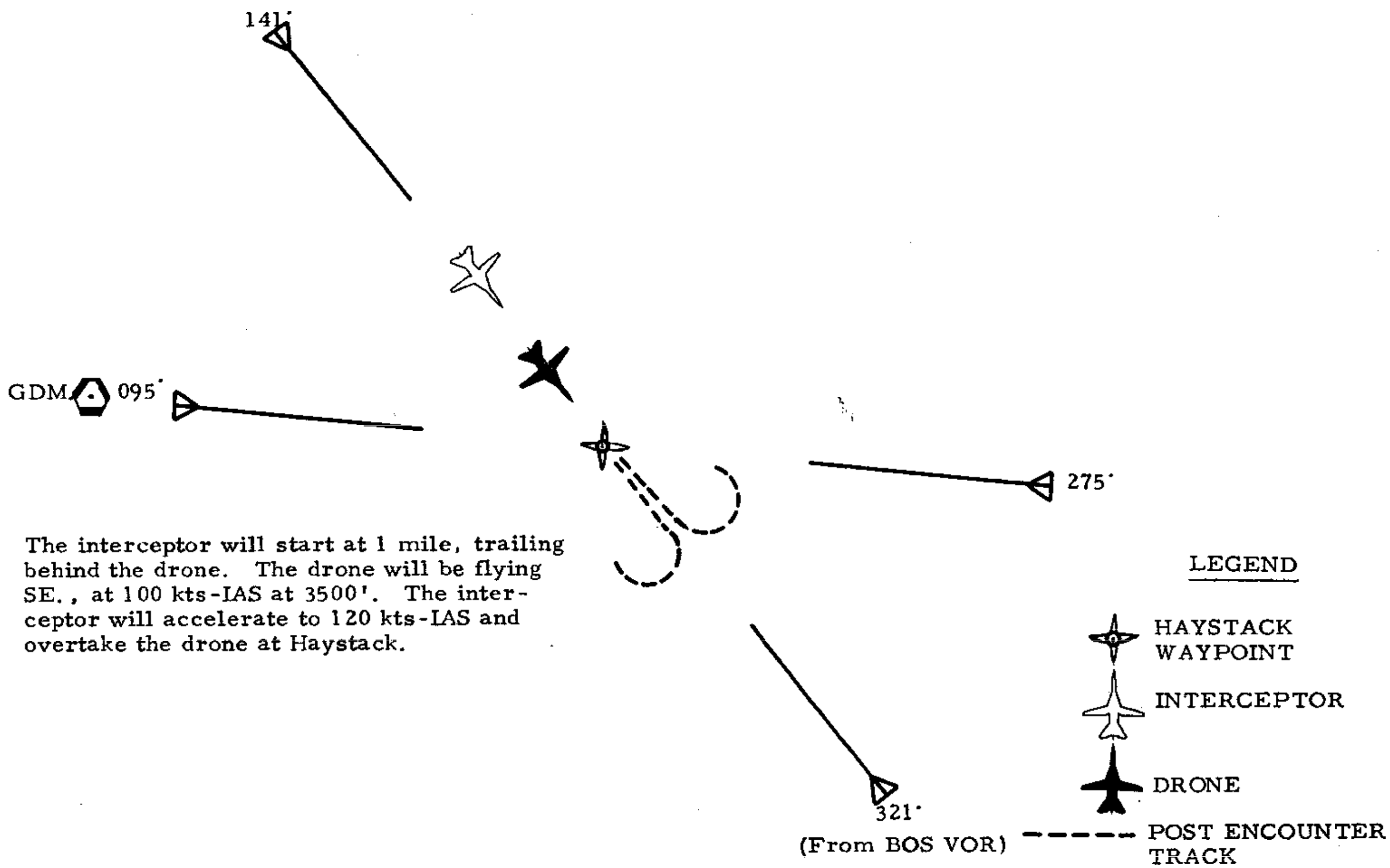
Flight Rules	Equipment	Type Approach	X-Angle (deg)	Airspeeds (kts-IAS)	Proj. Miss (nmi)	Initial Alt. Dif(ft)	Responding
VFR/VFR	DABS/DABS	S&L/S&L	180 Head-on	140/70	1/2	200	R/R



The interceptor will proceed SE., offset approximately 1/2 mile to the left of Haystack. Airspeed will be 140 kts-IAS; altitude 3300'. The drone will be tracking NW., at 70 kts-IAS and at 3500'. The intercept is head-on, offset approximately 1/2 mile.

Interceptor/Drone — Production Encounters — Encounter 4

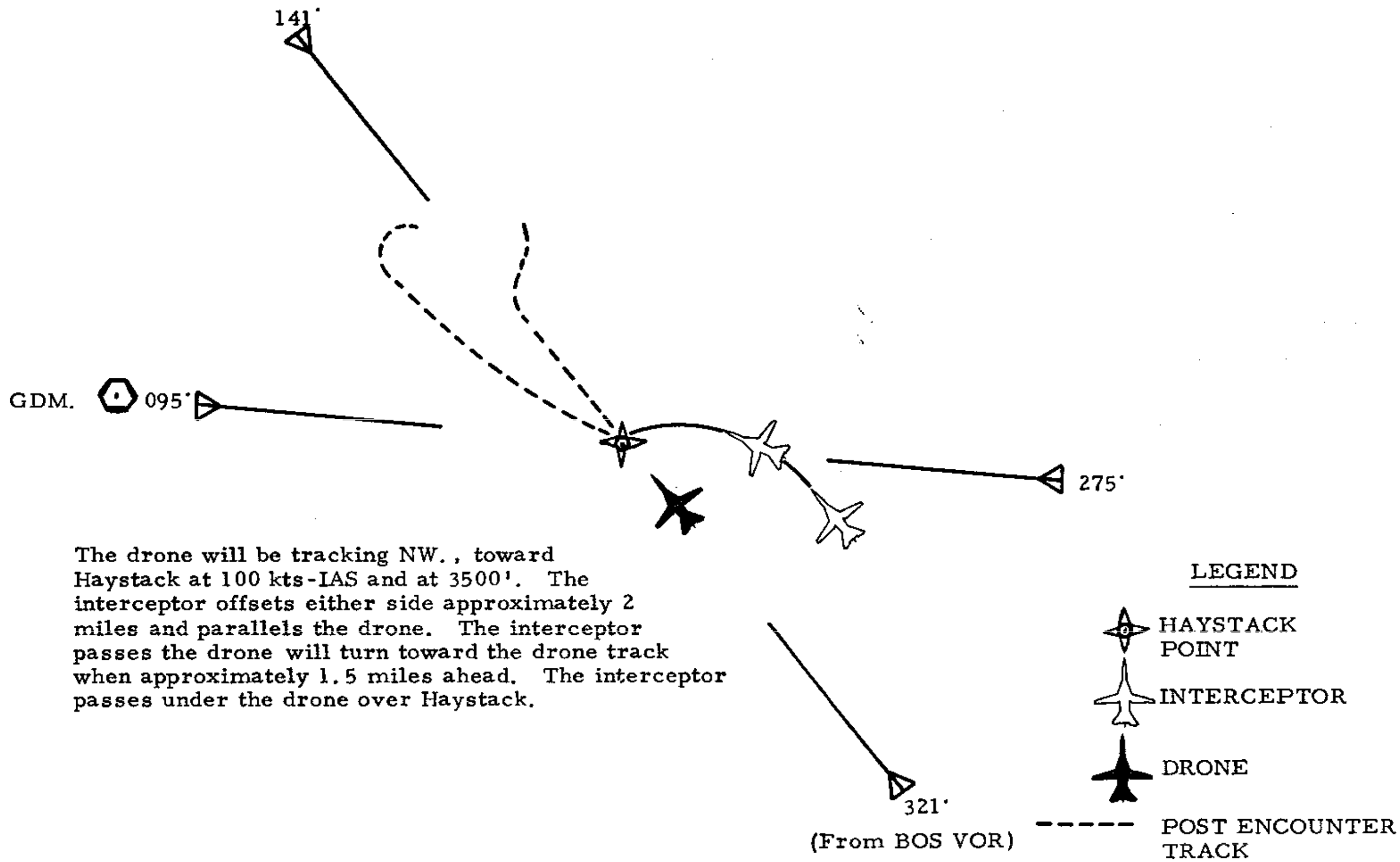
Flight Rules	Equipment	Type Approach	X-Angle (deg)	Airspeeds (kts-IAS)	Proj. Miss (nmi)	Initial Alt. Dif(ft)	Responding
VFR/VFR	DABS/DABS	S&L/S&L	0 (Tail)	120/100	0	200	R/R



