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FAA TECHNICAL CENTER LETTER REPORT

TCAS OPERATIONAL EVALUATION
Project Plan

by

ACT-140

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U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
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1.0 OBJECTIVES

- To verify the operation of the Dalmo Victor Prototype Traffic Alert and Collision Avoidance System (TCAS II).

- To validate the cockpit display configuration and operational procedures for the minimum TCAS II.

- To demonstrate Minimum TCAS II as installed in a B-727 to the aviation community.

- To reduce Piedmont's Supplemental Type Certification (STC) activity by conducting traceable tests in coordination with Aircraft Certification Office (ACO) (Atlanta).

- To develop training techniques for Piedmont (Phase II) and future air carrier evaluations.

2.0 INTRODUCTION

This document describes the Technical Center test and evaluation of the Dalmo Victor Minimum TCAS II Prototype. The organization of this document is:

Section 1.0 - Objectives	
Section 2.0 - Introduction	Contains paragraphs of program scope, overview, and scheduling. Also includes a description of the ACO involvement in the program.
Section 3.0 - Engineering Evaluation	Detailed description of the engineering evaluation of the TCAS II prototype.
Section 4.0 - Operational Evaluation	Detailed description of the operational evaluation of the TCAS II prototype.
Section 5.0 - Demonstration Tour	Description of National Demonstration Tour of the TCAS prototype.
Section 6.0 - Training	Detailed description of the production of pilot and observer training at the Technical Center.
Section 7.0 - Resource Requirements	Describes the facilities and equipment required for the test program.
Section 8.0 - Organizational Responsibilities	
Section 9.0 - Documentation	Describes the documentation to be produced as a result of the TCAS II prototype test plan.

2.1 SCOPE

The evaluation of the Dalmo Victor TCAS II will be divided into five efforts:

Engineering Evaluation
Operational Evaluation
National Demonstration Tour
Training Development and Validation
Support for Piedmont B-727 installation certification

2.1.1 Engineering Evaluation

The engineering evaluation will be a complete verification of prototype operation. This includes hardware and software, implementation, controls and displays, and aircraft interfaces.

The fundamental design of TCAS is based on a large amount of experience with collision avoidance systems. The Dalmo Victor system is an extension of engineering model systems wherein design problems were identified and corrected, and is a prototype for an operational TCAS. Therefore, the hardware and software evaluation will be a test of TCAS implementation rather than design; only a problem that causes TCAS to fail to perform its intended function will be investigated in detail.

2.1.2 Operational Evaluation

The operational evaluation of the Prototype TCAS II will consist of subject pilot testing in the Federal Aviation Administration Technical Center's B-727. Provision will be made to fly up to 12 subject pilots organized as two groups of 6; one group with previous TCAS experience, and one group with little or no experience. The subjects will fly in airspace near the Technical Center, under ground control (simulating air traffic control), and will experience unanticipated encounters with one or two Technical Center intruder aircraft. A trained observer riding in the cockpit will annotate data regarding pilot performance and pilot opinion relative to TCAS. After the encounter flights, the subject pilots will be invited to fly the 727 into major airports to experience first hand TCAS operation in the air carrier environment. A trained observer will be riding in the cockpit and annotating pilot performance and opinion data.

2.1.3 National Demonstration Tour

With TCAS II installed and checked out, the Center's B-727 will be flown on a National Tour to demonstrate TCAS II installed in a transport cockpit to the aviation community. Present planning is to fly to crew bases, domiciles, and areas convenient to home offices of major air carriers. Representatives of the airline industry will be invited to observe TCAS as the B-727 flies in the actual air carrier environment.

2.1.4 Training Package Development and Validation

The pilot training package being prepared for Piedmont will consist of a video tape and a manual. The video tape is being prepared at the Technical Center and the manual at MITRE corporation. Subject pilots that participate in the operational evaluation will have the use of the materials prior to flying. Their comments on the quality of the materials will be documented and used for the improvement of the materials.

2.2 PROGRAM OVERVIEW

The first three areas of the test program, Engineering Evaluation, Operational Evaluation, and National Demonstration Tour comprise the validation of the TCAS prototype. The Engineering Evaluation will consist of bench, ramp, and flight testing. Current planning is to perform the bulk of bench testing at Dalmo Victor to minimize repair delay time in case of equipment failure. Ramp and flight testing will be conducted at the FAA Technical Center. Parameters such as antenna and rf stage performance will be investigated in detail. Note that these flight tests are being developed as standardized tests which may be used to support future air carrier evaluations. These flight tests will also provide an opportunity to test and debug the observer data collection and analysis procedures.

The operational evaluation will be subject pilot testing wherein two distinct types of data will be collected. The first of these is data regarding the subject pilot's evaluation of the minimum TCAS II system and operational procedures. These data will be gathered in preflight and postflight interviews with the subjects, and by the observer during and immediately following encounters during the flights. The observer data collection technique will also permit a second level of detail regarding certain issues, e.g. alarm timeliness, ambiguity, and utility.

All subject pilots will receive training by means of a training video tape and manual. The manual will be mailed to the subjects several weeks before their scheduled flight, and the video tape will be viewed by the subjects upon arrival at the Technical Center. After the pilot finishes with the video tape, his level of training will be tested in a preflight interview.

The operational evaluation will be followed by a national demonstration tour where TCAS II is demonstrated to prospective users. The tour follows the operational evaluation chronologically with some overlap in that representatives of the aviation industry will be invited to observe the subject pilot testing.

The Technical Center validation of TCAS will be overseen by the Aircraft Certification Office (ACO), whose function it is to certify Piedmont's B727 TCAS installation. The ACO will observe the Center's testing and will decide what portion of the test results they will allow Piedmont to submit in their STC application.

2.3 SCHEDULES

The projected completion schedule is shown in appendix E.

3.0 ENGINEERING EVALUATION

The engineering evaluation of the Industry Prototype TCAS II will be accomplished by bench testing, ramp (static) testing and flight testing. Most of the bench testing will be done at Dalmo Victor as part of the factory acceptance test scheduled for April 25, 1983. Some limited bench testing will be done at the Technical Center prior to the B-727 installation. Ramp checks will be made before the flight test program to validate the installation, and before each flight during the program as a measure of confidence in system operation. Flight testing will include measurements of angle of arrival (AOA) accuracy (bearing of intruder), range and altitude tracker accuracies, and CAS logic validation.

3.1 Bench Testing - Dalmo Victor

Bench testing at Dalmo Victor will be focused in three areas:

Hardware Validation
CAS Logic Validation
System Integration and Display Test

3.1.1 Hardware Validation. Procedures for the hardware validation are contained in Dalmo Victor Acceptance Test Plan (reference 1), and will not be repeated here. System parameters to be evaluated are:

1. RF Components

    a. Receivers
    b. Transmitters
    c. Video Processing

2. Degarbler Operation

3. Interface and Display Test

4. Rooftop Tracking Test

Data required from test items 1 and 2 are contained in table 1.

Data collected in these tests will be used primarily to indicate a go, no-go level of performance. The data will also be used to document any degraded system performance which has the potential to affect the subsequent operational testing.

Table 2 lists the interface testing required.

Data from this test is required to ensure minimum effort in transitioning from the Technical Center evaluation, to the Piedmont evaluation. Specifically, the symbol generator, control panel, and TCAS caution/warning switch may not be available for the factory acceptance test. However, if the interfaces are validated during the acceptance test, subsequent interconnection upon availibility should be straightforward.

Table 3 lists the display/control testing required.

TABLE 1. TCAS RF AND VIDEO PROCESSING TEST PARAMETERS

Parameter	Peformance Measure	Reference Test Procedure
1. Receiver Sensitivity	Demonstrate 90% reply probability for all receivers @ -77 dBm input level.	pp. 2.1.2.1 (reference 1)
2. Receiver Matching	Demonstrate AOA error of less than 1/4 o'clock position (7°).	pp. 5.1 (reference 1)
3. DMTL	Demonstrate proper tracking of multiple targets within 9 dB in amplitude.	pp. 2.1.2.2 (reference 1)
4. Degarblers	Demonstrate 75% track probability minimum for targets overlapped 50%.	pp. 2.2.1
5. Transmitter	Demonstrate maximum output power level of at least 57 dBm at the 8 RF/processor chassis. Also show whisper/shout sequence on oscilloscope. By inspection, determine proper relative amplitudes and waveshapes.	pp. 2.5.2 (reference 1)
6. Transmit Spectrum	Show concordance with ATCRBS spectrum system parameters to be evaluated during ATP.	None

TABLE 2. TCAS INTERFACE TEST PARAMETERS

Interface	Performance Measure	Reference Test Procedure
Air-Ground Switch	Demonstrate performance level (PL) switch.	Section 7 of Reference 1
Maximum Airspeed	Show proper system with and without the maximum airspeed interface connection.	
Weather Radar	Demonstrate WX radar display, unless Traffic Advisory (TA) or Resolution Advisory (RA) is posted in WX/TCAS mode. Demonstrate WX only.	
Flaps Discrete Gear Discrete	Demonstrate climb inhibit for contact closure on both of these.	
Radar Altimeter Input (Analog)	Demonstrate PL switch at: Less than 500 ft(10.00 +/-.5volts)= PL2 Less than 2500 ft(26.093 +/-.25 volts)=PL4	
Radar Altimeter Status	Demonstrate TCAS use of these discreets, i.e., inhibit performance level switch if failure of the radar altimeter (ALT).	
Mode C Altimeter	Demonstrate correct interface connections for all grey code bits. Also, demonstrate climb command inhibit at 34,000 foot (or greater) altitude.	
Control Interfaces	Demonstrate TCAS caution/warning switch interface; also TCAS Instantaneous Vertical Speed Indicator (IVSI) interface.	
Clock/Recorder	Demonstrate Piedmont Configuration Interface (RS-232 - for time of day). If available, record data on Genisco cartridge tapes and provide a printout of the first minute of data.	
Fine Altitude Interface	If ARINC-429 input from the AIR data computer data is implemented, produce detailed documentation of expected data format.	
Mutual Supression	Demonstrate that TCAS supplies a suppression pulse per MOPS 2.2.12.1, and that TCAS inhibits during suppression periods.	
Symbol Generator	Using a symbol generator and display per Piedmont phase 2. Demonstrate the RS-232 interface.	

TABLE 3. TCAS DISPLAY AND CONTROLS TEST PARAMETERS

Interface	Performance Measure	Reference Test Procedure
IVSI Positive Advisories Negative Advisories Bailout Vertical Speed Limit	Demonstrate proper lighting of the eyebrow and arrow lights for the threat scenarios in 3.1.2	Section 8 of Reference 1
TCAS Abort		
CRT Resolution Advisories Traffic Advisories Proximity Information	Demonstrate proper symbology, clutter reduction color selection, and symbol location for the threat scenarios in 3.1.2.	
TCAS Caution/Warning Indicator	Demonstrate timing and proper lighting of the indicator, and validate the alarm cancel feature of the switch.	
TCAS Control Panel	Related to the Wx Radar interface. Demonstrate Mode Switch including Track extend feature and self test.	
TCAS Performance Monitor	The Tektronix 4052 will be used extensively during ATP and flight testing. Demonstrate operation on the RS-232 bus.	
TCAS Control Unit (TCU)	Demonstrate all modes of the TCU, including self test, and PL switch.	
Aural	For the threat scenarios in 3.1.2, demonstrate proper tone and voice selection.	

Tapes from item (4) will be returned to the Technical Center for processing. The processing will consist of summary plots of Central Processing Unit (CPU) idle time and reply count versus time, and plots of mode C and non mode C surveillance tracks versus time. The format for these plots is shown in figures 1 and 5 of reference 2.

The information contained in these plots will indicate coasting in range and AOA tracks versus time, range and density. While an extremely accurate analysis of track data won't be performed, the go,no-go performance of the prototype Mode C and non Mode C tracking will be indicated. Tracks should not be excessively broken or fragmented, and non Mode C tracks should not be generated by weak or garbled Mode C replies.

The rooftop test should be conducted with the TCAS mode C altitude from the test box set to an altitude of 10,000 feet. At that altitude, most of the traffic will be more than 1500 feet below "own" altitude; few CAS tracks will be generated preventing the usual data loss problem. This technique was used successfully in the acceptance testing of November 4,1982.

3.1.2 CAS Logic Validation

The purpose of this test is to validate the implementation of version 11.0 logic in the prototype. Through this bench testing, the following system functions will be exercised:

Displays:

CRT - symbology and color
- anti clutter feature (for overlapping targets)

IVSI - positive and negative RA display
- bailout

Aural - All tones and voice enunciation of commands

Logic:

Single Intruder Logic - TAU selection
- command selection
- PL selection
- firmness test
- abort logic
- RA inhibit
- inhibit advisories against ground targets

Multiple Intruder Logic - Advisory selection intruder causes RA on Prox traffic

Table 4 contains encounters which have been selected to exercise these functions and have been run through version 11.0 logic on the Center's Honeywell computer. The simulation is called the Fast Time Encounter Generator (FTEG) and the format of the FTEG output is shown in figure 1. All of the encounters in table 4 were run on the FTEG and the CAS plots were generated. As part of the factory acceptance test, Dalmo Victor will run these same encounters in bench tests on the prototype.

Part of the bench test deliverables required of Dalmo Victor is the capability to rapidly produce plots containing the same information as figure 1 in order to simplify the validation of the CAS logic; displaying the prototype response this way will facilitate inspection of the prototype output compared to the FTEG output and will illuminate any differences which could be faults. Dalmo Victor has several mechanisms to generate these plots, but it is strongly suggested that software be written for the Tektronix 4052 performance monitor to provide output similar to figure 1. This feature will be a valuable tool in subsequent operational testing at the Technical Center.

