FAA TECHNICAL CENTER
LETTER REPORT

DALMO VICTOR ACTIVE BEACON COLLISION AVOIDANCE SYSTEM
FLIGHT TEST DATED SEPTEMBER 28, 1981

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by

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Introduction

The purpose of this flight test program is to evaluate the performance of the prototype Active Beacon Collision Avoidance System (ABCAS), manufactured by the Dalmo Victor Corporation, according to the objectives of the Test Plan for Dalmo Victor Active Beacon Collision Avoidance System (ABCAS) dated July 1981.

This report contains the results of the seventh flight in a series of test plan performance flight tests which were initiated on August 19, 1981.

The purpose of this report is to provide flight descriptions, test results, and preliminary evaluations of the September 28, 1981, flight test to program participants. These descriptions and results are provided in the form of encounter and logic plots, encounter data summaries, flight profiles, and a mission report. In addition to the present flight results, previous flight data will be reported in a cumulative table of results.

Methodology

a. Tests Conducted and Related Configurations.

The planned flight profiles and details are contained in appendix 1. The present flight plan was generated to satisfy the High Density Performance - Phase B of the Technical Center's Dalmo Victor test plan. The flight plan consisted of flying four low approaches into Washington, D.C.'s National Airport and 16 encounters in the Washington, D.C. airspace. The encounters consisted of 2 each of head on, tail chase, 90° and 270° target approaches to the Dalmo Victor ABCAS equipped aircraft. The target aircraft was equipped as an ATCRBS and DABS intruder. The DVCAS was manually set at performance level five for the encounters and combinations of performance levels five-four-two for the low approaches. The test aircraft were the Technical Center's Boeing 727 (N78) and Convair 580 (N91). The 727 was DVCAS directional antenna equipped and the 580 was DABS transponder equipped. The encounters were flown at an average altitude of 8500 feet.

Prior to the flight program, preflight system checks were conducted by turning on the system in N78 while N91 activated its DABS transponder while on the ground. In addition, targets of opportunity flying in the vicinity were tracked. Using the system performance monitors and an oscilloscope, real time evaluations were conducted. The evaluations indicated that the system was functioning properly and that the flight should be conducted.

b. Data Collection and Reduction.

Data was recorded on the Dalmo Victor system's 9-track magnetic tape. The Tektronix provided real time range and altitude plots. Subsequent to completion of the flight, the data tape was submitted to the Honeywell computer for data reduction and plotting. Appendix 2 contains the performance data and associated plots for each 16 planned encounters, one unplanned encounter, and the one low approach for which an advisor was generated.

c. Data and Plot Descriptions.

1. Data Matrix - consists of planned flight data, start and end times and types of resolution advisories, CAS logic generated data, and system established parameters. Appendix 3 contains acronym definitions and related plot information.

2. Range and Altitude Plots - consists of plots of ABCAS equipped and intruder aircraft altitudes versus time, and relative range of the two aircraft versus time. Each of the plots consists of a segment of interest of the total CAS track. The plots additionally contain the start and end of each resolution advisory. The solid lines represent the beginning of an advisory and the dashed lines represent the end of an advisory sequence.

3. Angle of Arrival Plots - consist of plots of range versus intruder angle of arrival over the same time period as the altitude and range plots. The intruder angles are with respect to the BCAS aircraft as the coordinate system whose right wing is at 90°. Using the flight profiles in appendix 1 and the start and end arrows on the angle of arrival plots, the angular position of the two aircraft can be observed from an initial range separation through crossover (closest point of approach) and final range separation over the time interval.

4. CAS Logic Plots - consists of six plots in which time is plotted against:
Vertical Missed Distance and Relative Altitude
Range and Altitude Warning Times
Relative Range and Range Closing Rate
ABCAS and Intruder Altitudes and Relative Range
ABCAS and Intruder Range Rates
Angle of Arrival and Angle of Arrival Rate

The plots additionally contain associated system established parameters (performance level dependent) and resolution advisory indications. Interpretation of these indicators appear in appendix 3. These plots provide a pictorial representation of the per second CAS logic parameters as they develop resolution advisories.

Test Results and Analysis Summary

All 16 of the encounters and the four low approaches were completed in accordance to plan. The first two low approaches were conducted in performance levels 5-4-2 and the last two were conducted in performance levels 5-4. All of the planned encounters were resolved by the CAS logic. Resolution advisories were generated and responded to by the project pilots.

a. Encounter Performance Summary

1. Timely warnings were provided (TAUR = 25 seconds) in all valid encounters. The average TAUR for the 8 DABS encounters was 23.2 seconds and for the 8 ATCRBS encounters was 22.8 seconds.