The interceptor will start at 1 mile, trailing behind the drone. The drone will be flying SE., at 100 kts-IAS at 3500'. The interceptor will accelerate to 120 kts-IAS and overtake the drone at Haystack.

Interceptor/Drone — Production Encounters — Encounter 5

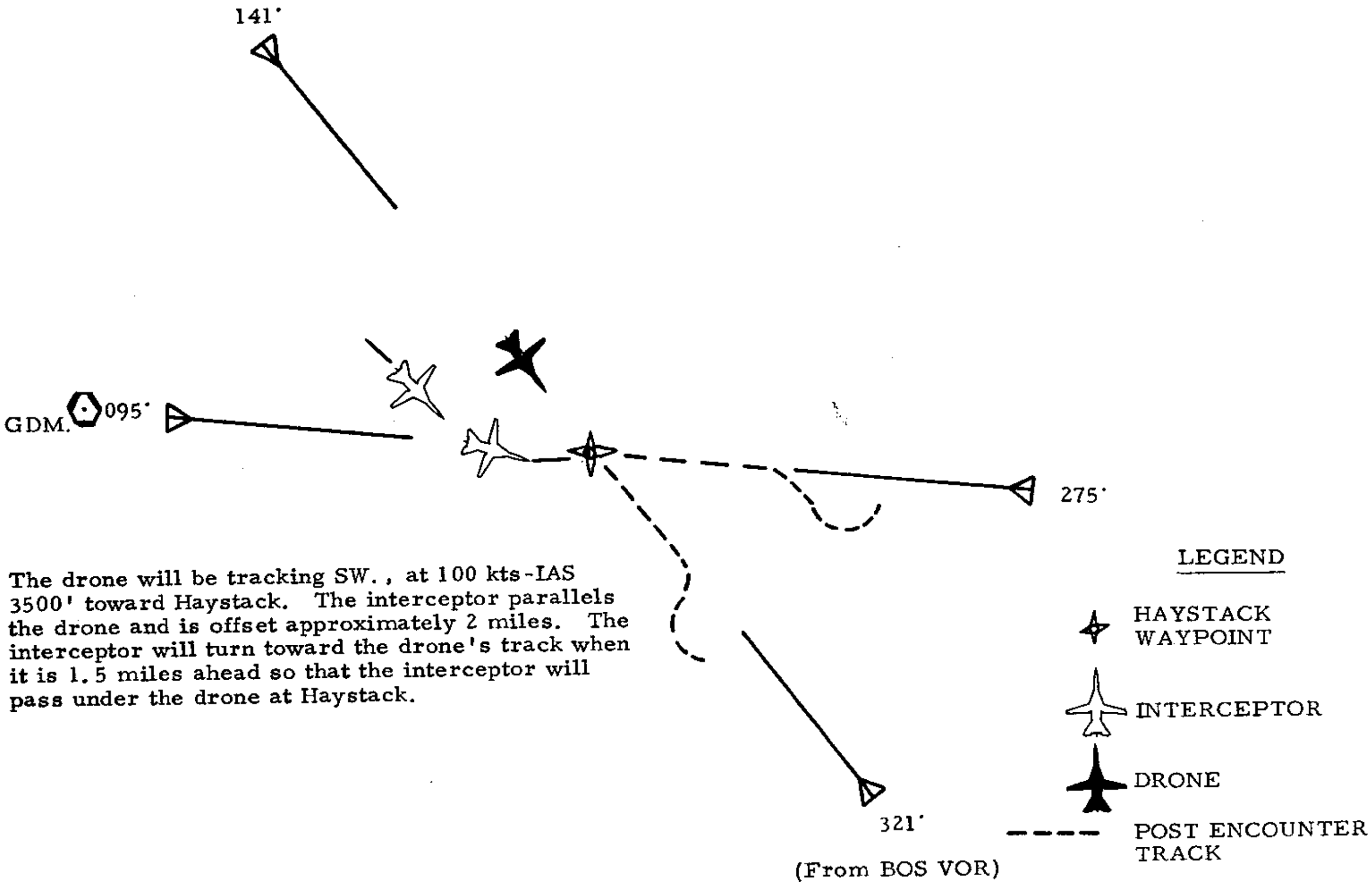
Flight Rules	Equipment	Type Approach	X-Angle (deg)	Airspeeds (kts-IAS)	Proj. Miss (nmi)	Initial Alt. Dif(ft)	Responding
VFR/VFR	DABS/DABS	Turn/S&L	0 Parallel	100/100	3/4 to 0	200	R/R



The drone will be tracking NW., toward Haystack at 100 kts-IAS and at 3500'. The interceptor offsets either side approximately 2 miles and parallels the drone. The interceptor passes the drone will turn toward the drone track when approximately 1.5 miles ahead. The interceptor passes under the drone over Haystack.

