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Volume III.
Flight Test Results.

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16. Abstract

This report summarizes the ADEDS flight test effort performed on the NASA 515 737-100, between January 8 and March 15, 1974. A brief description of each flight is provided as well as pertinent comments regarding system performance. A summary of all test data is given along with an operational critique of the system. Appendix A provides an update of the ADEDS functional and software requirements originally released as report FAA-SS-73-19, released at equipment delivery to Boeing. Appendix B provides a summary of the flight test data for crosstrack, altitude, and time errors. Appendix C provides the definition of additional flight paths used during the ADEDS flight test that were not included in the basic flight path catalog originally defined in report FAA-SS-73-22-1, released in February 1974. Appendix D provides a summary of display and navigation equipment problems that occurred during the flight test and corrective action taken for each problem.

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PREFACE

This report, produced as part of the DOT/SST Technology Follow-On Program, phase II, task VI—Advanced Electronic Display System (ADEDS), is the final report to be submitted under this program. The purpose of this report is to provide a summary of the flight test results and a subjective critique of the operational design.

The basic objective of the ADEDS task was to complete the system development effort initiated during the prototype SST program and to make the results of such effort available to industry. This objective has been achieved, as evidenced by data provided by this report and the referenced reports.

The flight test effort involved 53.5 hours with the flight deck equipment—EADI, MFD, and NCDU—installed at the first officer's position on a 737-100 (No. NASA 515). This test airplane was provided as Government-furnished property to Boeing by NASA Langley Research Center.

This flight test program was supplemented by a joint Boeing/DOT/NASA flight test (23.5 flight hours) of an advanced guidance and control system (AGCS). Partial information relating to this testing is given in this report. Boeing document D6-41593, *Supplemental Flight Test Report*, provides more details on this aspect of the overall NASA 515 flight test effort.

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ABBREVIATIONS

ACNORM	Normal acceleration
A/D	Analog-to-digital
ADD	Air data—DME-DME
ADEDS	Advanced electronic display system
ADIZ	Air defense identification zone
AGCS	Advanced guidance and control system
AGL	Above ground level
ALPA	Airline Pilots Association
Alt, ALT	Altitude
ARINC	Aeronautical Radio, Incorporated
ARTCC	Air route traffic control center
ATC	Air traffic control
Baro	Barometric
BIT	Built-in test
BLI	Identifier for VORTAC at Bellingham, Washington
BRP	Brake release point
CAS	Computed airspeed, calibrated airspeed
CLR	Clear
CRT	Cathode-ray tube
CWS	Control wheel steering
DA	Drift angle
D/A	Digital-to-analog
DME	Distance measuring equipment

DS	Display system
DTOGO	Distance to go
EADI	Electronic attitude director indicator
ECR	Engineering change record/request
EPH	Identifier for VORTAC at Ephrata, Washington
EPR	Engine pressure ratio
ETA	Estimated time of arrival
EXEC	Execute, executive
FD	Flight director
flt	Flight
FLT PLN	Flight plan
FPA	Flightpath angle
FPAC	Flightpath acceleration
GEG	Identifier for VORTAC at Geiger Field, Spokane, Washington
GMT	Greenwich mean time
GRP	Ground reference point
GS	Groundspeed, glide slope
GUID	Guidance
HDG	Heading
HDOT	Vertical speed
HER	Altitude error
hr	Hour
HRAD	Radio altitude
HSG	Hybrid symbol generator

IAS	Indicated airspeed
ICPS	Incremental control processor system
IDD	Inertial–DME-DME
IDV	Inertial–DME-VOR
ILS	Instrument landing system
INIT	Initialize
INS	Inertial navigation system
I/O	Input/output
IVV	Inertial VOR/VOR
IXD, IDX	Inertial–DME
IXX	Inertial
KBFI	Boeing Field International, Seattle, Washington
KMWH	Grant County Airport, Moses Lake, Washington
KPAE	Paine Field, Everett, Washington
KPDX	Portland International Airport, Portland, Oregon
KSEA	Seattle-Tacoma International, Seattle, Washington
kt	Knot
LAT	Latitude
LED	Light emitting diode
LND	Land
LOC	Localizer
LON	Longitude
LOP	Lift-off point
MCU	Manual control unit