2. Slow closing rates require tail chase encounters to be initiated at approximately 4 NM. Since this is well within the system's 20 NM acquisition range, these tail chase encounters are not included in the average acquisition range calculations. For those encounters which exclude the tail chases, the average acquisition ranges based on 6 encounters each, were 15.7 NM for ATCRBS targets and 12.1 NM for DABS targets.

3. On previous flights in the Dalmo Victor test series, the system exhibited excellent CAS track continuity prior to the closest point of approach. In the previous five flight test reports, which were flights in the Technical Center's airspace, a total of 4 track drops occurred. In the present Washington, D.C. environment flights, a total of 9 track drops occurred, 7 of which occurred when flying the 270° encounters. CAS track densities and perceived fruit levels are presently being accumulated to make Washington and Technical Center comparisons.

4. The angle of arrival plots in appendix 2 indicate track continuity and angles which appear reasonable for the planned encounters.

5. It can be seen from table 1 that the DABS acquisition range of 12.1 nautical miles (NM) is significantly less than the 18.2 NM's of the September 23, 1981 data. This difference is being evaluated as well as the dual track (ATCRBS and DABS) occurrences of the 9/23/81 flight.

6. In all encounters, resolution advisories were provided which were consistent with the CAS logic and in directions away from the intruders.

b. Terminal Flight Summary

The Washington, D.C. terminal flights consisted of four low level approaches which were to provide insight into the performance level sequencing effects on terminal advisories. All approaches were made to runway 36. N78 was handled by air traffic control personnel as if it were an air carrier making a terminal approach. Automatic sequencing was not available on N78 and therefore manual sequencing was used. Manual sequencing was initiated at 2500 and 500 feet altitudes based on aircraft encoder inputs. The first two approaches were transitioned through a 5-4-2 sequence and no advisories were generated. Recognizing that this sequence was apparently effective in preventing advisories, it was decided to leave the system in performance level 4 (below 2500 ft.) on the 3rd and 4th approaches. The 3rd approach did not develop any advisories but the 4th resulted in a climb and no descend. These advisories occurred on the approach (own altitude = 175 ft.) to the runway and were a result of multiple encounters with 3 ground positioned aircraft. Based on the system recorded gray code altitude, the manual transitions occurred at the following:

Approach Altitude Performance Level Sequencing

Approach #	Inbound Altitude (ft.)		Outbound Altitude (ft.)	
	Performance Level		Performance Level	
	4	2	4	5
1	2400	500	600	2900
2	2400	400	300	2700
3	2200	--	--	2900
4	Never out of 4 Altitude less than 2500 ft.			

c. Detailed CAS Logic Evaluations

Sixteen planned encounters (numbers 1 through 16), evenly distributed between DABS and ATCRBS threats, were flown in performance level 5 (25 second look-ahead). All were straight and level, with varying crossing angles (0°, 90°, 180° and 270°). Appropriate resolution advisories (RA's) were generated in all cases and tracked vertical separation at CPA was uniformly good. Only in #9 was this separation (300 ft.) less than the ALIM threshold (here, 340 ft.). In this encounter, the BCAS aircraft descended and then leveled off in response to a "Descend," "Don't Climb" RA sequence. This leveling off caused the projected VMD, which is highly sensitive to small changes in tracked vertical rates, to break the ALIM threshold 9 seconds before CPA, resulting in a resumption of positive ("Descend") RA's. Even though this last "Descend" sequence was apparently ignored by the pilot, it probably came too late to have any effect on the 300 ft. vertical separation.

Negative to positive RA transitions occurred in 6 encounters. Mode C excursions were the cause in #7 (intruder mode C) and #5, #11, and #17 (own mode C). In #14, the extremely slow decay toward zero of the threat's tracked vertical rate, following a mode C excursion, caused the projected VMD to break the ALIM (340 ft.) threshold (resulting in a negative to positive RA transition) approximately 28 seconds after both aircraft began reporting level mode C altitudes that were just 300 ft. apart.

Another interesting negative to positive RA transition occurred in #12. Here an apparent multipath image (track 51) of the threat aircraft popped up at systime 1113, 5 seconds after the start of a "Don't climb" RA. This caused the TRFMAC module of the multi-aircraft logic to convert the negative RA to "Descend" at systime 1115. Track 51 lived for just 11 seconds (one report from surveillance plus 10 CAS coasts), where upon the "Don't climb" RA resumed.

Gaps in RA sequences occurred in encounters 2, 3, 4, 6, and 8. In #4, this

was due to a mode C excursion by the threat aircraft while the other examples occurred when the BCAS aircraft leveled off in response to the negative portion of a positive-negative RA sequence, causing the projected VMD to again drop below the ZTHR (750 ft.) threshold.