Interceptor/Drone | Production Encounters | Encounter 6

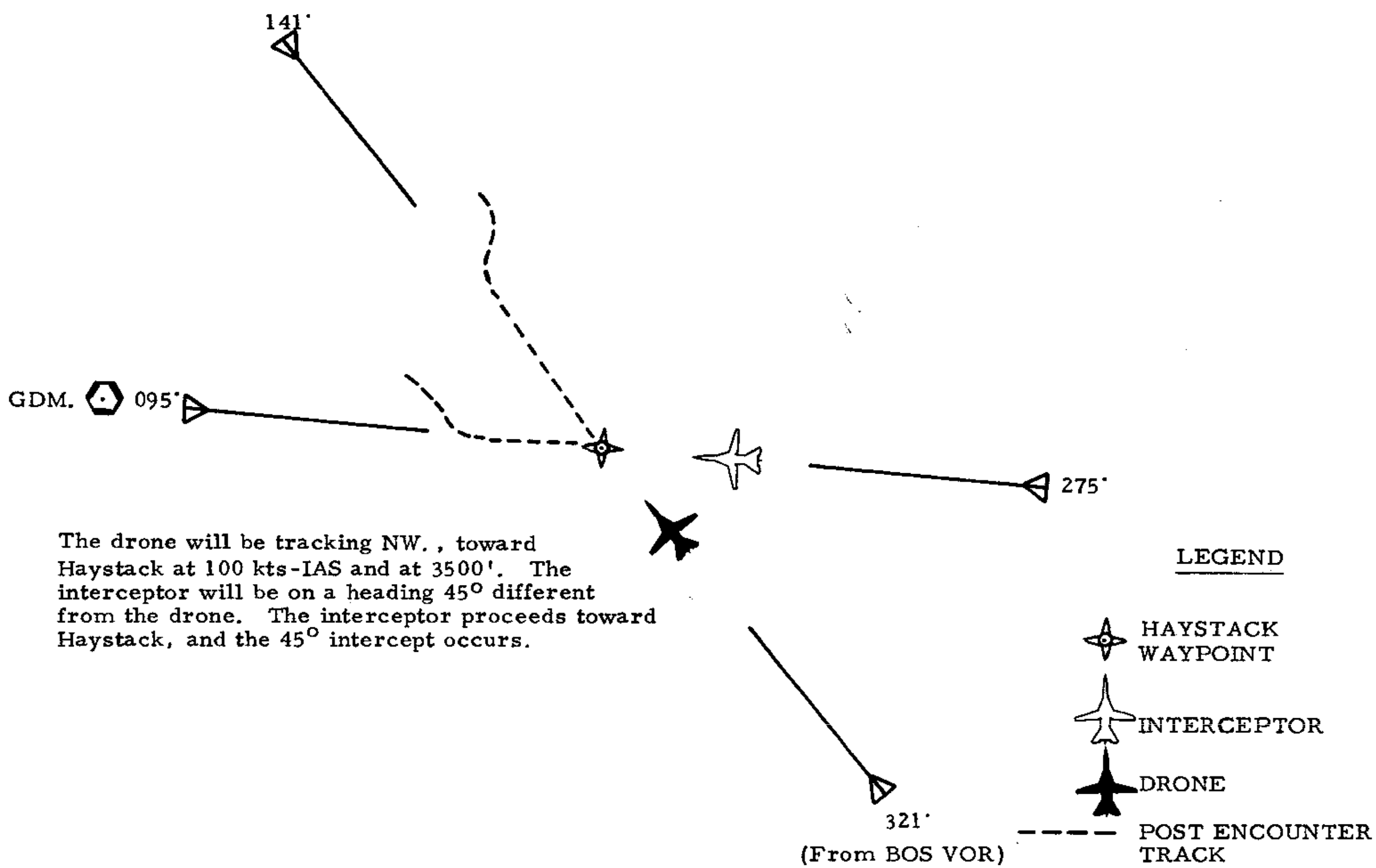
Flight Rules	Equipment	Type Approach	X-Angle (deg)	Airspeeds (kts-IAS)	Proj. Miss (nmi)	Initial Alt. Dif(ft)	Responding
VFR/VFR	DABS/DABS	Turn/S&L	0 Parallel	100/100	3/4 to 0	200	NR/R



The drone will be tracking SW., at 100 kts-IAS 3500' toward Haystack. The interceptor parallels the drone and is offset approximately 2 miles. The interceptor will turn toward the drone's track when it is 1.5 miles ahead so that the interceptor will pass under the drone at Haystack.