TABLE 4. ENCOUNTER DESCRIPTIONS ACCEPTANCE TEST

Encounter	Figure	Situation	Description	Expected Advisory Sequence[1]
1	D-1	1	Head on - Both level	Removed τ= 3 s after closest point of approach (CPA), Climb τ= 27 s
2	D-1	2	Head on - Both level	Removed τ= 2 s after CPA, Descend τ= 27 s
3	D-1	3	Advisory Inhibit	Radar Altimeter <12.5v 700' Change "Descend" to "Do Not Climb"
4	D-1	4	Head on - Both level	Removed τ= 3 s after CPA, Climb τ= 25 s
5	D-1	5	Head on - Both level	Removed τ= 3 s after CPA, Do Not Descend τ= 35 s
6	D-1	7	Advisory Inhibit	Pressure Altitude >24,000' Change "Climb" to "Do Not Descend"
7	D-1	8	Head on - Both level Intruder is non-mode C	Traffic Advisory at τ= 45 s, removed τ= 2 s after CPA
8	D-2	1	Vertical Rate - TCAS level	Removed τ= 3 s after CPA, Do Not Descend τ= 29 s, VSL 500 τ= 19 s, vertical speed limit (VSL) 1000 τ= 9 s
9	D-2	2	Vertical Rate - TCAS level	Removed τ= 2 s after CPA Do Not Descend τ= 28 s, VSL 500 τ= 15 s, VSL 2000 τ= 5 s
10	D-2	4	Vertical Rate - TCAS level	Removed τ= 2 s after CPA Climb τ= 34 s, VSL 2000 τ= 5 s
11	D-2	6	Vertical Rate - Intruder level	Do not climb τ= 27 s, VSL 500 τ= 17 s, VSL 1000 τ= 7 s, removed τ= 2 s after CPA

TABLE 4. ENCOUNTER DESCRIPTIONS ACCEPTANCE TEST (CONTINUED)

Encounter	Figure	Situation	Description	Expected Advisory Sequence
12	D-2	7	Vertical Rate - Intruder level	Do not climb $\tau=$ 28 s, VSL 500 $\tau=$ 15 s, VSL 2000 $\tau=$ 5 s, removed $\tau=$ 2 s after CPA
13	D-2	9	Vertical Rate - Intruder level	Decend $\tau=$ 34 s, VSL 2000 $\tau=$ 5 sec, removed $\tau=$ 3 s after CPA
14	D-2	11	Vertical Rate - TCAS level	Climb $\tau=$ 27 s, remove $\tau=$ 2 s after CPA
15	D-2	7	Advisory Inhibit	Do not descend $\tau=$ 27 s, removed $\tau=$ 2 s after CPA
16	D-3	2	Level Off (firmness test)	Descend $\tau=$ 25 s, removed $\tau=$ 2 s after CPA
17	D-3	9	Level Off (firmness test)	Descend $\tau=$ 25 s, removed $\tau=$ 2 s after CPA
18	D-3	7	Level Off (TCAS Abort)	Climb $\tau=$ 27 s, advisory not O.K. $\tau=$ 15 s, removed $\tau=$ 2 s after CPA
19	D-4	2	Popup (firmness, tracker test)	Resolution advisory delay = 6 s after pop-up
20	D-4	3	Tail Chase	Descend $\tau=$ 25 s, removed at CPA
21	D-4	6	Tail Chase	Descend $\tau=$ 25 s, removed at CPA

TABLE 4. ENCOUNTER DESCRIPTIONS ACCEPTANCE TEST (CONTINUED)

Encounter	Figure	Situation	Description	Expected Advisory Sequence
22	D-4	9	Tail Chase	To be furnished[2]
23	D-4	10	Tail Chase	Climb τ= 25 s, removed at CPA
24	D-4	11	Tail Chase	Climb τ= 25 s, removed at CPA
25	D-4	12	Tail Chase	To be furnished
26	D-4	13	Tail Chase	Traffic advisory at τ= 40 s, removed at CPA
27	D-4	14	Tail Chase	No Traffic Advisory Altitude >15,500'
28	D-6	1	Both AC Climb	To be furnished
29	Not Shown		Display Clutter Test	No overlap of intruder tag
30	D-7	1	Multiple Aircraft	Descend τ= 27 s, removed τ= 3 s after CPA
31	D-7	2	Multiple Aircraft	Climb τ= 27 s, removed τ= 3 s after CPA
32	D-8	1	Multiple Aircraft	Descend τ= 25 s, removed at CPA
33	D-8	2	Multiple Aircraft	Climb τ= 25 s, removed at CPA

1 The variable   is used to indicate the warning time given by TCAS before encounter.

2 Logic results will be updated when non mode C portion of version 11 logic becomes available.

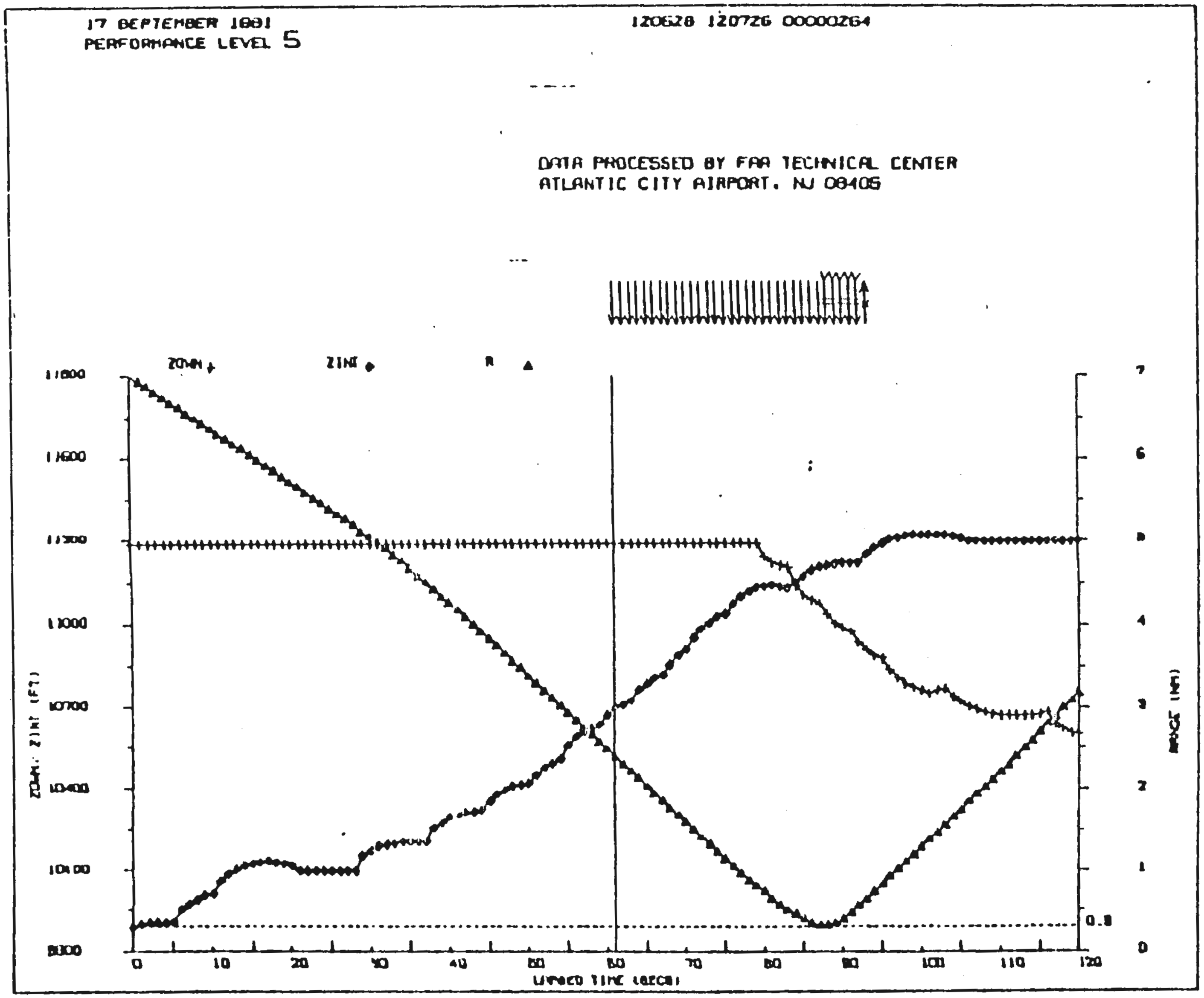


FIGURE 1. HONEYWELL FTEG PRINTOUT

To simulate the encounters in bench testing, at Dalmo Victor, the following is required:

Software

Software to permit rapid response plots of the encounter.

Software to drive target generators (see hardware requirements)

Hardware

Target generator

Must be capable of generating up to 3 targets simultaneously

Target Characteristics are:

Target 1: moving with at least two segments of vertical rate

Target 2: moving with at least one segment of vertical rate

Target 3: fixed

RF Apparatus

RF oscillators (qty=3) capable of stability in accordance with ATCRBS specification

PIN modulators (qty=3)

Directional Couplers, RF loads, etc. (qty as required)

Delaying pulse generators (qty=2) to select desired transmit pre-trigger (tpt) pulse

Altitude rate generating equipment for the TCAS prototype including:

pitot static test stand
pressure altitude encoder

Tektronix hard copy unit

ACT-140 will coordinate with project personnel at Dalmo Victor to identify specific equipment types and resource availibility at both locations. At present ACT-140 plans to supply one target generator capable of two segments of vertical rate, one PIN modulator, a hard copy unit, and directional couplers as required.

Parameters for each of the encounters in table 4 are given in appendix D. Note that the scenarios in the table are cross referenced to the figures in appendix D. The intent of the information in appendix D is to fix "waypoints" in the scenarios to be used in the design of the bench simulation. By using the waypoints to design the bench simulation, the FTEG will precisely duplicate the bench and make the subsequent analysis easier.

3.1.2.1 Encounter Descriptions

Refer to table 4 for the discussion in the following subparagraghs. Table 4 contains expected responses and associated timing for each encounter. This information is based on Technical Center FTEG simulation and forms the baseline criterion against which the prototype CAS implementation is to be tested.

3.1.2.1.1 Positive Advisories-Level Flight. Encounters 1, 2, 4 and 10 should generate positive advisories. The advisory sequence and timing associated with each encounter are shown in table 4.

3.1.2.1.2 Negative Advisories-Level Flight. Encounters 5, 8, and 9 should generate negative advisories (advisories that do not require a deviation in the existing flight path). The advisory sequence and timing associated with each encounter are shown in table 4.

3.1.2.1.3 Advisory Inhibit. Encounter 3 is a duplicate of encounter 2 and should produce a descend command except that the simulated radar altimeter input indicates own ship less than 900 foot altitude. In this case, the descend RA should be changed to a do not climb RA. The expected advisory sequence and timing are shown in the table.

Encounter 6 is a duplicate of encounter 1 and should produce a climb command except that the simulated own ship altitude is 35,000 feet. The present CAS logic has an inhibit feature that inhibits climb commands above 34,000 feet pressure altitude. In this encounter, the climb RA should be changed to a do not descend RA. The expected advisory sequence and timing are shown in the table.

Encounter 15 is a duplicate of encounter 12 and should generate a climb command except that the flaps and gear discretes prevent the RA.

Encounter 27 involves a non mode C intruder with own ship altitude above 15,000 feet. At or above 15,000, the expected operating ceiling for GA aircraft, the CAS logic inhibits TA on non mode C intruders. Therefore, no advisory should be generated.

3.1.2.1.4 Resolution Advisory-Level Off Encounters. Encounters 8 through 14 refer to cases where either the intruder or own ship is maintaining a high vertical rate and suddenly levels off. If the level off occurs about 5 seconds prior to TAU, the TCAS tracker responds and selects the appropriate positive or negative RA. Expected RA sequences for these encounters are shown in table 4.

Two special cases exist where the level-off causes the RA to be selected abnormally. Case one occurs when the vertically moving aircraft (either own ship or intruder) levels off 1 or 2 seconds before the RA sense is selected. The CAS tracker senses the level off and delays the selection of the RA. The process of sensing abrupt maneuvers is part of a process called firmness testing. The CAS logic uses the firmness test to delay command selection while recomputing projected positions in order to select the correct RA. Encounters 14 and 17 were designed to illustrate the delayed sense selection. Encounter 14 is an altitude crossing maneuver for which a climb command should be (correctly) given. Encounter 17 initially has the maneuver following exactly the same trajectory; at TAU = 29 seconds, two seconds before the RA selection, the intruder levels off suddenly and should pass above TCAS. The RA should now be a descend. The expected RA sequence and timing (the delay expected) are shown in the table. Special case two involves the abort logic.

3.1.2.1.5 Abort Logic. Case two of the level-off occurs when the vertically moving aircraft levels off after the RA is selected resulting in aircraft separation at closest point of approach (CPA) less than altitude limit (Alim). TCAS should detect the abrupt maneuver, recompute projected positions and find that the RA is either valid or invalid. Encounter 18 is a situation where the original RA is invalid. TCAS should invoke the abort logic. The expected RA sequence and timing are shown.

3.1.2.1.6 Traffic Advisory Logic. Encounter 7 involves a head on with a non-altitude reporting intruder, and should invoke the traffic advisory logic. No RA should be posted, but TCAS should provide aural and visual warning via the TCAS caution warning switch and weather radar display (symbol appears amber with "??" in altitude field)

Encounter 26 involves a non altitude reporting aircraft climbing into the TCAS aircraft. For purposes of bench simulation, the simulated target will be at close range closing slowly. The purpose of this test is to verify the traffic advisory and to verify the anti-clutter feature of the symbol generator driving the weather radar display. Anti-clutter will prevent the identification tag of the intruder from overlapping the own ship symbol.

3.1.2.1.7 Tail Chase and Pop Up. Encounter 19 is called a pop up and refers to an intruder whose transponder is turned on within the protection volume of TCAS. The time required by TCAS to establish a firm track and post an RA is called the firmness delay. FTEG simulation indicates that the firmness delay is about 6 seconds.

Encounters 20 and 21 involve an intruder descending onto own ship. TCAS should always generate a descend advisory.

In encounter 22, an intruder is descending onto own ship while own ship is descending at 500 feet per minute. TCAS should always generate a stable descend advisory.

Encounters 23 and 24 involve own ship descending onto a level intruder. TCAS should always generate a climb advisory.

In encounters 25 and 26 the intruder is climbing into TCAS. Encounter 26 involves a non-mode C intruder (see 3.1.3.6); encounter 25 involves a mode C intruder. TCAS should generate a climb advisory in both cases.

3.1.2.1.8 Multiple Aircraft. Encounter 28, the display clutter test, includes a moving target which passes through a fixed target. Both are mode C. The symbol generator should arrange the symbols on the weather radar display such that the identification tags for each symbol do not overlap other tags or any symbols and are always readable.