RA's were generated on 4 occasions in addition to the 16 planned encounters. The last low approach into Washington National (#0A), in performance level 4, produced a multi-aircraft conflict with 3 aircraft on the ground. A "Climb" RA began when the BCAS aircraft's altitude reached 175 ft.

Shortly following #16, a brief multi-aircraft encounter (#16A) developed involving 3 tracks, all having similar altitudes and bearings (multipath?). Each track consisted of just 1 or 2 surveillance reports plus 10 CAS coasts and here, as in #12, the multi-aircraft logic caused a positive RA to be displayed. A similar brief encounter (#16B) involving two threats with like altitudes and bearings began 15 seconds after #16A ended.

Finally, on the return leg to New Jersey, while flying at 13,400 ft. in performance level 6, an encounter of opportunity (#17) occurred having a fairly high (600 knot) closure rate. Here both aircraft were level, the intruder 500 feet below BCAS. Thirty-eight (38) seconds of "Don't climb" were displayed, transitioning to "Descend" when the BCAS aircraft broke the 13,500 ft. mode C quantization threshold, causing the relative altitude to fall below ALIM (here, 440 ft.).

d. Cumulative Results

The following table provides a basis for flight to flight comparisons.

TABLE 1. DALMO VICTOR ENCOUNTER PERFORMANCE

Acquisition Range (NM)			
Date	Average	# of Encounters	Type of Target
8/19/81	17.3	4	ATCRBS
8/25/81	19.0	8	ATCRBS
8/25/81	18.0	8	ATCRBS
9/11/81	13.4	9	ATCRBS
9/17/81	14.1	7	ATCRBS
9/23/81	18.2	12	DABS
9/23/81	17.3	5	ATCRBS
9/28/81 1]	15.7	6	ATCRBS
9/28/81 1]	12.1	6	DABS 2]

1] Tail chase encounters not included.

2] Two acquisition ranges (10.94, 12.47) are not truly representative in that previous encounter tracks were not dropped.

Warning time (TAU Sec.)			
Performance Level	TAUR Avg.	TAUV Avg.	# of Encounters
4 (20 sec.)	18.3	-	4
4 (20 sec.)	18.6	-	8
5 (25 sec.)	23.3	23.6	7
5 (25 sec.)	23.8	-	9
5 (25 sec.)	23.5	-	7
5 (25 sec.)	23.6	-	14
5 (25 sec.)	23.6	24.6	2,1 1]
5 (25 sec.)	22.8	-	8
5 (25 sec.)	23.2	-	8

1] ATCRBS, DABS

Conclusions

The September 28 flight results relative to TAUR warning times and acquisition ranges are satisfactory for both DABS and ATCRBS encounters.

A degradation of ATCRBS track continuity is evident by the increase in track drop occurrences compared to Technical Center results. No track drops occurred within 6.3 NM of an intruding aircraft.

The September 23 DABS encounter results indicated occurrences of simultaneous ATCRBS and DABS tracks and acquisition ranges of 18 NM. The present results exhibit generation of only DABS tracks and acquisition ranges of 12 NM.

All DABS and ATCRBS encounters resulted in advisories which avoided altitude crossings. Logic evaluations indicate that the advisories were appropriate and the tracked vertical separation at closest point of approach was uniformly good.

Multiple tracks on the intruder aircraft in encounter #12 caused the multiple logic to be activated and resulted in an advisory transition from negative to positive.

Multiple tracks on intruder aircraft in encounters 16A and 16B exhibited high range rates (1340 and 830 NM/Hr.) and also caused the multiple logic to be activated.

The four low approaches indicate that ground positioned aircraft with transponders operating can cause advisories to be generated in performance level 4. Performance level 2 will inhibit such advisory occurrences.

APPENDIX 4

SUBJECT: MISSION REPORT, SEPTEMBER 28, 1981

Test Objective

Primary objective was to determine the higher aircraft density effects on system performance by flying planned encounters and to obtain a preliminary insight into terminal approach - performance level interactions.

The secondary objective was to provide ASO, AFO, ARD, ARINC, and Piedmont representatives with a system demonstration.

Resources Scheduled

N78 (DVCAS equipped B727), N91 (CV580 DABS and ATCRBS equipped target), Washington National ARTS facilities.

Pre-Mission Briefing

Flight crew briefed by W. Gadow, ACT-100J. Project personnel briefed on profiles and assignments by test director, ACT-100J. Observers and Washington National ATC representatives briefed by ACT-100J representatives and project pilots.