Interceptor/Drone — Production Encounters — Encounter 7

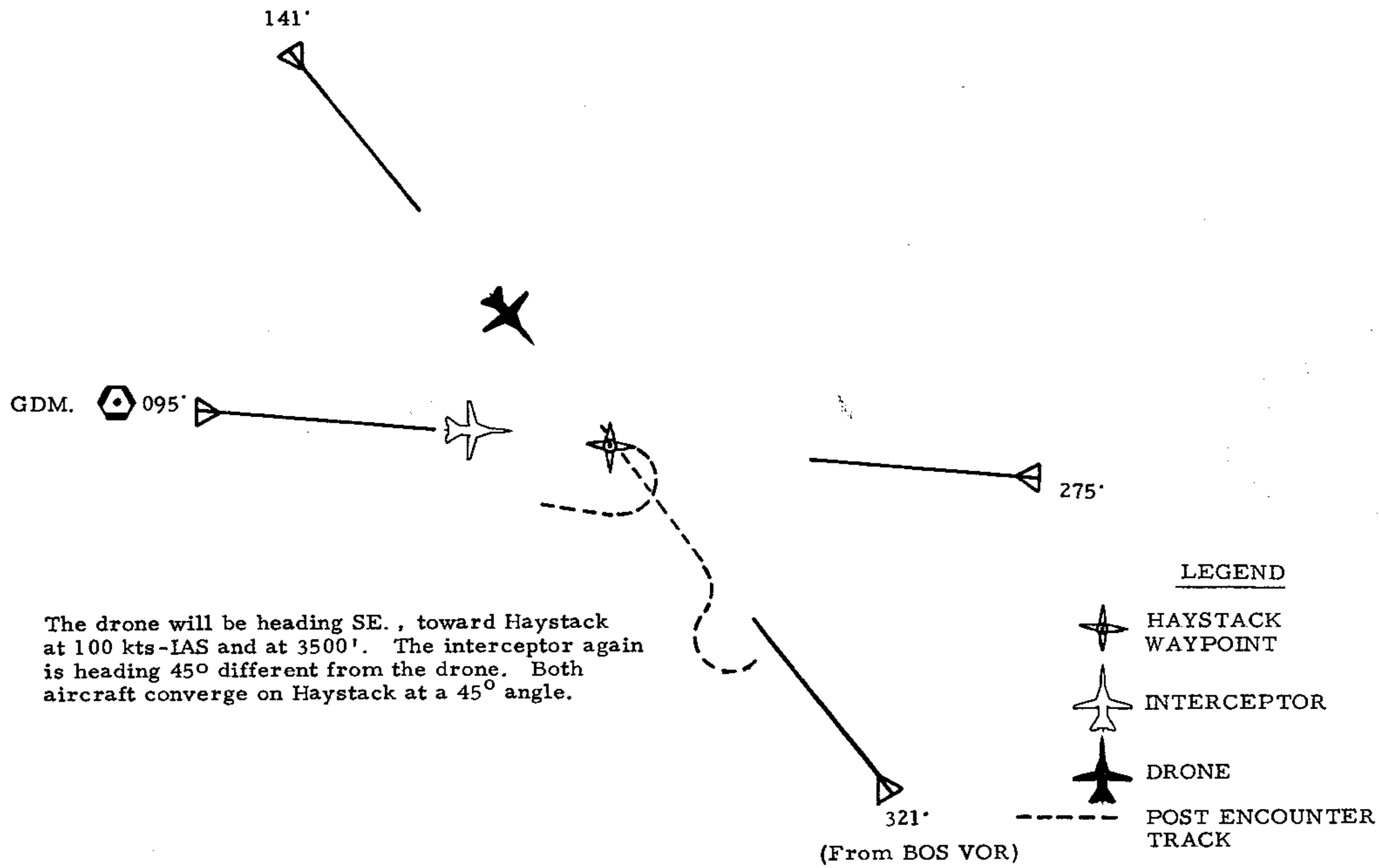
Flight Rules	Equipment	Type Approach	X-Angle (deg)	Airspeeds (kts-IAS)	Proj. Miss (nmi)	Initial Alt. Dif(ft)	Responding
VFR/VFR	DABS/DABS	S&L/S&L	45	100/100	0	200	R/R



The drone will be tracking NW., toward Haystack at 100 kts-IAS and at 3500'. The interceptor will be on a heading 45° different from the drone. The interceptor proceeds toward Haystack, and the 45° intercept occurs.

Interceptor/Drone | Production Encounters | Encounter 8

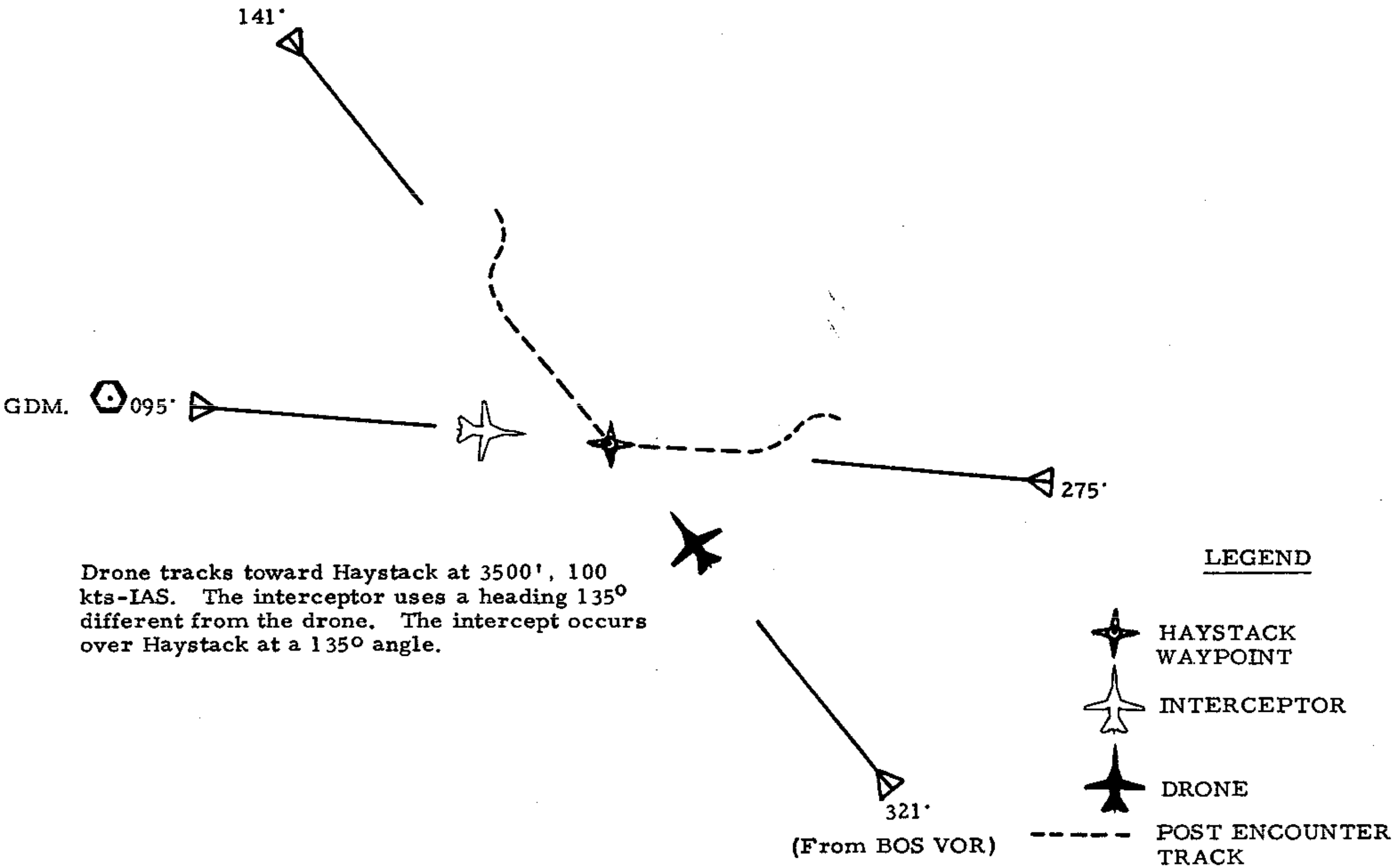
Flight Rules	Equipment	Type Approach	X-Angle (deg)	Airspeeds (kts-IAS)	Proj. Miss (nmi)	Initial Alt. Dif(ft)	Responding
VFR/IFR	DABS/DABS	C/S&L	45	100/100	0	1500	R/NR



The drone will be heading SE., toward Haystack at 100 kts-IAS and at 3500'. The interceptor again is heading 45° different from the drone. Both aircraft converge on Haystack at a 45° angle.