Encounters 29 and 31 involve two intruders each: one is a threat and one is only proximity traffic. The proximate traffic should not appear on the weather radar display until the display is triggered by the threat. Furthermore, TCAS should not create a second threat by generating RA's which force own ship into the proximate traffic.

Encounters 30 and 32 involve two threatening intruders. Normally, the intruder at +/-300-foot relative altitude creates a negative advisory. In this case, the TCAS response is based on its multiple aircraft logic. The expected advisory sequences and associated timing for these encounters are shown in the table.

3.1.3 System Integration

The complete TCAS II prototype including all displays, controls, and the display symbol generator should be assembled for the CAS logic validation bench testing. As the simulated encounters are run, proper display/control operation will be documented.

3.2 BENCH TESTING-TECHNICAL CENTER

Approximately one week will be allocated to perform bench testing, and to install the prototype on N-78. The hardware parameters to be tested are:

Transmitter

- frequency
- peak power
- unwanted output power
- whisper shout attenuator

Receiver:

- sensitivity
- receiver matching

In addition to these tests, display test will be performed with the prototype interfaced to the Airborne Intelligent Display (AID). This test will consist of simulated encounters 1 thru 7 (table 5) using the center's bench test facilities. All encounters will be run with 20,000 replies/sec of simulated fruit.

3.3 RAMP AND FLIGHT TESTING

Ramp testing will require approximately 2 days and is designed to validate the aircraft installation, and provide some of the data required by the Type Inspection Authorization (TIA) of N-78. A subset of the initial ramp test will be performed each day of flying to provide a measure of confidence in system operation.

TABLE 5. ENCOUNTER DESCRIPTIONS CAS VALIDATION

Encounter	Figure	Situation	Description	Expected Advisory Sequence
1	D-1	2	Head On - Both Level	Reference encounter 2 in table 4
2	D-1	5	Head On - Both Level	Reference encounter 5 in table 4
3	D-1	8	Head On - Non Mode C	Reference encounter 7 in table 4
4	D-2	6	Vertical Rate - Intruder Level	Reference encounter 11 in table 4
5	D-2	7	Vertical Rate - Intruder Level	Reference encounter 12 in table 4
6	D-2	7	Vertical Rate - TCAS Level	Reference encounter 12 in table 4
7	D-3	9	Level Off (Firmness Test)	Reference encounter 17 in table 4
8	D-3	2	Level Off (Firmness Test)	Reference encounter 16 in table 4
9	D-3	7	Level Off (TCAS Abort)	Reference encounter 18 in table 4
10	D-4	2	Popup (Firmness, tracker test)	Reference encounter 19 in table 4
11	D-4	9	Tail Chase	Reference encounter 22 in table 4
12	D-4	10	Tail Chase	Reference encounter 23 in table 4
13	D-4	11	Tail Chase	Reference encounter 24 in table 4
14	D-4	13	Tail Chase	Reference encounter 26 in table 4
15	D-7	1	Multiple Aircraft	Reference encounter 30 in table 4

TABLE 5. ENCOUNTER DESCRIPTIONS CAS VALIDATION (CONTINUED)

Encounter	Figure	Situation	Description	Expected Advisory Sequence
16	D-8	1	Multiple Aircraft	Reference encounter 32 in table 4
17	Not Shown		Advisory Inhibit at 700 feet	
The Following Encounters are Not Shown in the Profiles in Appendix D				
18			TCAS Makes Low Approaches; Aircraft On Ground Have Their Transponders Operating. No Alerts Should Be Encountered	None Expected
19			Orbit Patterns (Reference 3) Range and AOA Accuracy Testing.	Not Applicable

The flight test program was designed to validate overall TCAS operation in low and medium density airspace, and to "shake down" selected routes to be used in subject pilot testing. Engineering flight testing will require 5 weeks.

3.3.1 Ramp Checks. The prototype TCAS II will be installed on N-78 and tested with a transponder mounted in a van, and with targets of opportunity. The tests will consist of observing the system performance monitor and control unit to verify the aircraft interfaces. After the interface test, the air/ground switch input will be disconnected from the project junction box (J-box); the prototype will operate in PL 2. In this mode, TCAS will track ATCRBS targets of opportunity with the track information observed on the performance monitor. After the tracking test, the radar altimeter input will be disconnected from the project J-box and connected to a d.c. power supply of at least 10 volts (>500'). With this input, TCAS will switch to PL 4. The test target will be the transponder equipped van that will stop at various survey points around the airfield. In this test, a measure of the power output and AOA accuracy will be obtained (reference 3), the aircraft interfaces (eg mutual supresssion) will be validated, and a go, no-go indication of TCAS performance will be provided.

Before each flight in the CAS logic validation, and in the operational evaluation flight tests, TCAS will be ramp tested to provide a measure of confidence in the system. The preflight ramp test will include activation of TCAS self test (for a description of self test, see reference 5), and a traffic of opportunity tracking test with TCAS operating in PL 2. The self test precession and target tracks will be observed on the display control unit.

Ramp tests designed to partially satisfy one TIA requirement on N-78 will be performed in the initial 2 day test period. The essence of the requirement is to demonstrate that TCAS avionics installation and operation do not interfere with existing aircraft systems. The process to accomplish this (statically) is:

1. Move N-78 into the hangar for the TCAS installation process. Just prior to starting the installation, order an inspection and calibration of the following aircraft systems:

a. Transponders 1 and 2
b. VOR receiver
c. DME equipment
d. ADF receiver
e. Comm, including UHF, VHF and HF
f. Omega navigation equipment
g. Altimeters, pressure and radar

2. Move N-78 onto the ramp. The TCAS project pilot will coordinate with the tower and avionics shop to run through an equipment checklist (items a-g) with TCAS installed but powered off. All equipment indications and operation will be noted.

3. Power on TCAS and again run the checklist, documenting the results. Any differences in equipment performance, including an increase in noise level on any comm or VOR audio channel, will be measured and documented.

Documentation of the ramp data will be in accordance with section 9.1.

3.3.2 Flight Test - CAS Logic Validation. This section discusses the encounter geometries, data collection and reduction methods, and scheduling required for the CAS validation.

3.3.2.1 Encounter Geometries. Appendix D shows the flight test geometries that will be used. There are, however, certain deletions and additions necessary because certain encounters involve excessive range or altitude rates and are suitable for bench testing but are impractical in a flight test program. The profiles to be used in the flight test program are listed in table 5. Those encounters to be flight tested are listed along with the expected TCAS response.

3.3.2.2 Accuracy Testing. Two days of flights will be conducted to determine the accuracy of the TCAS range and altitude trackers, and AOA data. The scenarios are listed in table 5 and are described in detail in the Dalmo Victor Feasibility Model test plan (reference 3).

Range and altitude tracker accuracy will be determined by comparing TCAS data with NIKE reference data adjusted for aircraft pitch and yaw (see ship state rack section 7.1). Statistics of the differences will be generated and histograms will be plotted.

AOA errors versus azimuth and elevation will be recorded and plotted on polar coordinates. This data will be generated as the target aircraft flies orbits around the TCAS aircraft at relative altitudes of +/- 2000', +/- 1000', +/- 500', and coaltitude. NIKE radar data, coordinate tranformed for B-727 position, will be the position reference.

3.3.2.3 Data Collection and Analysis. The purpose of this flight test is to verify and document the proper CAS logic response for a given encounter. A real constraint in the continuation of the test program is the assurance that TCAS is functioning. Another constraint is the time requirement on the test program. Therefore, some form of rapid response in the data analysis is mandatory. The technique that will be used is to generate CAS response plots, in flight as the encounter develops, using the software developed for Dalmo Victor's bench test program for the TCAS performance monitors (see section 3.1.2). These hard copy reproductions of the performance monitor display will be compared to baseline plots generated by the FTEG processing surveillance data from the 9 track data tapes from the flight. Just as in the bench test program, the FTEG output will be the version 11.0 truth data (given the TCAS surveillance data as input) and the performance monitor output will be the test data.

The only remaining issue is how well the test aircraft follow their intended trajectories. If the aircraft do not follow properly, the intended logic function may not be exercised properly. The quality of each encounter can be determined by the CAS track shown on the FTEG or performance monitor output. Any encounters that are questionable will be reflown; schedule time has been allotted for duplication of every encounter.

In addition to the rapid response analysis, a more detailed analysis using NIKE and Mode S radar (see section 7) support will be performed. The radar support will indicate the tracking accuracy and reliability of TCAS and will be used to determine the cause of differences between TCAS and FTEG responses. This parameter is especially important in encounters where TCAS advisory sequence timing is significantly (more than 4 seconds) different than FTEG sequences.

In addition to flight data tapes and performance monitor hard copy, observer data and flight log data will be collected during the flight test. Observer data is to consist of annotated notes of the TCAS project pilot's opinion of the correctness of TCAS responses. The Technical Center's project pilot has flown many encounters using both CAS and CDTI systems; he is knowledgable in the logic in terms of protection volumes, typical responses and warning times. Any encounters in which the pilot feels TCAS gave an improper response will be examined in detail, and reflown if necessary.

Flight log data will be kept by project personnel during each flight noting data such as encounter start and stop times, incidence of auto restarts/resets, and incidence of targets of opportunity.

3.3.3 Flight Test - Operational Dry Run. The purpose of this test is to fly the encounters that the subject pilots will see during the operational evaluation to identify any problems that would impact the operational evaluation. For example, the Center's tracking radars have blind spots at low altitudes for certain azimuths due to buildings, terrain, etc.

The encounters in this test are described in section 4.3, and will be flown following the procedures the subject pilots are expected to fly. An observer will be in the cockpit gathering operational data on pilot performance (see section 4.1.3.2). The observer data will be subjected to the analysis described in section 4.2 in order to validate the observer data collection procedures to be used in the operational evaluation of the TCAS prototype.

This flight test is expected to require two days.

3.3.4 Flight Test - Medium Density. A series of one day flights will be made into major airports, including Chicago, Atlanta, Philadelphia, and larger non-TCA airports including Norfolk, Virginia and Winston Salem, North Carolina. The purpose of these flights is to expose the TCAS prototype to medium density traffic, so as to validate mode C and non mode C tracking under these conditions. CAS tracks (figure 2) will be plotted for the flights; the incidence of false or short tracks, and tracks generated by multipath will be noted. Also CAS logic plots will be generated for all advisories (reference 2). Two of the flights, New York and Philadelphia, will involve a target FAA aircraft creating encounters (see table 5) around the airports. Performance criteria for TCAS will be proper selection of advisories and timeliness of advisories.

This test is to validate the higher density performance coupled with operational procedures of TCAS in preparation for subject pilot testing and the national demonstration tour (see section 4.5). An observer will be in the cockpit gathering operational data on each encounter using the techniques developed for the operational evaluation. The TCAS project pilot will be instructed to follow the operational procedures developed for Piedmont phase 2. This test is expected to require four days of flying.

3.3.5 TCAS Validation - Post Operational Evaluation. The TCAS prototype will incorporate an ARINC STD-429 interface to decode fine altitude (altitude reports quantized in 1-foot increments) from the B-727 airdata computer. In order to validate this interface, the TCAS prototype will be removed from N-78 and installed on N-40, because N-40 is equipped with the proper airdata computer. Due to aircraft availability, this validation will take place

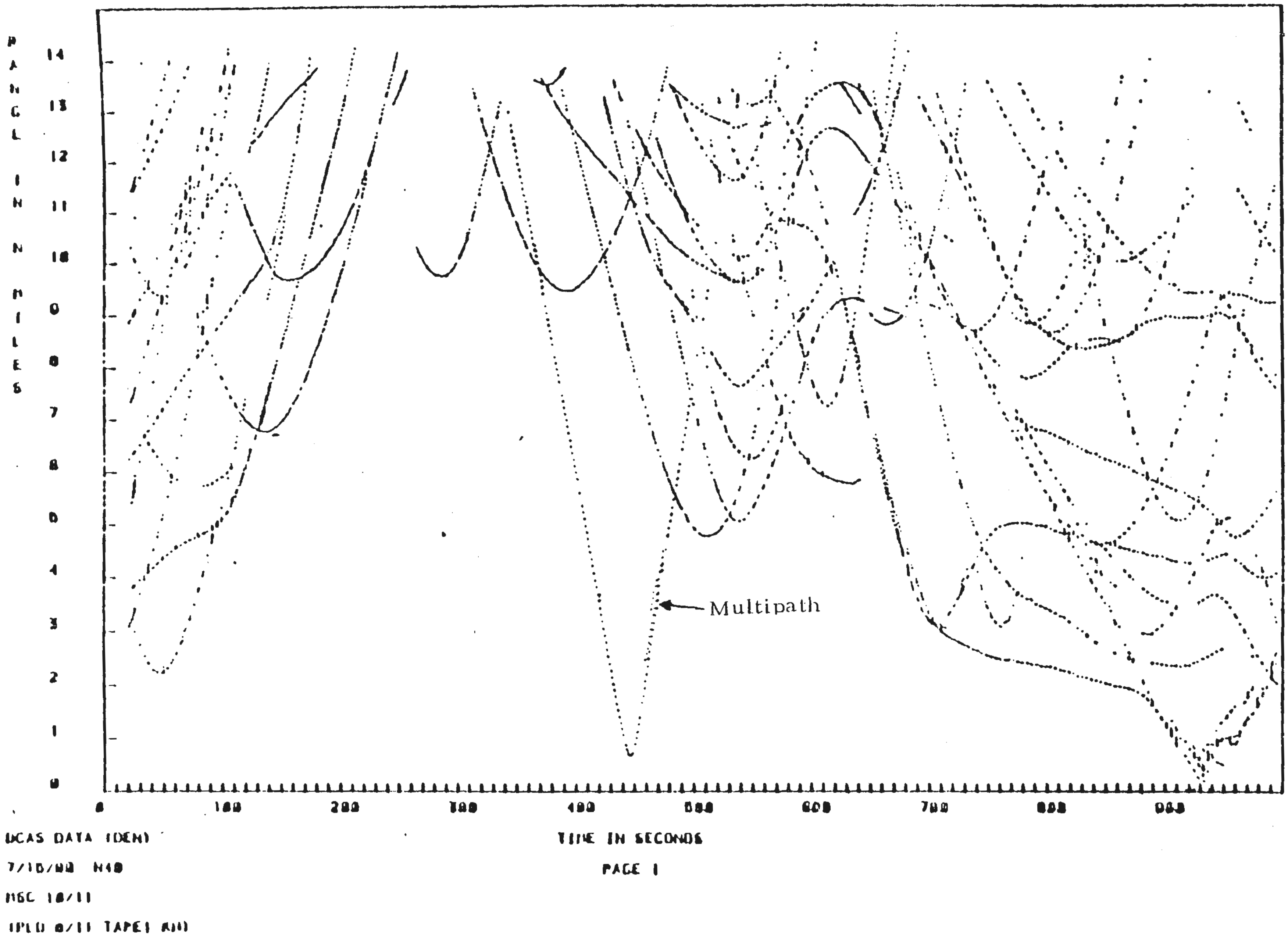


FIGURE 2. CAS TARGET PLOTS

after the operational evaluation. The validation itself is straightforward. With TCAS installed, N-40 will be flown over the Technical Center, and will be tracked by NIKE radar. Proper interface operation will be demonstrated by plots of own ship altitude tracks (figure 3). The track should be continuous, monotonic, and accurate, when compared to the Mode C track.