Pre-Mission System Test

On September 28, 1981, Messrs. J. Warren, A. Cushman, B. Scharaga, F. Musson, and E. Glowacki of the Technical Center performed system checks. The TRU-2A DABS equipped aircraft (N91) stationary target and targets of opportunity in surrounding airspace were used to ground test system #2. System evaluations were performed by means of the performance monitors (Tektronix and 3-inch CRT displays) and oscilloscope hardware monitor. The 3-inch CRT gave an indication of an ARINC timeout (no data messages) F-D1 failure. At this point it was decided to replace the system #2 processor with that of system #1. The 3-inch CRT gave an indication of a transmitter power or 2-level attenuator failure (F1). Based on previous F1 failure modes, it was decided to exchange the A4 boards between systems 1 and 2. At this point the system performed satisfactorily and a decision was made to proceed with the flight.

Mission Conduct

All of the planned four low approaches and 16 encounters (8 DABS and 8 ATCRBS) were conducted. Encounters were flown by Technical Center pilots and system performance was observed and discussed by all test flight participants. Upon the return flight to the Technical Center a target of opportunity was encountered and a negative advisory was generated. The equipment and communications operated satisfactorily. Nine track magnetic tape data, Tektronix hardcopy printouts, and hand flight logs were generated on system performance.

Problems Noted

The cockpit IVSI continues to be utilized with the 1000 to 2000 light segment inoperable.

Mission Results

Successful system performance was indicated by real time assessments by participating personnel. The encounters provided advisories which were directed away from the intruders. Approach advisories can be controlled by the present performance level transitions. Upon landing, the flight data 9-track tape was duped and submitted for data reduction and analysis.

Post Mission Debriefing

Due to the successful test flight results, a flight debriefing was not conducted with project participants. Observer and pilot reports will be provided.

APPENDIX 5

OBSERVERS' COMMENTS BCAS FLIGHT DCA, 9/28/81

(Flight in the Washington, D.C. area between 1147' - 1450' with B727, N-78 and CV580, N-91, 9/28/81.)

Four low approaches down to 50' to runway 36 were flown in N-78. Sixteen encounters, four tail chases, four head ons, four 90's and four 270°'s were flown with both aircraft, initially 300' vertical separation.

N-91, due to lack of RNAV or inertial NAV equipment was positioned along the Nottingham VORTAC radial 170° between the station and 22 NM S of station. For the head on and tail chases, N-78 also utilized this radial. For the 90's and 270°'s, N-78 used the Omega system for positioning. Block altitudes of 8000 and 9000' were used. Accurate encounter crossovers during the 90's and 270s was extremely difficult due to 57K winds from the NW at flight altitude.

A Tech Center test pilot flew the approaches and all of the encounters except the Head on's. Piedmont Airliner Chief Pilot flew the four head on encounters, numbers 9 through 12.

All received alarms appeared normal and commands followed with the following exception:

#1. VSL do not climb, no command. A/C passed 350' apart.

#7. No good. 90° winds affect positioning. Never in position to get indication.

#11. Piedmont pilot put climb needle back into yellow at crossover after initiating a climb on command.

Several extra alarms received as a result of maneuvering both A/C in close proximity to each other after encounters, prior to next one.

APPENDIX 6

PILOTS' COMMENTS BCAS FLIGHT SEPTEMBER 28, 1981

Following a briefing with Mr. William Canty at the Washington National Airport Control Tower, a flight demonstration was conducted with N78, Boeing 727 and N91, Convair 580. The list of the attendees is shown below.

1. Four ILS low approaches were conducted to runway 36 at DCA from a standard radar vectorized pattern with the Boeing 727. These approaches were broken off at 100 ft.

2. After a rendezvous with N-91, a series of encounters was conducted. These included "tail chase," head on 270° and 90° crossover."

Comments: In each case a sound warning alerted the crew in ample time of a possible threat. The "do not climb" or "do not descend" command on the IVSI appeared on each encounter and was correct in direction. The descend or climb red arrow appeared in ample time to initiate a gentle descent or climb at 500 ft/min.

Several times this arrow did not appear. This was due to the vertical distance between the two test aircraft greater than 300 feet. However, the commands of "do not descend," or "do not climb" was a sufficient warning.

A qualified Piedmont Boeing 727 captain was invited to fly the test aircraft on four head on encounters with a FAA Tech Center safety pilot in the right seat.

Attendees of the TCAS project flight at DCA on September 28, 1981:

Bob Miller	ASO-213
Ed Booth	ASO-216
Larry Youngreu	ASO-ACDO 33
Tom Berry	ARINC Research
Fred Womack	Piedmont
Al Lenderman	Piedmont
Ben Tollison	AFO-260
Tom Williamson	ARD-242