MFD	Multifunction display
M_{MO}	Maximum operating Mach
MOUVE	Mount Vernon, Washington, waypoint
NAV, Nav	Navigation
NCDU	Navigation control and display unit
NCU	Navigation computer unit
nmi	Nautical mile
NUW	Identifier for TACAN facility at Whidbey Island, Washington, Naval Air Station
OLM	Identifier for Olympia, Washington, VORTAC
PCU	Program control unit
PDX	Identifier for Portland, Oregon, VORTAC
PPC	Path perspective command
PPOS	Present position
PPS	Path perspective situation
PTA	Planned time of arrival
REF	Reference
R-NAV	Area navigation
RNI	Radio navigation interface
rwy	Runway
SC	Speed command
SCMD	Acceleration command
SCU	System control unit
SDCC	Speed command for reference point (time box)
SEA	Seattle

SEL	Select
SID	Standard instrument departure
SN	Serial number
SPBP	Split phase bipolar
STAR	Standard terminal arrival route
TACAN	Tactical air navigation system
TAS	True airspeed
TDZ	Touchdown zone
TE	Time error
TH	True heading
TK	Track
TX	Transmitter
VAM	Visual approach monitor
VDC	Vertical deviation command
VDO	Vertical deviation only
VEL	Velocity
VGSDOT	Along-track acceleration
V_{MO}	Maximum operating velocity
VNAV	Vertical navigation
VOR	Very high frequency omnidirectional range
VORTAC	Collocated VOR and TACAN facility
VPC	Vertical path command
V+W	Vertical plus waypoint
WPT	Waypoint
XTKE	Crosstrack error (nmi)

1.0 INTRODUCTION

The ADEDS flight test configuration is shown in figure 1-1. This configuration was supplemented by the addition of the advanced guidance and control system (AGCS) to the ADEDS flight test airplane. The resulting total equipment configuration and involved redundancy levels are reflected in figure 1-2. Note that the major element of equipment added by the AGCS installation was the triple-redundant incremental control processor system flight control equipment. This triple-channel digital flight control equipment was developed under task IV of the SST Technology Follow-On Program, phase II. This equipment was integrated and installed in the ADEDS flight test airplane as part of a joint Boeing/DOT/NASA program that was performed at no cost to the DOT.

The AGCS flight test was performed in parallel and on a noninterference basis with the ADEDS flight test on the NASA 515 737-100. The parallel performance of these two flight test efforts was possible because the ADEDS was concerned primarily with terminal area operation, while the AGCS was concerned primarily with autoland. The concurrent availability of the ADEDS/AGCS equipment on the test airplane significantly enhanced the operational capability and flexibility of the flight test airplane in support of the respective flight test efforts.

Reference 1 provides a detailed discussion of the ADEDS installation in the NASA 515 airplane, and reference 2 gives a more detailed description of the results of the AGCS flight test.

During the ADEDS flight test, numerous revisions were made to the ADEDS equipment functional and software requirements. These revisions are summarized in appendix A. The baseline requirements are provided in reference 3 and represent the equipment requirements at the time of delivery from the equipment subcontractors.

The ADEDS flight test was performed between January 8 and March 15, 1974. Table 1-1 summarizes the flights conducted during this period, including those related primarily to the AGCS testing. The ADEDS flights were categorized into three basic groups: (1) engineering acceptance flights, (2) operational evaluation flights, and (3) system demonstration flights. These flight categories are outlined in detail in reference 4. Each flight is summarized in section 2.1.

Prior effort accomplished under the prototype SST program and subsequent Boeing research provided a strong data base for preparing the equipment specifications, but a considerable portion of the hardware and software remained to be translated from design/performance specifications to working equipment. The ADEDS equipment as tested during the flight test program performed within the specified requirements with some minor exceptions. Problems encountered with the installed equipment were within expected levels for development hardware and software of this type. A summary of the major problems with the equipment after airplane installation is given in section 2.1, 2.3, and 2.4 of this report. For a discussion of the simulation development and integration of the equipment prior to installation, see reference 5.