Interceptor — Production Encounters — Encounter 9

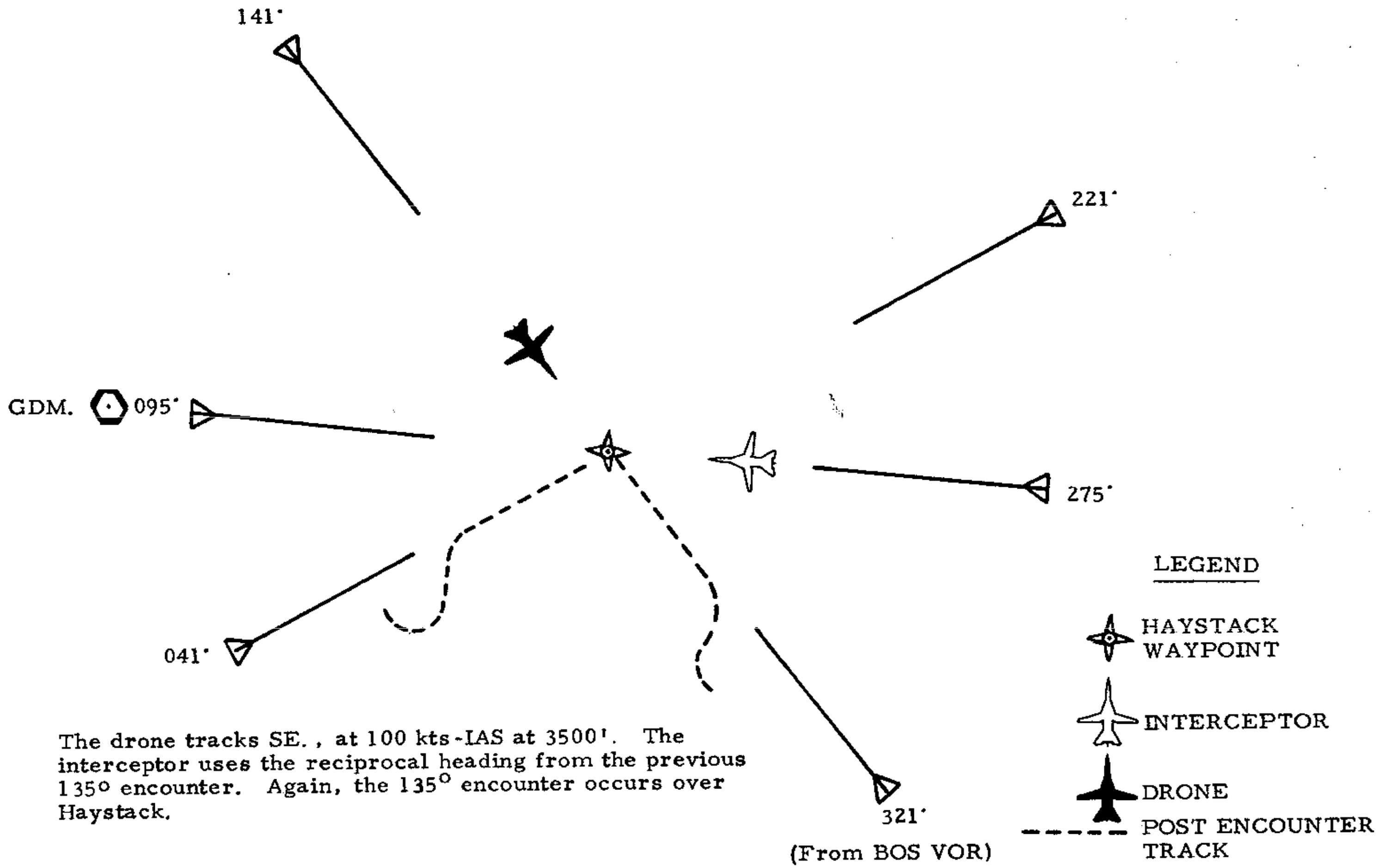
Flight Rules	Equipment	Type Approach	X-Angle (deg)	Airspeeds (kts-IAS)	Proj. Miss (nmi)	Initial Alt. Dif(ft)	Responding
VFR/VFR	ATCRBS/ DABS	D/S&L	135	100/100	0	1500	NR/R



Drone tracks toward Haystack at 3500', 100 kts-IAS. The interceptor uses a heading 135° different from the drone. The intercept occurs over Haystack at a 135° angle.