The Piedmont TCAS installation will use a symbol generator from Sperry Systems Inc. to drive their color weather radar display in the TCAS mode. In anticipation of potential delivery delays, the Center's operational evaluation has provisions to use the Lincoln Laboratory AID as a symbol generator. The TCAS display is identical to both units. If the Sperry driver is not delivered in time for the flight testing at the Technical Center, testing will proceed with the AID, and the validation of the Sperry driver will occur coincident with the ARINC 429 interface validation.

4.0 OPERATIONAL EVALUATION

This section describes subject pilot testing of the minimum TCAS II prototype. Subject pilots will be invited to fly the Technical Center's B-727 equipped with TCAS II. Two types of operational data pilot evaluation and performance data will be gathered and used to document TCAS as it will be configured in Piedmont. The subject pilot evalution will occur in a structured postflight interview with ACT-140, the flight crew and the subject pilot. Pilot performance data will be noted by an inflight observer as the subject participates in the flight test.

4.1 TEST DESIGN

The scope of the operational evaluation is limited to certain types of encounters. These include situations where TCAS provides the appropriate response and situations where TCAS generates improper response, but without creating a dangerous situation. Certain encounter types will not be exposed to subject pilots:

(a) TCAS abort-generated by sudden level off after intruder has been moving at a high vertical rate.

(b) Altitude Crossing Maneuvers - where RA requires the subject to manuever through the intruder's altitude.

(c) Encounters in Instrument Meteorological Conditions (IMC).

Subjects will fly routes selected in a corridor of airspace blocked out by New York ATC. The corridor is approximately 50 miles long and 20 miles wide and should be free of traffic. The routes are comprehensive, with several phases of flight including climbs, approaches, turns (standard and nonstandard), ATC communications, navigation, etc. A proposed route is shown in figure 3.

After the subject pilots complete the encounter flights, they will be invited back to the Technical Center to participate in a 1 day mission into a major airport and a non-TCA airport. Current planning is to fly south to Atlanta with a stop in Norfolk or Charlottsville.

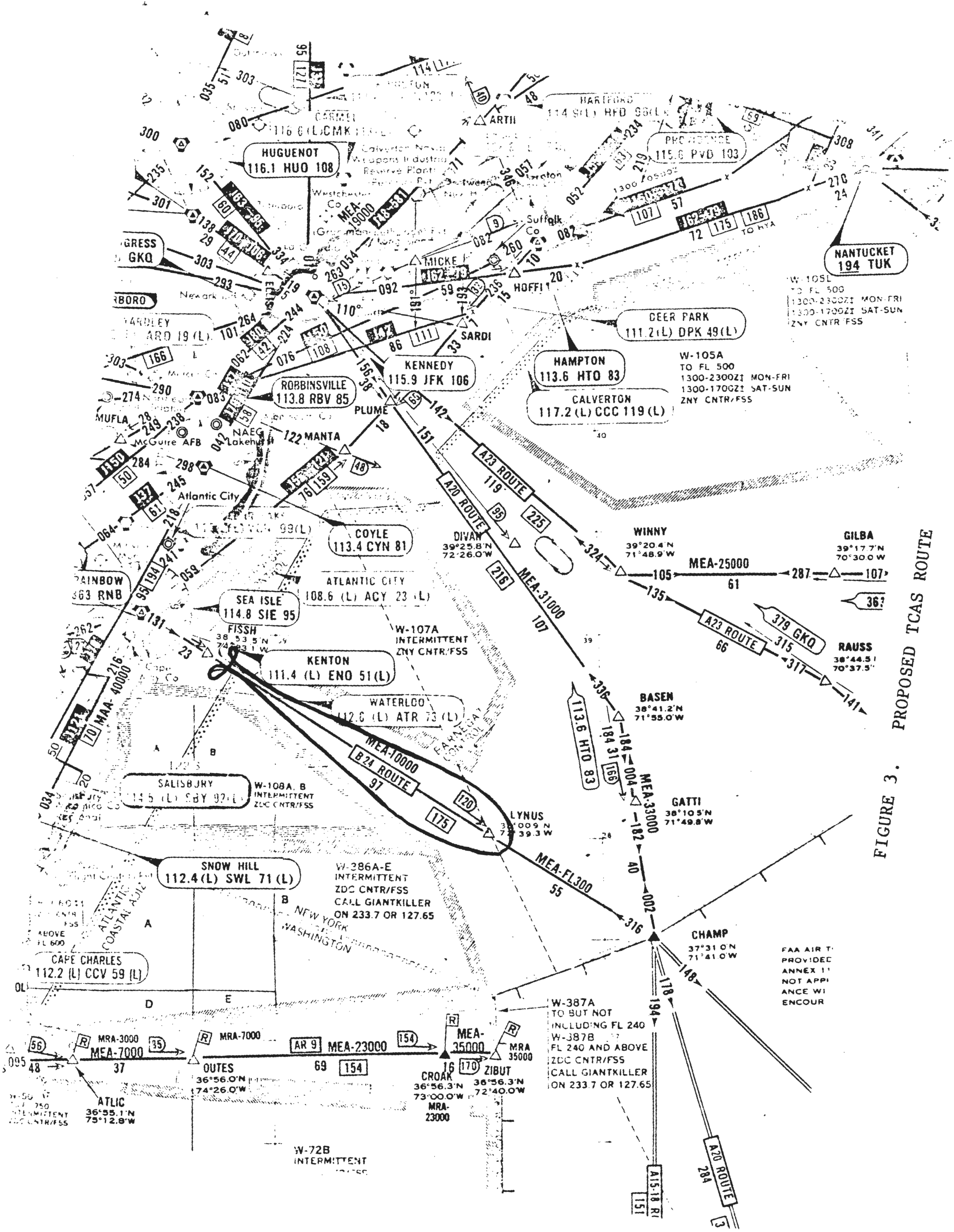


FIGURE 3. PROPOSED TCAS ROUTE

4.1.1 Subject and Pilot Observer Selection. Up to two groups of 6 subjects will be invited to participate in this evaluation. One group will consist of subjects with prior experience with collision avoidance. These will be selected from the following organizations:

(a) Piedmont - 2 each
(b) AFO - 1 each
(c) ACT - 2 each
(d) Piedmont Principal Operations Inspector (POI)
(e) ACO (Atlanta)

The TCAS project pilot will not participate as a subject pilot, but will act as safety pilot. The safety pilot will assist the subject pilot as co-pilot if requested to do so, but will retain responsibility for the safety of the missions.

After testing is completed with the first group, a second group of six subjects will be invited to fly. It is important to have six subjects in the second group also if operational data from the first group is to be compared to the second. In a word, the sample sizes must be the same. This second group of subject pilots will be selected from Piedmont.

Four inflight observers will be used in the Technical Center evaluation. These will be selected as follows: 3-Technical Center, 1-AFO. Four observers were selected in order to have a reserve in the event that one or two are unable to participate in a flight mission. Of the four observers, three are current pilots with many hours of flight time, and are also familiar with TCAS. The fourth is not a pilot but has an indepth understanding of TCAS and has made several flights in the B727 cockpit jump seat.

4.1.2 Flight Test Design. Each subject pilot will fly two missions. In one mission approximately 1.5 hours long, the pilot will experience nine different encounters. The first three encounters of the mission will have to be resolved without TCAS (displays off) so that baseline data can be gathered on the subject (see 4.1.3.2).

The second mission will be a 1 day flight into one or two major airports so the subject pilot can experience TCAS in the operational environment. Present planning is to fly south to Atlanta with a stop in Norfolk, or Charlottesville in order to gain experience in Terminal Control Area (TCA) and non-TCA airspace.

All subjects will see the same encounters in the same order, so the flight test design is not counterbalanced. However, the object of this operational testing is not to quantitatively determine some measure of pilot performance (eg response time), but to have subject pilots "rate" TCAS as a cockpit tool. Therefore, counterbalancing, a commonly used technique in experimental design will not be used here. Furthermore, counterbalancing would complicate the flight test past the point of diminishing returns.

The types of encounters selected for this test range from "easy" to "hard". Easy refers to encounters where the intruder is easily visible or is closing at a slow rate. Hard encounters involve high closing rates. Their order, seen by the subjects, is listed in table 6.

TABLE 6. ENCOUNTER DESCRIPTIONS

Encounter No. 1. Outbound from terminal; the intruder approaches from between 10 to 11 o'clock and is below and climbing. ATC calls; intruder passes below.

Encounter No. 2. Flying Enroute. Subject sees a coaltitude tail chase. ATC calls traffic.

Encounter No. 3. Non-standard (teardrop) turn to fly inbound. After turn subject sees a headon encounter. ATC calls.

Encounter No. 4. Climbing out from takeoff, overtaking an intruder who is visible above and to the side, but far enough away so that no TA or RA is generated. ATC calls traffic. To see traffic on AID, pilot must use track extend button.

Encounter No. 5. Flying outbound but still in terminal; receive a TA on a GA non-Mode C (aero commander) who is climbing. The CV-580 will be in vicinity of GA but not close enough to generate a threat. ATC calls traffic.

Encounter No. 6. Flying Enroute. The CV-580 generates a 90° encounter; ATC calls traffic.

Encounter No. 7. Descending into a terminal area. Receive a climb RA; TCAS is overtaking a slower aircraft. ATC calls.

Encounter No. 8. Just before 90° turn onto final, receive a climb command from intruder; ignore the command because the turn onto final eliminates the threat.

Encounter No. 9. Execute a missed approach; upon climbing out receive a climb command from intruder underneath climbing.

The flight plan filed for each mission will be IFR so that the subject will be under control of a simulated ATC facility, and will receive instructions for various phases of flight. An air traffic controller will be stationed at the Center's Mode S facility, and will have PPI display of the TCAS aircraft and the two intruders. Mode S radar coverage was selected for two reasons; with discrete addresses, the project aircraft won't garble each other's replies as they would with ATCRBS, especially in tail chase maneuvers where the aircraft are very close for extended periods. The second reason for using Mode S is the Center's capability to extract track data from Mode S tapes, and plot the aircraft tracks. This feature will be extremely useful in reviewing events of the flights with the subject pilots, especially if they wish to verify aircraft separation at CPA or study their deviation from the flight path due to TCAS RA's, etc.

Encounters that are seen by the subject pilot will be unanticipated; the only indication of traffic the subject will have will be either an ATC call or visual acquisition. The controller will also issue instructions to each of the two intruders, and to fictitious aircraft in the area, to provide as realistic a situation as possible.

4.1.3 Data Collection. Operational data will be collected by means of preflight, inflight, and postflight questionnaires, which are described in the following subparagraphs. The questionnaire designs make extensive use of seven anchor rating scales. This technique was chosen because experience (reference 10) has shown that rating scales permit rapid precise assimilation of data. Seven anchors were chosen because subjects typically avoid the extrema and tend to moderate their responses; therefore two data points are generally lost. However, five anchors provides a sufficient distribution of data. In addition, the anchors were chosen to result in unimodal distribution of subject data which will simplify the analysis by allowing T and F testing.

As a matter of course, each time the prototype is flown, TCAS performance data will be recorded on magnetic tape. The performance data will be subjected to the same analysis used in the engineering evaluation to identify subtle system failures or to catch any obscure problems previously undetected.

4.1.3.1 Preflight Questionnaire. The format is shown in appendix A. The preflight questionaire will be completed in an interview with the subject after he has used the training materials but before his first mission. There are three specific requirements of this data:

(a) Determine subject's level of CAS experience
(b) Determine subject's expectations of minimum TCAS II
(c) Determine subject's level of training.

Items (a) and (b) attempt to identify any preconceived notions or expectations that may have an effect on the results of the testing. Item (c) is the most critical of the three; experience (reference 6) has shown that the biggest factor affecting the pilot's use of TCAS is a lack of understanding of the intent of TCAS. The questionnaire in appendix A is divided into these three areas, and forms the structure for the preflight interview.

4.1.3.2 Inflight Questionnaire. A trained observer (section 5.2) will be in the cockpit riding the jump seat. During the flight he will be annotating pilot activity for each of the encounters including the three baseline encounters without TCAS. The observer will be looking for specific activities such as:

(a) Pilot reaction to TA and RA based on

 (1) alarm timeliness (subjective)
 (2) correctness
 (3) necessity
 (4) usefulness

(b) Pilot response to RA

 (1) no response - why not
 (2) hesitated or sudden responses
 (3) interaction with ATC
 (4) amount of deviation from cleared altitude
 (5) agreement with procedures

(c) Pilot integration of TCAS TA and RA information with other cockpit information

The format for the observer questionnaire shown in appendix B, consists of two parts: the activity matrix and comment space. In the Technical Center evaluation, one inflight form will be completed for every encounter. When the encounter begins, signalled by an ATC traffic call, the observer will place a check mark in the first column next to "ATC Call," and will circle the appropriate phase of flight. Then every 5 seconds after, the observer will place a mark (in succeeding columns) in the row corresponding to the current activity in the cockpit at the time. The type of mark depends on whether the pilot or copilot is involved in the activity. C for copilot, P for pilot, or B for both. (Note: time events i.e., incidence of RA's are indicated by checkmarks.) This activity sampling continues until the threat aircraft has passed. After the sampling, the observer checks the appropriate answers to the questions in the comment space, asks the pilot for his rating of the encounter, and annotates any comments.