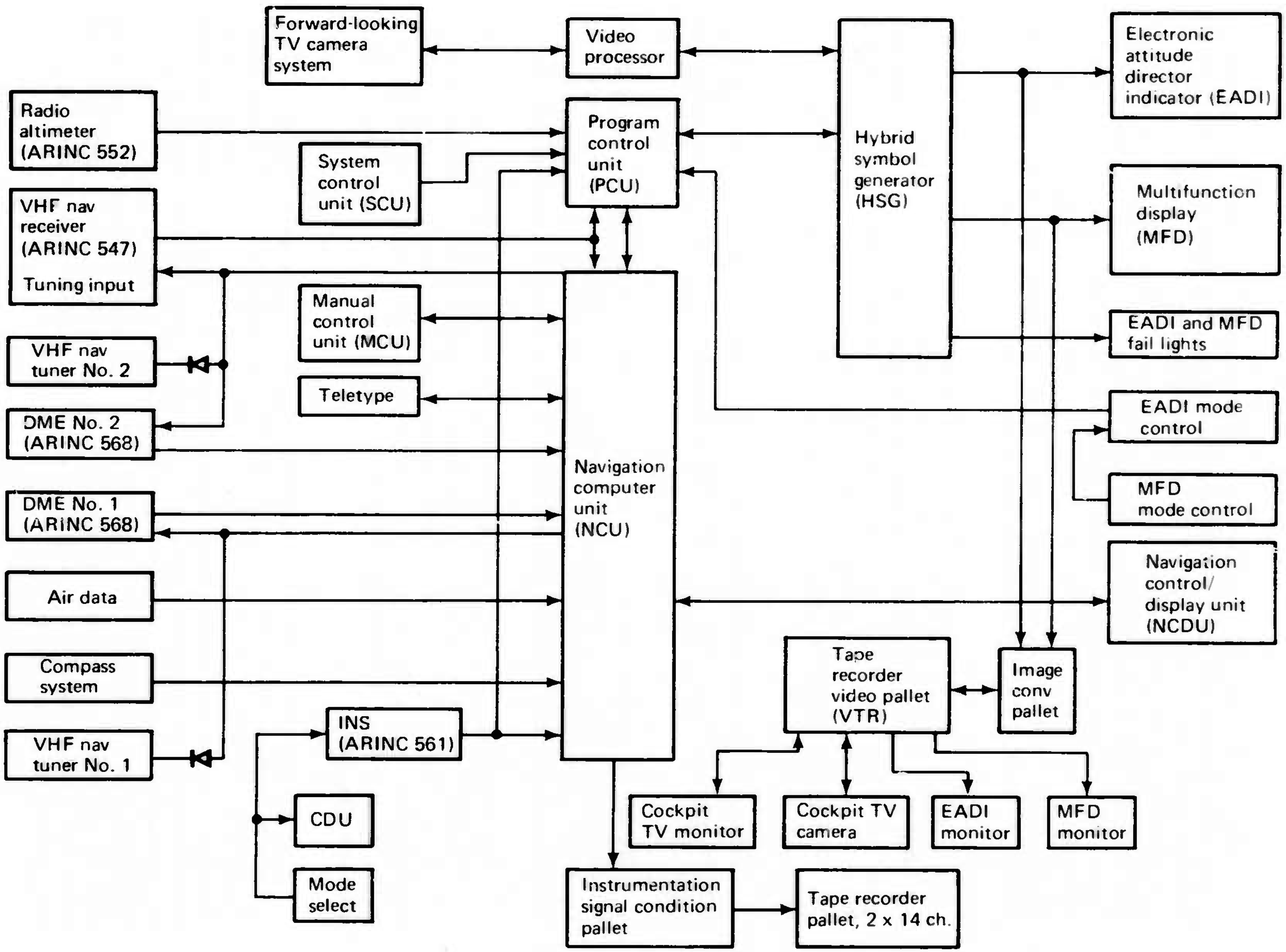


FIGURE 1-1.—ADEDS INTERFACE BLOCK DIAGRAM

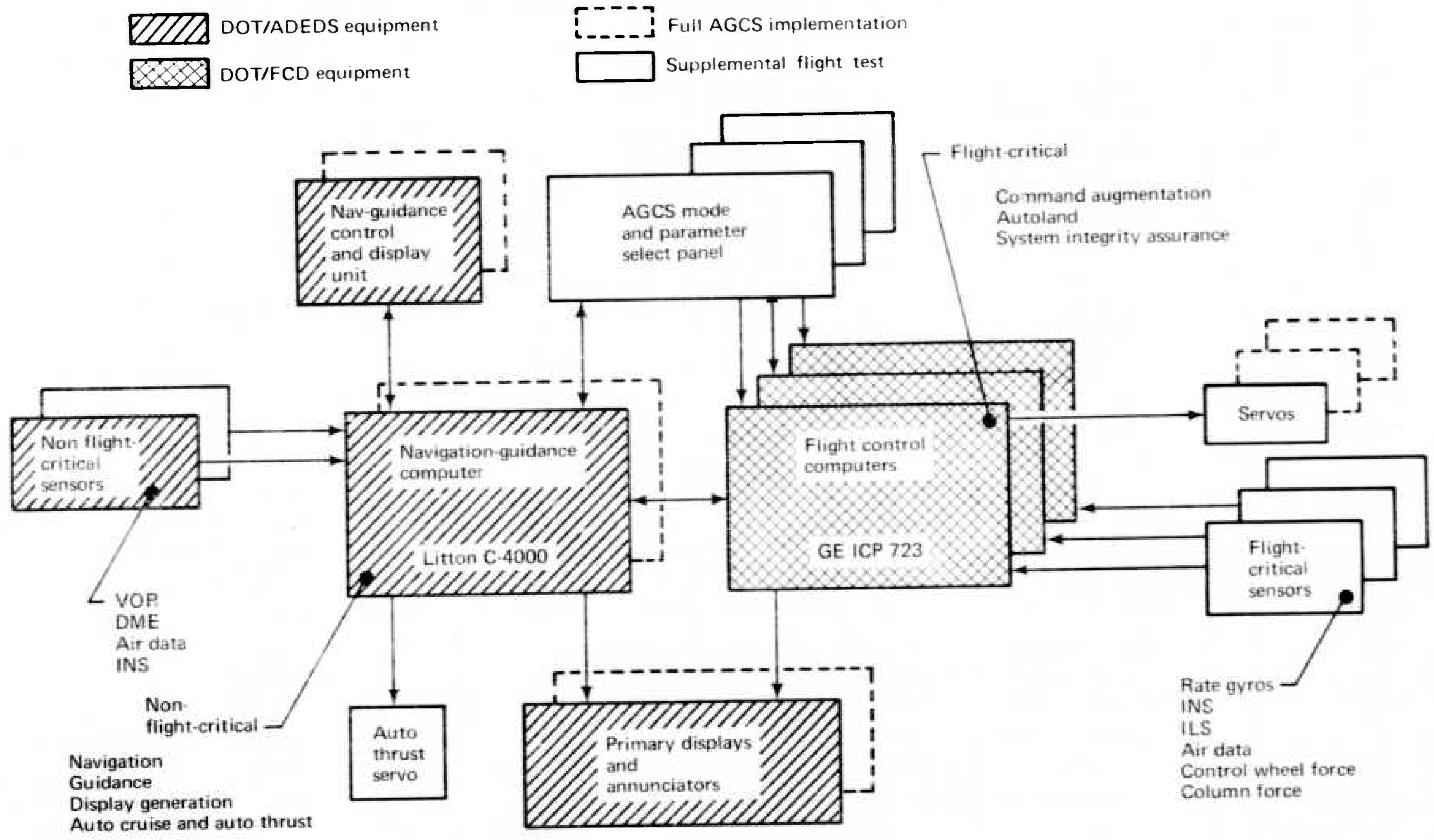


FIGURE 1-2.--SUPPLEMENTAL FLIGHT TEST CONFIGURATION

TABLE 1-1.—FLIGHT SUMMARY

Flight No.	Date	Previous airplane time	Time		Airplane time to date	Type of flight	Pilot	Landings	
			ADEDS	AGCS				Total	Auto
4-1	12/19/73	867:33	:15	:30	869:08	Airplane check		1	1
5-01	1/8/74	869:08	2:00	1:00	872:08	Engrg accp		5	5
5-02	1/11/74	872:08	2:00	:37	874:45	Engrg accp	Decker, Swain	5	3
5-03	1/18/74	874:45	2:37		877:22	Engrg accp	McPherson, Wygle	1	1
5-04	1/23/74	877:22	2:12	:45	880:19	Engrg accp	McPherson	6	3
5-05	2/5/74	880:19	:44	1:00	882:03	Engrg accp	McPherson	1	
5-06	2/8/74	882:03	3:00	1:00	886:03	Engrg accp, Op eval	McPherson, Twiggs	8	4
6-01	2/13/74	886:03	3:15	:45	890:03	Op eval	McPherson, Decker	10	5
6-02	2/14/74	890:03	2:00		892:03	Op eval	McPherson, Gannett	5	
6-03	2/15/74	892:03	2:06	:45	894:53	Op eval	Decker, Armstrong	7	6
6-04	2/18/74	894:53	:49		895:42	Op eval	Decker, Armstrong	2	
6-05	2/20/74	895:42	3:22	:40	899:44	Op eval	McPherson, Swain	10	3