Interceptor/Drone | Production Encounters | Encounter 10

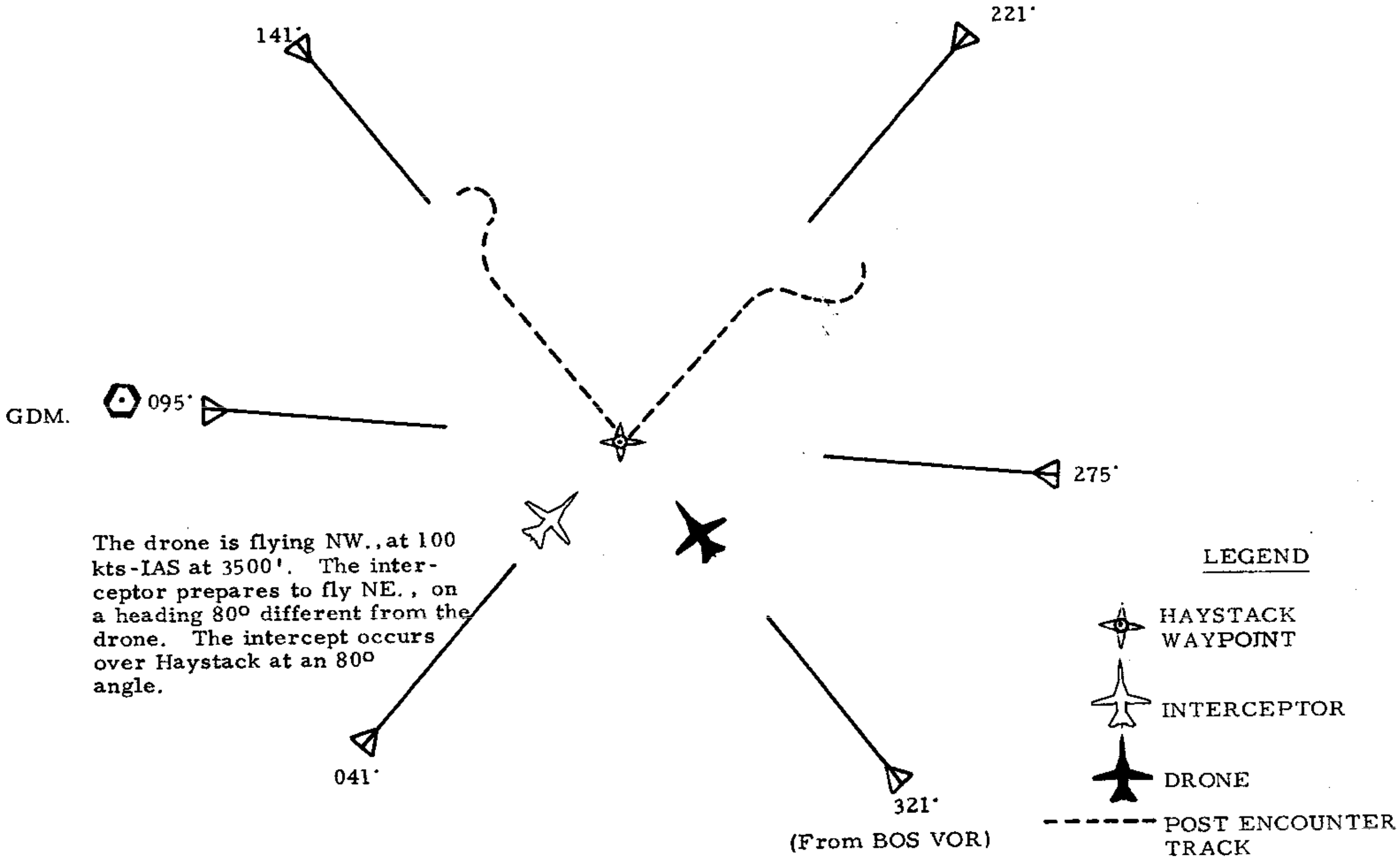
Flight Rules	Equipment	Type Approach	X-Angle (deg)	Airspeeds (kts-IAS)	Proj. Miss (nmi)	Initial Alt. Dif(ft)	Responding
VFR/VFR	DABS/DABS	S&L/S&L	135	100/100	0	200	R/R



The drone tracks SE., at 100 kts-IAS at 3500'. The interceptor uses the reciprocal heading from the previous 135° encounter. Again, the 135° encounter occurs over Haystack.

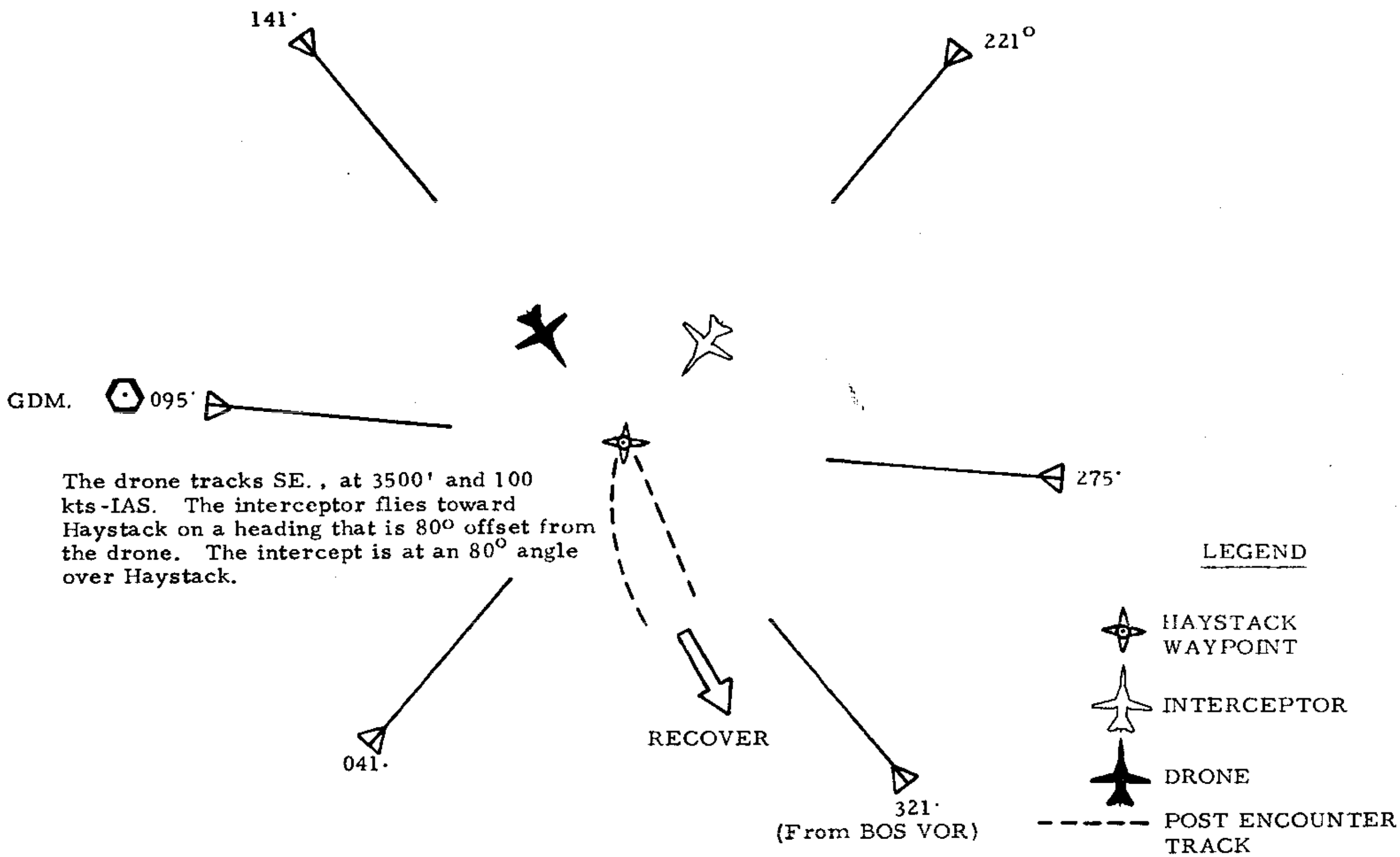
Interceptor/Drone — Production Encounters — Encounter 11

Flight Rules	Equipment	Type Approach	X-Angle (deg)	Airspeeds (kts-IAS)	Proj. Miss (nmi)	Initial Alt. Dif(ft)	Responding
VFR/IFR	DABS/DABS	S&L/S&L	80	100/100	0	200	R/R



Interceptor/Drone — Production Encounters — Encounter 12

Flight Rules	Equipment	Type Approach	X-Angle (deg)	Airspeeds (kts-IAS)	Proj. Miss (nmi)	Initial Alt. Dif(ft)	Responding
VFR/VFR	DABS/ ATCRBS	S&L/S&L	80	100/100	0	200	R/NA



The drone tracks SE., at 3500' and 100 kts-IAS. The interceptor flies toward Haystack on a heading that is 80° offset from the drone. The intercept is at an 80° angle over Haystack.