The numerical anchors for the pilot rating scale are:

+3 - TCAS absolutely essential; could not resolve conflict without TCAS.

+1 - TCAS gave correct response and was helpful, but not essential.

0 - TCAS was of no consequence; did not use TCAS at all.

-1 - TCAS gave incorrect response; created a potentially dangerous situation.

-2 - TCAS created a dangerous situation.

This rating scale will be reviewed with the subject pilots in the preflight interview and again in the preflight briefing.

In addition to the questionnaire sheets which are to be checked off during encounters, the observer will have an audio tape recorder to record comments which are too detailed or lengthy to write down.

4.1.3.3 Post Flight Questionnaire. Immediately after each mission, a debriefing session will be held with ACT-140 flight test personnel, the subject and safety pilots, flight engineer, and ACT-140 interviewer. The session will provide an opportunity for the subject pilot to discuss the operation of TCAS and present his opinions. The interview will be structured according to the questionnaire in appendix C. The issues of concern in the postflight interview are:

(a) Utility and quality of alerts and displays
(b) Utility and appropriateness of procedures
(c) Integration of TCAS with ATC
(d) Magnitude of workload

4.2 DATA ANALYSIS

Subject pilot questionnaire data will be analyzed subjectively and quantitatively. The subjective analysis consists of comparing pilot opinion data with pilot performance data (from observer questionnaires) and radar track data. Table 7 summarizes the analysis.

Quantitative analysis include T and F testing of parametric data and histogram plotting of questionnaire responses and summaries of pilot activity. (The term

TABLE 7. SUBJECTIVE ANALYSIS FORMAT REFERENCE QUESTIONNAIRE

Topic Pilot Opinion	Preflight	In Flight	Post Flight	Appropriate Data
Alarm Utility		X		Pilot awareness and pilot acceptance of advisory delay, use of alarm cancel
Utility of TA Display		X		Time spent using TA display; communication with ATC, time spent in visual search
Confidence in Separation at CPA		X		Pilot's evaluation of encounter compared to Mode S track plot indicate actual separation, visual/no visual, correctness of procedures
Recommended Procedure Changes	X	X	X	Level of training, level of experience, level of confidence
ATC Interaction		X		Communication with ATC, time spent resolving TCAS with ATC information, pilot tendency to use either TCAS or ATC
TCAS Utility	X	X		Pilot preparation for RA using TA, response delay time, use of track extend switch, relative workload with and without TCAS
Aircraft Maneuvering	X	X		Mode S track plot shows deviation from flightpath, track plot shows escape rate, pilot acceptance of alarm, conformity to procedures

sample group refers to the separation of data according to the test parameter; e.g., for the parameter Preflight vs. Postflight, each questionnaire becomes a sample group.) The test parameters are:

1. TCAS vs no TCAS prior experience.
2. TCAS vs no TCAS for conflict resolution.
3. Preflight vs Postflight questionnaire data.

The sample groups for parameter 1 are subject pilots with previous CAS experience and subjects with little or no experience (section 4.1.1). Sample groups for 2 are inflight observer questions for encounters 1-3 with TCAS (table 8) and 1-3 without TCAS. Sample groups for parameter 3 are questions in the preflight and postflight questionnaire.

Histogram plots will be made for questionnaire responses on the rating scales. These plots will show trends for a given topic rather than specific questions. For example, responses to questions with the IVSI from all subjects will be plotted. If the IVSI is generally accepted, the histogram will indicate a trend toward the + direction with a small variance. Histograms will be made for the following topics:

(a) Alerting System
(b) Acceptance of RA and TA information
(c) TA Display
(d) IVSI Display
(e) Procedures
(f) ATC Interaction
(g) Overall TCAS quality

The form of the inflight observer questionnaire permits an assessment of the pilot's and copilot's activities during each encounter. The analysis of the activity data consists of determining the portion of time spent in each activity by both the pilot and copilot. A percentage will be calculated by dividing the time spent in each activity by the total time of the encounter. This percentage will be written in the blank space, at the right most column, of the row corresponding to the activity.

5.0 DEMONSTRATION TOUR

The purpose of this tour is to demonstrate TCAS II to prospective users in the aviation community. To do this, airports where major crewbases are located are being identified (see table 9). From this list, centralized locations convenient to several airlines will be selected as stops along the tour. At each location, representatives from nearby airlines will be invited to see the TCAS installation on the center's B-727, and to observe TCAS operation in flight along air carrier routes around the airport.

Arrangements for travel to selected cities will be made by the project coordinator for ACT-140. Present planning is to fly an Eastern seaboard tour for approximately one week, and then fly a round robin tour in the west for another 1 to 2 week period.

TABLE 8. SUMMARY OF OPERATIONAL DATA ANALYSIS

Issue	Parameters 1	2	3	Results
1. Pilot Confidence	X		X	T&F Tests; compare sample groups. T&F Tests; compare questions in preflight and postflight questionnaires for each group.
2. Utility of IVSI	X		X	Same as 1.
3. Utility of TA display	X	X	X	T&F test compare conflict resolution with and without TCAS.
4. Quality of Alerting	X		X	Same as 1.
5. Quality of Procedures	X		X	Same as 1.
6. Requirement for TCAS			X	
7. TCAS Reliability				

Legend:

Parameter 1 Prior CAS vs No CAS experience
2 TCAS/No TCAS for conflict resolution
3 Preflight/Postflight

TABLE 9. AIRLINE MAJOR CREWBASE LOCATIONS

Air Cal
3636 Birch Street
Newport Beach, CAL 92660
714-752-7000
John Tucker, Opns Eng.

Air Florida
3900 N.W. 79th Avenue
Miami, FL 33165
305-592-8550
Richard Skully, Opns

Alaska International
Box 6769
6441 S. Air Park Pl.
Anchorage, AK 99502
907-243-1414
W. R. Hayes, Dir Opns

Aloha Airlines
Box 30028
Honolulu, HI 96820
808-836-4101
Lysyd K.

American Airlines
DFW Airport TX, 75261
817-267-2211

Continental Airlines
Los Angeles Int'l Airport
Los Angeles, CA 90009
213-646-2810
C. M. Stubben, Flt Ops

Delta Airlines
Hartsfield Atlanta Int Airport
Atlanta, GA 30320
404-765-2600
F. F. Rox, Flt Ops

Eastern Airlines
Miami Int'l Airport
Miami, FL 33148
305-873-2211
W. R. Brady, Opns

Frontier Airlines
8250 Smith Road
Denver, CO 80207
303-398-5151
Guy Lewis, Opns

Norwest Airlines
Minneapolis St Paul Int Airport
612-726-2111
J. T. Fredrickson, Opns

Ozark Airlines
Box 10007
Lambert Field
St Louis, MO 63145
314-895-6600
Peter Sherwin, Opns

Pacific Southwest Airlines
3225 N. Harbor Dr.
San Diego, CA 92101
714-574-2100
Don Lewis, Opns

Pan America World Airways
John F. Kennedy Int Airport
Jamaica, NJ 11430
212-632-2121

Piedmont Airlines
Box 2720
Smith Reynolds Airport
Winston Salem, NC 27102
919-767-5100
F. D. Womack, Opns

Republic Airlines
7500 Airline Drive
Minneapolis, NM 55450
612-726-7411
Louis Farrell Opns

Texas Int Airlines
Box 12788
Houston, TXC 77017
8451 Lockheed Street
713-641-7100
Robert Lemon, Opns

Trans World Airlines
Box 66100
Chicago, IL 60666
312-952-4000

US Air
Pittsburgh Int'l Airport
Pittsburgh, PA 15231
412-777-7000
Capt William Leefe, Opns

Western Airlines
Box 92005
6060 Avion Drive
Los Angeles, CA 90009
213-646-2345
Seth Oberg, Opns

World Airways
Box 2320
International Airport
Oakland, CA 94614
415-577-2000
Robert Mamick

Strategic Air Command HQ
Offutt AFB
Omaha, NB

Military Airlift Command
Travis AFB
California

6.0 TRAINING

This section describes the methods for observer training and subject pilot training to be developed.

6.1 VIDEO TAPE TRAINING.

A video training tape is being prepared at the Technical Center. The purpose of the tape is to provide training that can be used by pilots to gain familiarity with TCAS operation, display information, and operating procedures. A draft script (see reference 7) has been prepared, and forms the basis for the tape.

Filming for the tape will begin in Mid-March 1983 and will be completed at least five weeks before subject pilot testing is scheduled to begin in June 1983.

The center's B-727 (N-78) will be outfitted with all display and controls per the proposed Piedmont installation. The Dalmo Victor TCAS feasibility model and AID will be interfaced to the displays and controls. Filming will consist of airborne footage of pilot procedures, aural effects and intruder aircraft acquired visually. Scenes, such as closeups of the weather radar display and control actuation will be shot with the aircraft on the ground.

6.2 OBSERVER TRAINING.

The purpose of observer training is to minimize the variance in data from inflight encounters. Several considerations apply in observer training:

(a) The observers must all receive the same level of TCAS training.

(b) The observers should receive the same level of TCAS training that the pilot receives.

(c) The observers should be clear on what to look for during an encounter.

(d) The observer should clearly understand the significance of the anchors in the rating scales on the questionnaire.

Items (a) and (b) are critical factors but do not present a problem because the training video tape and manual will be used to ensure a constant level of training. Item (c) is to be discussed in classroom-type sessions with the observers and an ACT-140 interviewer. However, careful design of the inflight questionnaire will play a major part in normalizing the observed data. Item (d) will also be discussed in the classroom, and is more a matter of understanding the observers' intepretation of the anchors, so that his responses can be normalized. Careful design, e.g., using unambiguous anchors, will help to minimize rating scale variance.

7.0 RESOURCE REQUIREMENTS

7.1 FACILITIES AND EQUIPMENT.

The flight test programs described in this document will require up to three aircraft and various ground support facilities. The specific facilities are:

Nike Hercules - An X-Band radar tracking system capable of tracking two aircraft, used for obtaining accurate aircraft position data. This system will be used in the accuracy tests and CAS logic validation.

Mode S Facility - The Technical Center is operating an experimental Mode S (60 mi) site on center. The short range radar is equipped with a PPI display of traffic and will be used as the ATC facility for the operational evaluation.

HP3801A Total Station - A short range electro-optical distance and angle measuring instrument. The station will be used to fix survey points during ramp testing.

Van - a vehicle equipped with an ATCRBS transponder, 1 GHz antenna on a variable height mast, variable attenuator, and miscellaneous instrumentation such as oscilloscopes, spectrum analyzer, frequency counters, etc. The van will be used as a moveable target in the ramp testing.

Ship State Data Rack - A recording system which records (on 9-track tape) the aircraft state variables roll, pitch, and heading. These data are obtained from the B-727's Inertial Navigation Unit and are merged with NIKE radar data after the flight on the center's Honeywell computer to reduce errors in the NIKE reference data.

Aircraft Power Conditioning - The B-727 400 Hz project power system is known to suffer sags, surges and transients (reference 8). A conditioning unit will be installed to provide stable 60 Hz and 28 vdc power for project instrumentation and the Lincoln Aid. Note that the TCAS II prototype and Sperry symbol generator will be operated from unconditioned 400 Hz.

Target Aircraft - Two aircraft, N-91 and N-50, will be used as intruders during the accuracy, CAS validation, and operational testing. These aircraft are Mode S transponder equipped.

7.2 PERSONNEL.

The following responsibilities will be required for the test program:

Air Traffic Controller	2 each	ACT-100
Flight Coordinator	1 each	ACT-100
Project Pilot and Crew	1 each	ACT-600
TCAS Project Technicians	4 each	ACT-100
Inflight Observer	4 each	ACT-100, 200
Intruder Aircraft Pilot and Crew	2 each	ACT-600
Project Engineers	3 each	ACT-100
Aircraft Maintenance Crews		ACT-600

7.3 FACILITY UTILIZATION.

Based on the subject pilot testing and TCAS validation requirements, the following facility utilization was developed:

(a) Aircraft

1.	B-727	(N-78)	estimated	70 hours	from	March-July
2.	B-727	(N-40)	estimated	8 hours	in	June
3.	Convair 580	(N-91)	estimated	60 hours	from	May-July
4.	Aero Commander	(N-50)	estimated	30 hours	from	May-July

(b) Facilities

1.	Nike Radar	estimated	40 hours	from	March-June
2.	ARTS III	as required			
3.	Mode S facility (60mi)	estimated	30 hours	from	May-July
4.	Mode S facility (200mi)	estimated	24 hours	in	April-May
5.	Van	as required			

8.0 ORGANIZATIONAL RESPONSIBILITIES

The management of the Dalmo Victor TCAS II test program is the result of coordination with several organizations within and outside the FAA. Major organizational responsibilities are listed below:

ACO (Aircraft Certification Office) - for the issue of an STC to Piedmont for their B-727 installation.

ACT-140 - for the Technical test program management.

ACT-230 - for CAS logic simulation and analysis.

APM-330 - for the overall TCAS program management.

ARINC - for the Piedmont test program management.

Boeing - for TCAS cockpit display configuration development.

Dalmo Victor - for support and maintenance of the prototype hardware and software.

MIT - Lincoln Lab - for surveillance development and analysis.

MITRE - METREK - for CAS logic development and analysis.

8.1 AIRCRAFT CERTIFICATION OFFICE

Subsequent to the Technical Center evaluation, the Dalmo Victor prototype will be installed for in-service operational testing aboard a Piedmont B-727.

A supplemental type certificate (STC) will be issued by the Aircraft Certification Office (ACO) in Atlanta. To minimize the activity required by Piedmont, some of the airworthiness testing of TCAS will be performed at the Technical Center in direct coordination with ACO. The anticipated test process and level of coordination is described below:

1. The Technical Center will supply functional and detailed drawings of the proposed TCAS avionics installation on N-78 to the ACO.

2. The Technical Center will also supply ground and flight test plans to verify TCAS is operational and performs its intended function without interference to existing aircraft systems.

3. Once their preliminary requirements are met, the ACO will respond with a Type Inspection Authorization (TIA) for N-78.