6-06	2/21/74	899:45	3:57		[a]903:41	Op eval	Swain, Armstrong	9	3
6-07	2/22/74	903:41		1:48	905:29	Op eval	McPherson, Swain	4	4
6-08	2/25/74	905:29	:27	:26	906.22	Demo	Decker, Swain	2	2
6-09	2/26/74	906:22	1:22		907:44	Op eval	Decker, Twiggs	3	1
6-10	2/27/74	907:44	1:00	1:23		Op eval	Swain, Edmonds	6	3
			1:00			Engrg accp			
			:20		911:27	Demo			
6-11	3/4/74	911:27	2:48	1:00	914:15	Op eval	Swain, Edmonds	8	1
6-12	3/5/74	914:15	1:15	2:37	918:07	Op eval	Edmonds, Waddell	5	4
6-13	3/6/74	918:07	1:23	1:05	920:35	Op eval	Swain, Edmonds	6	3
6-14	3/7/74	920:35	1:01	1:00	922:36	Demo	Swain, Hunt	4	4
6-15	3/8/74	922:36	2:16	1:23	926:15	Op eval	Swain, Twiggs	10	6
6-16	3/11/74	926:15	:27	:26	927:08	Demo	Swain, Nelson	6	4
6-17	3/11/74	927:08	3:30	:25	931:03	Op eval	Decker, Armstrong	9	
6-18	3/12/74	931:03	2:58	:29	934:30	Op eval	Armstrong, Decker	8	3
6-19	3/13/74	934:30	:52	:52	936:14	Demo	Swain, McMurray	4	4
6-20	3/13/74	936:14	:22	:38	937:14	Op eval	Armstrong, Decker	4	1
6-21	3/14/74	937:14	2:50	1:36	941:40	Op eval	Decker, Armstrong	10	3
6-22	3/14/74	941:40			[a]943:14		Edmonds, Wallick	9	
6-23	3/15/74	943:15	1:20	1:13	945.47	Op eval	Armstrong, Wallick	2	
		TOTAL	53:27	23:23	[a] 78:14				

[a]Delta time is due to independent testing performed by Boeing/NASA on a visual approach monitor

The flight data recorded during the flight test effort are summarized in section 3.1. These data were recorded by the data acquisition system described in detail in reference 4. The procedure by which the raw recorded data were reduced to the form presented is reviewed in section 3.1.

One of the objectives of the ADEDS task was to provide flight test data for comparison with simulation evaluation data reported in reference 5. It must be recognized that the data samples for both these evaluations were limited in scope, and any comparisons must be properly weighted by this limitation.

The ADEDS flight test and simulation data were for a controlled test condition. Pilots were from the Boeing Flight Test organization and their prior experience with display and control concepts similar to those of ADEDS varied from extensive to very little.