APPENDIX C

HAYSTACK-MANCHESTER-GARDNER-HAYSTACK COURSE

This appendix describes a course designed for subject pilot missions based on the course used as an illustration in Section 5.1.2, Planned Course Operations, but flown in a counterclockwise direction. Haystack, Gardner-VOR (GDM), and Manchester-VOR (MHT) mark the corners of the triangular course. Eight encounters occur during one circuit of the course. The parameter values for each of the eight encounters are given.

Note that the notational convention for the slash line differs in this Appendix from that introduced in Appendix A. In this Appendix all items, which appear before the slash line, refer to the interceptor; whereas those items following the slash line refer to the drone.

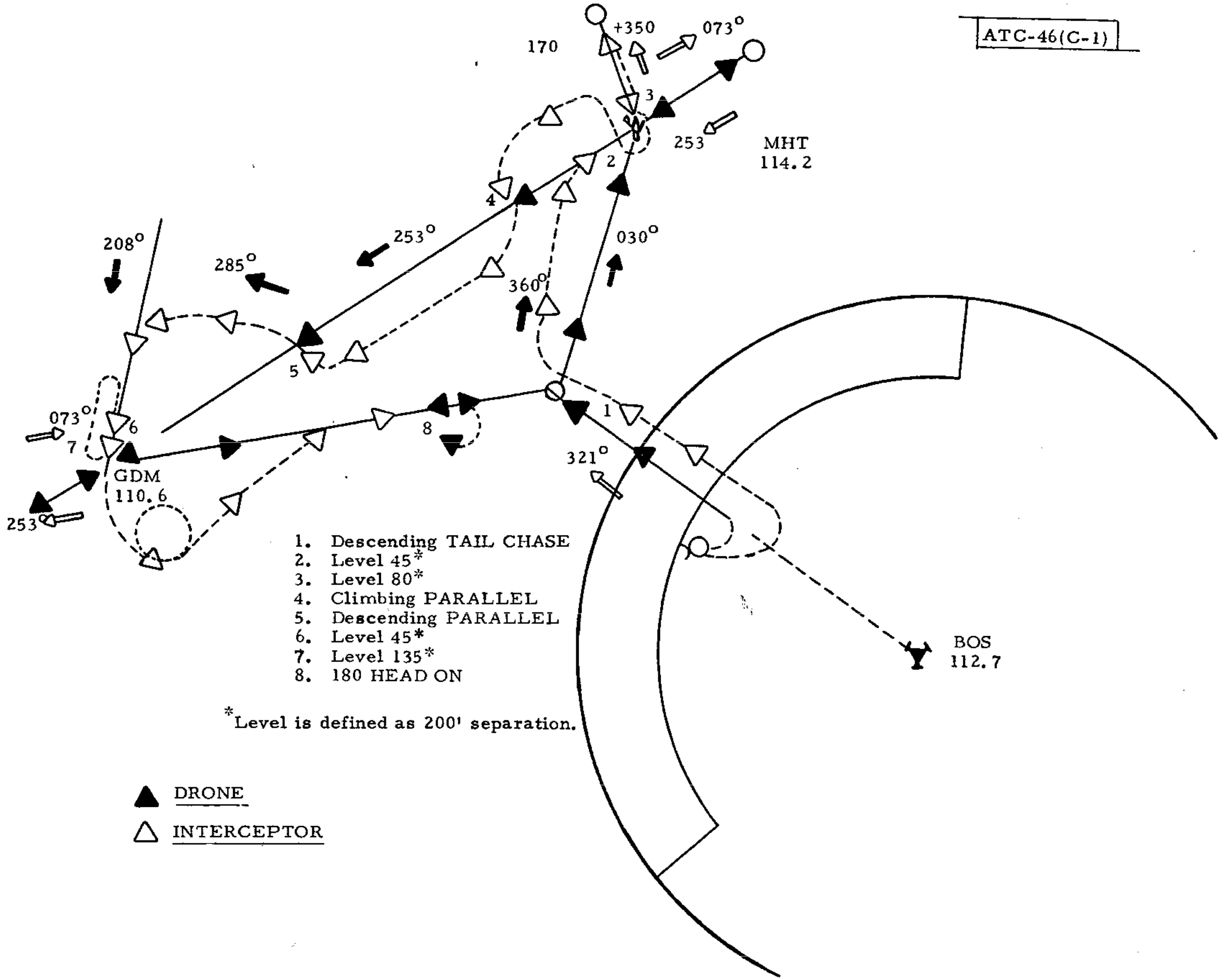


Fig. C-1. Counterclockwise triangle.

Run	Flight Rules	Equipment	Type Applied	X Angle	Airspd (kts.)	Hor Miss Dist.	Initl Alt Sep	Pilot Response	Expctd Commds	Remarks
1	VFR/VFR	DABS/DABS	D/S & L	Shallow 15°	145/100	0	+1000	R/R	C/D	
2	VFR/IFR	DABS/DABS	S & L/S & L	45°	100/100	0	+ 200	R/R	L/NCorR	
3	VFR/VFR	DABS/DABS	S & L/S & L	80°	100/100	0	+ 200	R/R	R/R	
4	VFR/VFR	DABS/DABS	C/S & L	Parallel 90° turn	145/100	0	-1000	R/R	R/R	Interceptor behind drone
5	VFR/VFR	DABS/DABS	D/S & L	Again	145/100	0	-1000	R/R	R/R	Interceptor behind drone
6	VFR/VFR	DABS/DABS	S & L/S & L	45°	100/100	0	0	R/R	L/L R/R	
7	VFR/VFR	DABS/DABS	S & L/S & L	135°	100/100	0	-200	R/R	R/R	
8	VFR/VFR	DABS/DABS	S & L/S & L	Headon 180°	145/100	0	-200	R/R	R/R	

(INTERCEPTOR/DRONE)

Fig. C-2. GDM (Gardner) triangle interceptors (counterclockwise).