4. With the issuance of the TIA, testing of the prototype will begin.

5. As outlined in sections 3 and 4 of this document, first the hardware validation and then the operational validation of TCAS will take place.

6. The ACO is on Technical Center document distribution. In addition, a representative from the ACO is expected to observe ramp testing and participate in the flight test program both as an observer (CAS validation) and a participant (subject pilot testing). The ACO is not expected to attend bench testing at Dalmo Victor but will receive a copy of the bench test report.

7. When the TCAS prototype is moved to Piedmont from the Technical Center, results of FAA testing regarding airframe worthiness (antenna mounting), electrical and electro-magnetic compatibility, and TCAS validation will be applied, and the ACO will issue a TIA to the Piedmont installation.

The ACO involvement will be valuable not only to minimize Piedmont's activity, but also to create a base of experience to be applied in future air carrier TCAS installations.

8.2 ACT-140 GUIDANCE AND AIRBORNE SYSTEMS BRANCH

Coordinates all Technical Center organizations and outside activities relative to the flight program. Develops and participates in conducting flight programs. Reduces and analyzes test results and generates reports relative to system performance.

8.3 ACT-220 ANALYSIS BRANCH

Provides system support relative to CAS logic to all participants. Assists in evaluating test results and performance inconsistencies. Develops software for flight data inputs to CAS logic.

8.4 ACT-600 FACILITIES DIVISION

Provide and operate ground support facilities (NIKE, EAIR) and aircraft interfaces. Assist in processing ground facility data tapes and developing hardware and software for airborne ground tracking data recording.

Responsible for providing an aircraft test bed, maintaining aircraft and interfaces with project equipment, making available and scheduling aircraft and supplying a crew to fly and maintain aircraft during flight programs at the Technical Center and other test areas. Assist project personnel in developing flight programs and subjective analysis of flight results.

8.5 ATC-AIR TRAFFIC CONTROL TOWER

Provide the clearances and coordination necessary to conduct a flight test program in the Technical Center airspace.

8.6 INPUT/OUTPUT COMPUTER SERVICES (CONTRACTOR)

Maintains primary responsibility to reduce flight data to useable analysis formats. Develops software to extract and format data from airborne tapes, creates data files, reduces, accumulates, plots, and displays data on CRTs and hard copy printouts. Interfaces with all other software and data analysis participants in order to assure a coherent software development and analysis effort.

9.0 DOCUMENTATION

Three types of reporting will be used to disseminate the data from the test programs. The documents are described in the following subparagraphs.

9.1 POST EXPERIMENT DATA REPORT

These reports will be short, rapid turnaround documents that will contain sectionalized descriptions of the specific test purpose conduct, and generalized results. Included in each section will be CAS logic plots and/or CAS track plots taken from hard copy reproductions of the Tektronix 4052 performance monitor display.

The reports will include annotations of equipment failures, resets or auto restarts or any other anomalous behavior. If the cause of the problem is discovered and the failure corrected, they will be reported. If the cause is not discovered, a plan to identify and correct the failure will be included.

These reports will not contain CAS logic plots generated on the Center's Honeywell computer in order to avoid delays in distribution.

These reports will be generated as follows:

(a) after bench testing at Dalmo Victor

(b) after bench testing at the Technical Center

(c) after the prototype validation flight test (Technical Center)

(d) after each day of flying in the CAS validation flight test

(e) after each day of flying in the Operational Evaluation

Distribution of these reports will be within 5 working days of the experiment date. Distribution is indicated in section 9.4

9.2 SUMMARY DATA REPORT

These reports will be issued after each test, e.g., bench flight test - validation, flight test operational evaluation, and will form the basis for the continuation of the program. These reports will contain performance monitor hard copy, Honeywell plots and statistics, and go, no-go analysis of TCAS performance. The reports will be organized by experiment type, eg, accuracy testing - AOA or encounters - Head on, and suborganized chronologically. Distribution is indicated in section 9.4. These reports will be issued within 1 week following the end of the particular test program.

9.3 FINAL REPORT

The final report containing detailed analysis and summaries of results will be published following the program completion. The date of issue is shown on the program schedule (section 2.2).

9.4 REPORT DISTRIBUTION

The following organizations will receive copies of all Technical Center documentation:

ACO - Aircraft Certification Office
ACT - Technical Center Distribution

(a) ACT-100
(b) ACT-200
(c) ACT-500
(d) ACT-600

APM-300
AFO-200, 500
ARINC
MIT Lincoln lab
MITRE
Key Aviation Industry Representatives Designated by the Operational Evaluation Working Group

10.0 REFERENCES

1. "Acceptance Test Plan Traffic Alert Collision Avoidance System, Dalmo Victor Operations," R-3711-10236A, September 1982.

2. "Data Reduction adn Analysis Requirements for DV TCAS II With Modifications," FAA Technical Center, January 1983.

3. "Test Plan for Dalmo Victor Feasibility Model," FAA Technical Center, CT-82-100-65LR.

4. "Test Plan for Dalmo Victor Active Beacon Collision Avoidance System," DOT/FAA/CT-81/204, July 1981.

5. Operational Notes of TCAS II Industry Prototype," FAA Technical Center, CT-82-100-128LR.

6. "Subject Pilot Testing at Massachusetts Institute of Technology, Lincoln Laboratory.

7. "Video Tape Script," to be published.

8. "Power Conditioning B-727," to be published.

9. "TCAS Operational Evaluation Test Plan," to be published.

APPENDIX A

PREFLIGHT QUESTIONNAIRE

Subject No. ________

Flight No. ________

Date ______________

Purpose: These questions are to be answered in a preflight interview with the subject pilot. The subject should answer based on his general impression of TCAS in actual air carrier operations.

Pilot Experience:

1. What is your experience recently in a B-727. ____.

2. Age. _______.

3. Total Flight Time ___________.

4. Please indicate your experience with CAS. ____.

5. What type of display format was used? ____.

6. Were you satisfied with the display format? If not, what changes would you propose? ____.

7. During the training session, you were given a prescribed procedure. Based on your expectations of TCAS, would you change the procedural response in any way?

____.

Pilot Expectation:

1. How much confidence do you have in TCAS' ability to properly resolve all encounter situations?

Very Low	Low	Moderately Low	Moderate	Moderately High	High	Very High

2. Compared to ATC, what would you expect the quality of TCAS traffic advisories to be?

Much Worse	Worse	Slightly Worse	Moderate	Slightly Better	Better	Much Better

3. Do you anticipate that, with TCAS, your flight deck workload will:

Decrease Substantially	Decrease	Decrease Slightly	Not Change	Increase Slightly	Increase	Increase Substantially

4. Compared to ATC traffic advisory frequency, how often would you expect TCAS traffic advisories?

Much Less Often	Less Often	Slightly Less Often	About the Same	Slightly More Often	More Often	Much More Often

5. Compared to ATC traffic advisories, when would you expect TCAS traffic advisories?

Much Earlier	Earlier	Slightly Earlier	About the Same	Slightly Later	Later	Much Later

6. In an encounter situation, how much traffic advisory information do you expect to receive from TCAS compared to ATC?

Much Less	Less	Slightly Less	About the Same	Slightly More	More	Much More

Training:

1. What do you expect will be the most valuable information provided by TCAS?

____

____

____.

2. Assume you have been given a TCAS resolution advisory. Would you move the aircraft in the following cases? (Circle one or more and explain.)

(a) No visual on intruder, cannot clear the airspace in the direction of the move.

(b) No visual on intruder, clear the airspace in direction of move.

(c) Visual on intruder, cannot clear the airspace.

(d) Visual on intruder, clear the airspace in the direction of move.

____

____.

3. Explain you perception of TCAS display information listed below:

(a) Traffic advisory information __________________________

____.

(b) Resolution advisory information ________________________

____.

(c) Proximity information ______________________________

____.

4. How would you integrate TCAS proximity information with a TCAS resolution advisory?

____

____.

Training (Continued):

5. How would you rate the training you received for this flight test program?

Video Tape:

Extremely Poor	Very Poor	Poor	Fair	Good	Very Good	Excellent

Training Booklet:

Extremely Poor	Very Poor	Poor	Fair	Good	Very Good	Excellent

APPENDIX B. INFLIGHT OBSERVER FORM

	Takeoff				Climbout				En Route					Approach				Final		
ATC Call																				
Visual Search																				
TA																				
RA																				
Cancel																				
CRT Scan																				
Visual Acquisition																				
IVSI Scan																				
Radio Comm (RE TCAS)																				
Pilot Response																				
CPA																				

Pilot Reaction Indicated He Considered Advisories:

Timely? _______ yes _______ no

Useful? _______ yes _______ no

Correct? _______ yes _______ no

Necessary? _______ yes _______ no

Pilot's Rating

+2 +1 0 -1 -2

APPENDIX C

POST FLIGHT QUESTIONNAIRE

1. In general, do you feel that a collision avoidance system should be:

___ a. Required on all aircraft immediately.

___ b. Required only on aircraft operating in terminal control areas.

___ c. Required only on aircraft operating above or below certain altitudes (indicate altitude ________).

___ d. Required on air carrier aircraft only.

___ e. Not required.

Comments: ____

____

____

2. Did you experience any of the following problems with the alerting system in the test aircraft? If so, please explain.

a. Traffic Advisory Display? Yes ___ No ___
b. IVSI? Yes ___ No ___
c. Aural Alerts? Yes ___ No ___

Comments: ____

____

____

3. Do you feel that the alerts used in the test gave you sufficient time to react?

Always Usually Sometimes Seldom Never

Comments: ____

____

____

4. If a pilot visually acquires the aircraft which he believes is causing an RA, can you think of any situations which would result in the pilot concluding that the RA is unnecessary? If so, what are they?

____

____

____

5. Would the pilot be justified in not following the RA in these situations? Why or why not?

____

____

____

6. Did you observe any instances in which the resolution advisory appeared to be inappropriate or incorrect? If so, please describe.

____

____

____

7. Compared to ATC advisories, when did you experience TCAS traffic advisories?

Much Earlier	Earlier	Slightly Earlier	About the Same	Slightly Later	Later	Much Later

8. What was the impact of TCAS on your flight deck workload?

Decrease Substantially	Decrease	Decrease Slightly	No Change	Increase Slightly	Increase	Increase Substantially

Comments: ____

____

____

9. Did the aural alarm affect the amount of time spent viewing the IVSI or TA display when no alarms were present?

____

____

____

10. When resolution advisories were not being presented, how often did you refer to the traffic advisories through the use of the TCAS tracks switch?

Very Seldom	Seldom	Moderately Seldom	Sometimes	Moderately Often	Often	Very Often

Comments: ____

____

____

11. Did you find using the information on the TA display distracting?

Never	Seldom	Moderately Seldom	Sometimes	Moderately Often	Often	Always

Comments: ____

____

____

12. Were non mode C traffic advisories useful? Explain.

____

____

____

13. Do you feel that adjustable limits, either automatic or manual, for the traffic advisory display (in the Tracks mode) would be helpful? Yes ___ No ___

Please explain: ____

____

____

14. In your opinion, is a traffic advisory feature required for a collision avoidance system? Yes ___ No ___

Please explain: ____

____

____

15. In following the RA, how often did you feel constrained due to prior instructions from ATC? Please comment.

Always	Usually	Often	Sometimes	Seldom	Very Seldom	Never

Comments: ____

____

____

16. Did you observe any instances in which the traffic advisory information appeared to be incorrect? Yes ___ No ___

Explain: ____

____

____

17. Were there ever instances in which you had difficulty in interpreting the display - i.e., you were not certain what you were supposed to do? Yes ___ No ___

Explain: ____

____

____

18. a. In the event that the information on the TA display seemed to conflict with the resolution advisory displayed on the IVSI or with ATC advisory what would you most likely do? Check more than one, if appropriate.

___ Follow the IVSI, ignore the TA
___ Follow the TA, ignore the IVSI
___ Wait for more positive commands on the IVSI
___ Attempt to visually sight the intruder using AID bearing information, maneuver
___ Do nothing

b. Additional Comments: ____

____

____

c. In the event that visual information seemed to conflict with the RA, what would you most likely do? Check more than one, if appropriate.

___ Follow the IVSI, ignore the TA
___ Follow the TA, ignore the IVSI
___ Wait for more positive commands on the IVSI
___ Attempt to visually sight the intruder using AID bearing information, maneuver
___ Do nothing

19. How would you rate the usefulness of the TCAS switch?

Totally Unnecessary	Unnecessary	Makes No Difference	Necessary	Completely Necessary Should Be Mandatory

Explain: ____________________

____

____

20. Did the prescribed procedures fit all the TCAS situations? Yes ___ No ___

If not, describe the situation for which it was not suitable, and explain the action you took.

____

____

____

21. Were there any problems integrating both ATC and TCAS advisories?
Yes ___ Possibly ___ No ___

Comment: ____________________

____

____

22. Describe any problems you had during the flight.

____

____

____

23. What way did TCAS change your relationship with ATC; did TCAS lead you to question ATC?

24. What changes do you feel should be required in aircraft and ATC operating procedures if TCAS were implemented?

Comments:

25. Based on your experience in this flight test program, how would you rate the training you received for this flight test program?

Video Tape:

Extremely Poor	Very Poor	Poor	Fair	Good	Very Good	Excellent

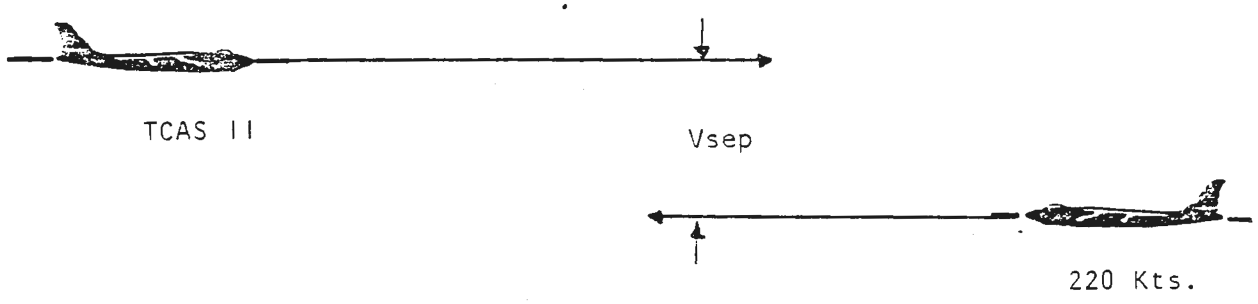
Training Booklet:

Extremely Poor	Very Poor	Poor	Fair	Good	Very Good	Excellent

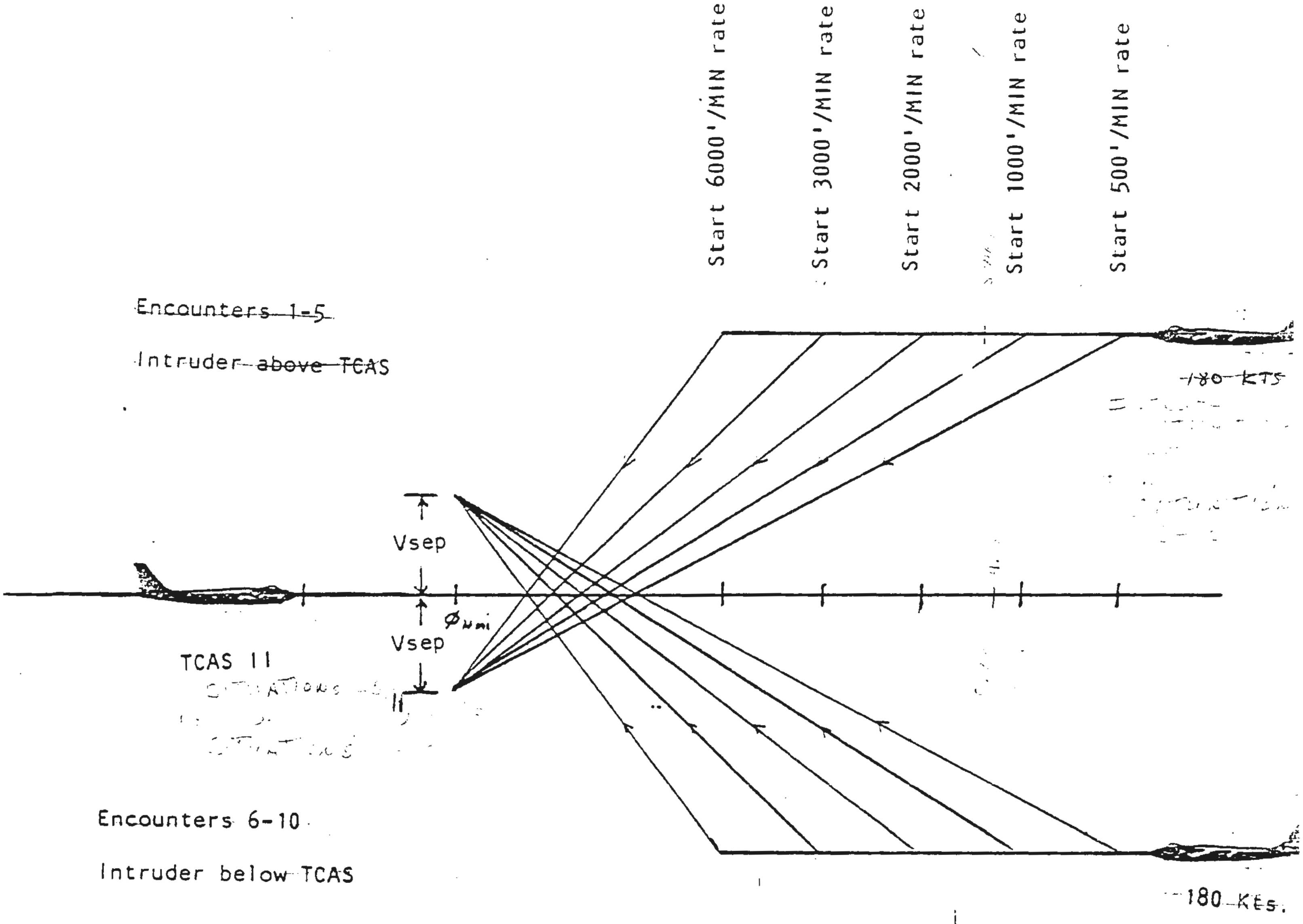
Comment:

APPENDIX D

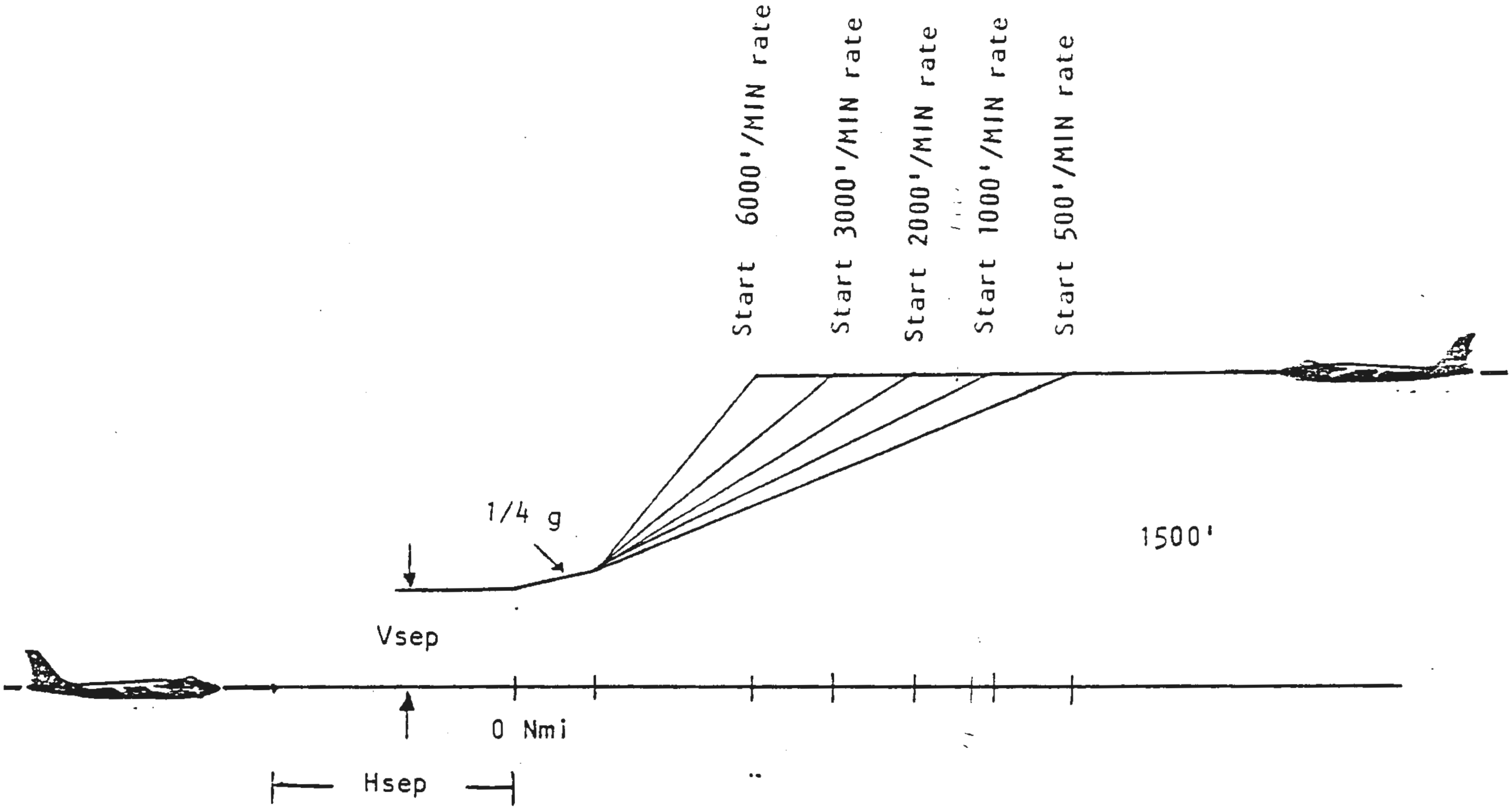
ENCOUNTER GEOMETRIES



Situation	Vsep	RDOT	Altitude	Notes
1	+300	450	9500	
2	-300	450	9500	
3	300	600	9500	~~Bench Test~~ Only.
4	300	1200	20,000	Bench ~~Test Only~~
5	500		9500	
6	500	1200	20,000	~~Bench Test~~ Only
7	300	450	35,000	Bench Test Only
8	??	330	9,500	Intruder is Non Mode C

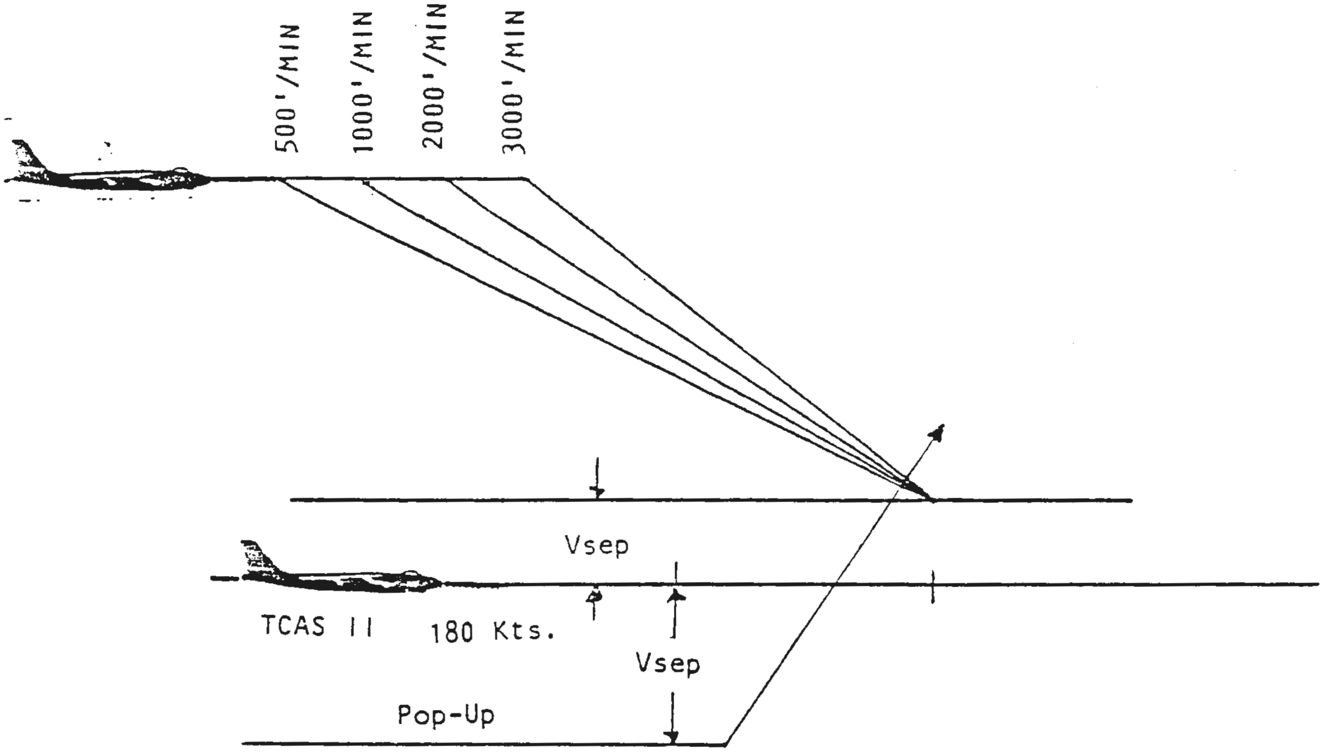


Situation	Vsep	RDOT	ADOT	TCAS Altitude	Notes
1	500	360	500	9500	
2	500	450	1000	9500	
3	750	500	2000	10,500	
4	1000	500	3000	20,000	Bench Test Only
5	1000	500	6000	35,000	Bench Test Only
6	Same as 1-5 except Intruder is Level;				
7					
8	TCAS is above				
9					
10					
11	250	330	1111	9,500	TCAS LEVEL



Situation	Vsep	Hsep	RDOT	ADOT	TCAS Altitude	Notes
1	250		360	500	9500	
2	250		450	1000	9500	
3	500		500	2000	20,000	
4	500		600	3000	20,000	Bench Test Only
5	500		600	6000	35,000	Bench Test Only
6	250		360	500	9500	
7	250		450	1000	9500	
8	250		500	2000	20,000	Bench Test Only
9	250		330	1111	9,500	

Profile 3

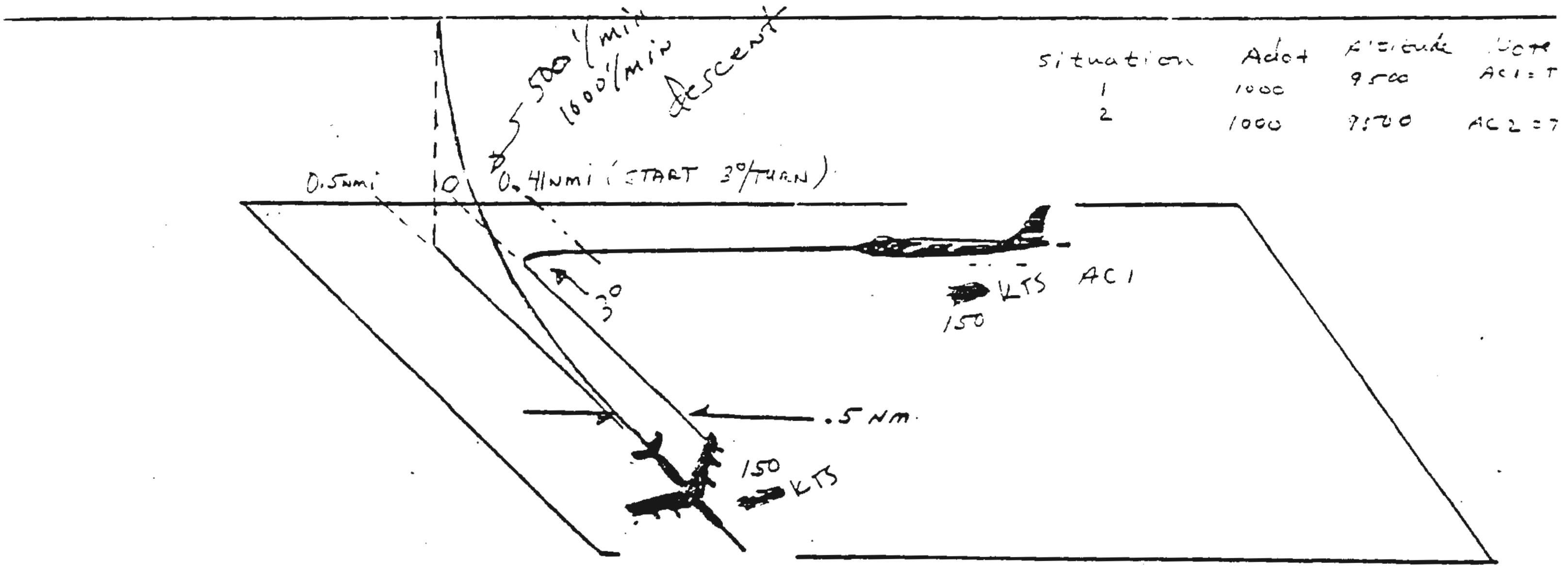


(Encounter 2)