APPENDIX D

IPC FLIGHT TEST COMMUNICATION FREQUENCIES

VHF frequencies, to be used by the test aircraft when flying encounters within a 60-nmi radius of DABSEF, are listed in Table D-1. The dedicated DABS control frequency is 132.8 MHz, and the DABS subject pilot frequency is 123.775 MHz. At the bottom, locations (Jaffrey, Raymond, Taunton, Plymouth and Haystack), which have been designated as waypoints, are listed and identified using two VOR stations. These waypoints are used by the test aircraft for RNAV navigation.

TABLE D-1

IPC FLIGHT TEST COMMUNICATION FREQUENCIES

Waypoint	Frequency (MHz)
DABS Control	132.8
DABS Subject Pilot	123.775
BED ATIS	109.5 (ILS)
GND	121.7 (TWR) 118.5
BOS FSS	122.4
BOS APCH	124.4, 124.1 (VOR), 112.7 (DME)
CTR	118.05 (WEST) 133.45 (SOUTH)
CON FSS	123.6 122.2 122.3
CON VOR	112.9 (DME)
EEN VOR	109.4 (DME)
ENE	117.1 (DME)
GDM	110.6
HTM VOR	109.0 (DME)
HYA VOR	114.7 (DME)
LWM VOR	112.0
MHT VOR	114.2 (DME) APCH 124.9
TWR	121.3 GND 121.9
PUT VOR	117.4 (DME)
PVD VOR	115.6 (DME)
PVD TWR	120.7
PVD GND	121.9
UNICOMM	122.8 INTERPLANE 122.9

RNAV WAYPOINTS	VOR	HDG	DISTANCE (nmi)
JAFFREY	CON230/28 EEN 095/15	326	37
RAYMOND	ENE 255/34 MHT 030/16	015	40
TAUNTON	HTM 215/14 PVD 080/16	184	37
PLYMOUTH	PVD 085/31 HYA 310/28	161	40
HAYSTACK	BOS 320/27 GDM 095/25	330	16

APPENDIX E

IPC FLIGHT TEST SAFETY PROCEDURES

This appendix lists safety procedures and rules that must be used during the IPC flight test series. These procedures will be followed for all validation as well as subject pilot missions. Flight safety rules are listed, and a radio failure procedure is given for test aircraft radio failure.

IPC FLIGHT TEST SAFETY PROCEDURES

Rigid safety controls for IPC flight test operations shall be maintained at all times. At least one of the three professional IPC test pilots presently employed by Lincoln Laboratory will be in the cockpit of each aircraft and responsible for its operation at all times. The following is a list of IPC flight test flying and safety rules that will be adhered to throughout the testing period:

(1) IPC Flight Test pilots are the command pilots at all times and are responsible for the safe operation of the aircraft. The IPC flight test pilot will assure that the aircraft is flown in accordance with FAA Part 91 - General Operating and Flight Rules, and that the aircraft is operated within the limitations established in the aircraft handbook.

(2) Mandatory procedures for all flights include:

- a. Obtaining a complete and comprehensive weather briefing with no flight being flown into an area where moderate or severe turbulence or icing is forecast
- b. Filing a flight plan with the appropriate agency
- c. Briefing the watch supervisors at Hanscom Tower and Boston Center
- d. A mission briefing
- e. Checking flight kits to include:
  1. Jeppesen Airway Manual
  2. Local area charts
  3. Fuel, oil, and data log
  4. Key
  5. Flight Plan Record (FAA Form 7233-3)
  6. Sic-Sacs.

(3) All VFR encounters will be flown with:

- a. A minimum 200-ft vertical separation until visual contact is established by the interceptor aircraft.
- b. VHF interplane and DABSEF communications.
- c. Five-mile visibility and 1000-ft clearance from clouds.
- d. An observer in each aircraft, whose main function is scanning for traffic and data collection. A secondary function is being in charge of the aircraft's radios and communications.

e. The flight and mission controller will monitor the encounters. The flight controller will issue advisories that will consist of aircraft separation, position of conflicting traffic and any assistance deemed necessary by the controllers or requested by the pilots.

(4) Radio failure procedures will include adherence to FAA Part 91 and the following:

a. Maintaining visual contact with accompanying test aircraft and landing at nearest suitable airport.

b. If out of visual contact, the affected aircraft will proceed to the next encounter fix and orbit for 10 minutes.

c. If no visual contact with the other test aircraft is established after orbiting for 10 minutes, the pilot will land at the nearest suitable field and call DABSEF on the land line to inform DABSEF of his problem.

d. If visual contact is made by the test aircraft, the unaffected aircraft will relay to DABSEF the problems being encountered and an ETA at the nearest suitable airport.

APPENDIX F
FLIGHT REVIEW CHECKLIST

A form similar to that included here will be used to evaluate subject pilots as described in Section 5. 3, Subject Pilot Operation. The completed checklist will be used as a guide in evaluating pilot reaction to the IPC system.

FLIGHT REVIEW CHECKLIST

ALL AIRCRAFT EQUIPMENT MAY BE USED FOR THIS REVIEW

This form is to be used as an aid in conducting a flight review. All significant maneuvers are listed; however, individual situations will dictate which ones will be explored with the participating pilot. After completion of the flight review, the form should remain with the pilot for his reference.

STUDENT ______________________________ TIME IN __________

INSTRUCTOR __________________ DATE __________ TIME OUT __________

AIRCRAFT NO. N__________ MAKE __________ MODEL __________ HP __________

PILOT HOURS: TOTAL __________ DUAL __________ SOLO __________

	GOOD	ACCEPTABLE	RUSTY	INSTRUCTOR REMARKS
Flight planning				
Engine starting & warmup				
Taxiing				
Preflight runup & use of checklist				
Normal takeoffs				
Crosswind takeoffs				
Normal climb				
Level off				
Straight & level flying				
Use of trim				
Ground track & ground reference maneuvers: Rectangular courses. "S"-turns across a road. Turns about a point. Pylon eights.				
Coordination & planning exercise: Slips. Medium & steep turns to specific headings. Chandelles. Lazy eights.				
Maximum performance maneuvers: Slow flight. Stall recognition and recovery.				
Emergency operations.				
Attitude instrument flying: Straight & level. Climbs, turns & descents. Unusual attitude recoveries.				
Traffic patterns.				
Normal landings.				
Crosswind landings.				
Soft field takeoffs & landings.				
Short field takeoffs & landings.				

	GOOD	ACCEPTABLE	RUSTY	INSTRUCTOR REMARKS
Use of flaps.				
Use of radio for communications.				
Use of radio for navigation.				
Pilotage.				
Smoothness on controls.				
Looking around for other aircraft.				
Shutdown & parking procedures.				

REMARKS

Signature of Pilot

FLIGHT REVIEW CHECKLIST (cont.)

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