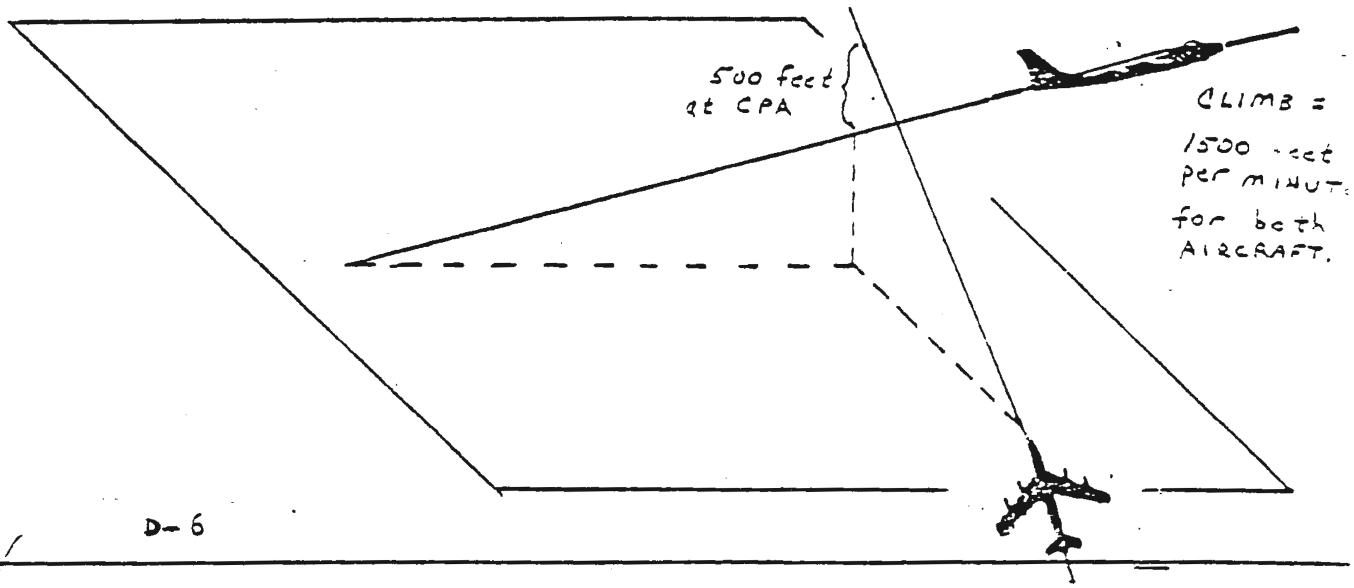
Encounter	Vsep	RDOT	ADOT	TCAS Altitude	Notes
1	0	40 Kts	0	9500	Transponder turn-on at .5 NMI
2	1000	40 Kts	1000	9500	Transponder turn-on at .5 NMI
3	0	60 Kts	0	9500	Test antenna coverage aft
4	300	60 Kts	500	9500	
5	300	60 Kts	1000	9500	
6	300	60 Kts	2000	9500	~~Bench Test Only~~
7	300	60 Kts	3000	9500	Bench Test Only
8					
9	300	0	500	9500	Both A/C Descending (TCAS=500'/m
10	300	60 Kts	1000	9500	TCAS Descending
11	300	-60 Kts	1000	9500	TCAS Descending
12					TCAS Level; Intruder Climbing
13	???	60 Kts			TCAS Level; Intruder Climbing
14	???	60 Kts		20,000	TCAS level; Non Mode C intruder Climbing

Figure 6, ENCOUNTER Profiles

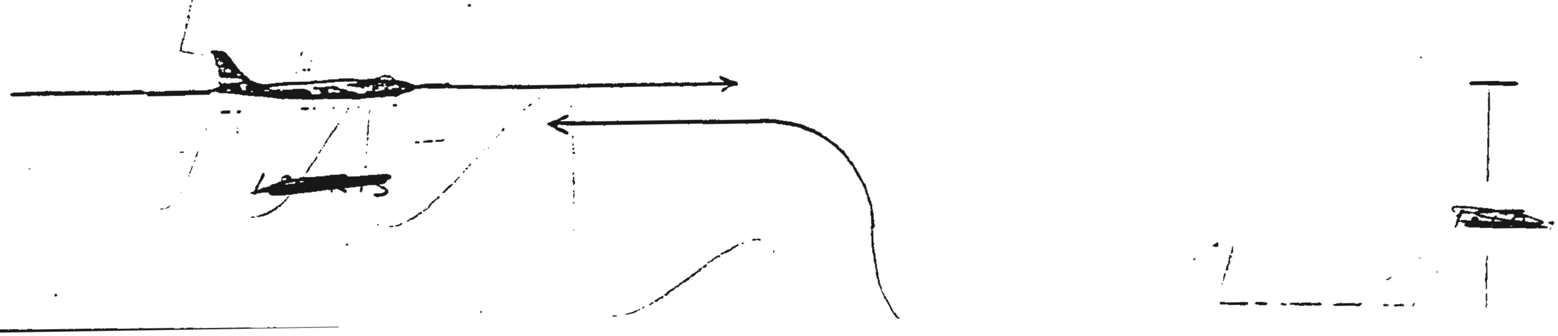
Unresolvable Trajectories

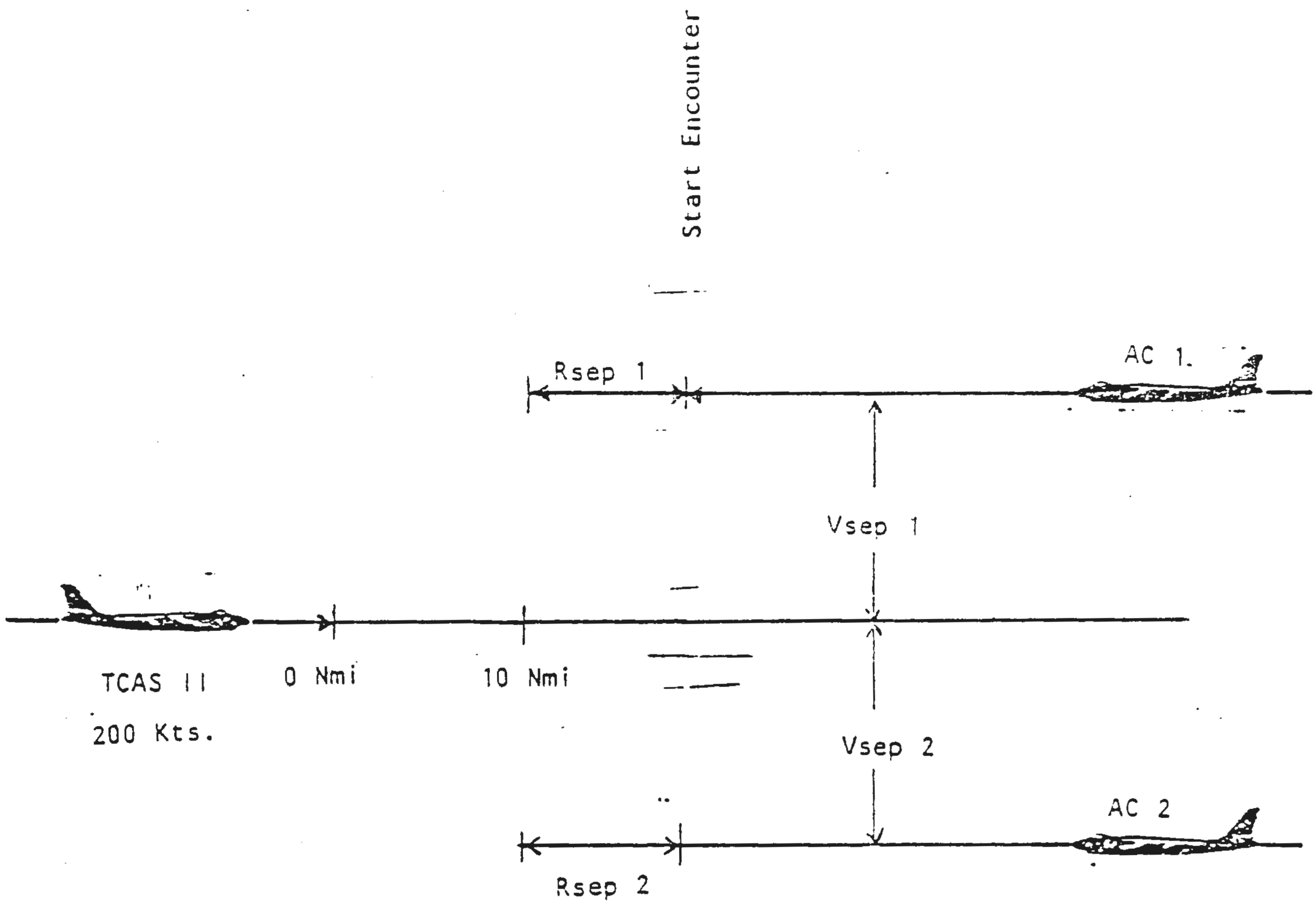


D-5

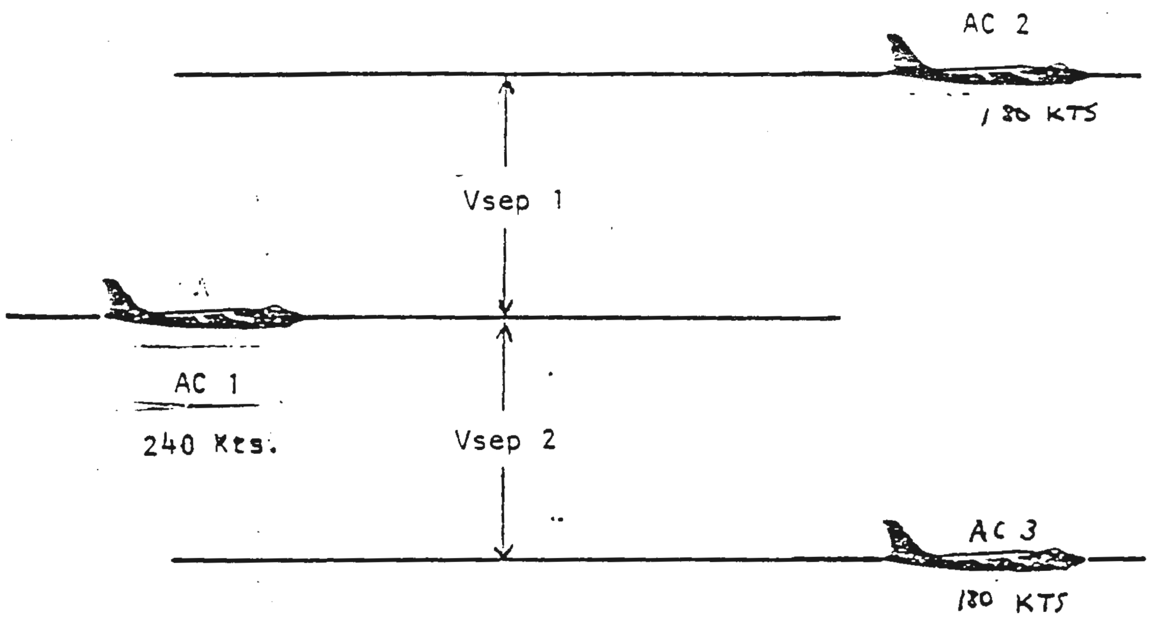


D-6





Situation	Vsep 1	Vsep 2	Rsep 1	Rsep 2	RDOT 1	RDOT 2	Altitude	Notes
1	300	1000	9 NMI	9 NMI	380	380	9500	AC1 = TCAS
2	1000	300	9 NMI	9 NMI	380	380	9500	AC1 = TCAS
3	400	400	9 NMI	9 NMI	380	380	9500	AC1 = TCAS
4	300	1000	9 NMI	12.5 NMI	380	450	9500	AC1 = TCAS;Bench or
5	300	100	20 NMI	20 NMI	1200	1200	20,000	AC1 = TCAS;Bench or
6	300	1000	10 NMI	10 NMI	400	400	9500	AC1 = AC2=TCAS
7	1000	300	10 NMI	10 NMI	400	400	9500	AC1 = AC2=TCAS
8	400	400	10 NMI	10 NMI	400	400	9500	AC1 = AC2=TCAS
9	300	1000	10 NMI	10 NMI	400	400	9500	All TCAS
10	1000	300	10 NMI	10 NMI	400	400	9500	All TCAS
11	400	400	10 NMI	10 NMI	400	400	9500	All TCAS



Situation	Vsep 1	Vsep 2	RDOT 1	RDOT 2	Altitude	Notes
1	300	1000	60	60	9500	AC1 = TCAS
2	1000	300	60	60	9500	AC1 = TCAS
3	400	400	60	60	9500	AC1 = TCAS
4	300	1000	60	60	9500	AC1 = AC2 = TCAS
5	1000	300	60	60	9500	AC1 = AC2 = TCAS
6	400	400	60	60	9500	AC1 = AC2 = TCAS
7	300	1000	60	60	9500	All TCAS
8	1000	300	60	60	9500	All TCAS
9	400	400	60	60	9500	All TCAS

APPENDIX E - SCHEDULE