The flight test data are summarized in section 3.1. A more complete set of data from which these results were obtained is contained in appendix B. For the size data sample available, the data are considered basically to show that the operational capability improvement potential that has been attributed to ADEDS-type systems can in fact be realized under operational flight conditions. The data indicate that the specific display guidance mode used does not significantly affect tracking performance. The data further indicate that display formats that combine vertical and horizontal guidance information on one display result in comparable tracking performance regardless of minor differences in symbology. The magnitude of these improved position control parameters in automatic and/or manual modes indicates that their availability in the operational environment would provide potential improvement in terminal area operations. It should be recognized that guidance modes demonstrated during the ADEDS flight test also provide potential improvements in performance during climb-out, cruise, and descent legs of the flight profile.

The supporting operational ATC environment is one of the key elements in establishing operational design adequacy and realizing the effective application of an ADEDS-type system. The scope of the ADEDS task did not include the design or analysis of future ATC environments. Plans to perform at least limited flight testing in an advanced ATC environment (ARTS III with metering and spacing) at NAFEC or Atlanta were not realized due to test site scheduling and equipment availability problems. Therefore, the ADEDS evaluation was performed totally under the control of operational ATC personnel with supporting operational procedures acceptable to the active controllers.

The ADEDS flight test was afforded outstanding support by Seattle Center, Seattle Approach Control, Grant County Tower, and Grant County Approach Control personnel. Several controllers and supervisory personnel from each facility participated in the preflight and postflight meetings. In addition, several controllers flew on the airplane during operational evaluation flights. This active participation and interest by the respective ATC facility personnel contributed significantly to the success of the ADEDS flight test effort by providing an informed basis for their comments regarding potential benefits and problems related to use of an ADEDS-type system in a future ATC environment. For a description of the flight profile catalog used to coordinate the flight test with ATC, see reference 4 and appendix C of this report.

At this point, it should be stated that the ATC support afforded ADEDS was from operational centers and towers. As such, the personnel involved were not expressing the opinion of the FAA ATC development organizations but were expressing opinions regarding their experience during support of the system test.

The consensus of controller comments appears to be that an ADEDS-type system does provide potential improvements in terminal area ATC operations. This potential improvement could be partially realized by existing or planned improvements in ATC equipment and procedures. Effective realization of the full potential will require additional parallel analysis and development of both airborne and ground equipment and proedures. This development would necessarily be performed in an environment where the ATC equipment and procedures could be altered as were those of the ADEDS airborne equipment. Such variations are not possible in an operational environment.

It should be noted that the potential improvements are for an ADEDS-type system. The formal definition of design and performance requirements of the final system is considered part of the preceding suggested development effort.

Another major consideration affecting the potential application of an ADEDS-type system is the ability of the flightcrew to effectively utilize its capability without compromising safety. There are two basic considerations that must be given to any interpretation of flightcrew comments regarding the ADEDS operational design adequacy. First, the data sample of pilots is small and, therefore, somewhat subjective. Second, the ADEDS operational design was in conformance with a development effort that required flexibility to evaluate a broad spectrum of operational modes and, therefore, included numerous requirements that would not be present in a production system. These requirements often resulted in less than optimum system/crew interfaces.

The primary flightcrew comments were obtained from the controlled ADEDS group of four pilots. However, comments were also obtained from numerous Government, airline, and supporting Boeing test pilots. Flightcrew comments can be categorized in two major groups: (1) comments regarding the future operational application; i.e., post-1980, and (2) comments regarding application to contemporary operational usage. For the most part, pilot comments were related to one of these groups depending upon the respective pilot background, experience with experimental systems, and current job description. The ADEDS task was performed on the basis of potential future application and was, therefore, primarily interested in comments fitting into the first group.

In summary, the flightcrew comments were as follows:

1) The simulation effort was invaluable in the development and preflight checkout of flightcrew procedures.

2) CRT displays provide an ideal medium for presenting situation/command/status information to the flightcrew. This is particularly true for ADEDS-type systems that encompass advanced navigation/guidance/flight control equipment, supporting sensors, and procedures.

3) The flight test clearly demonstrated that 3D/4D operations are feasible from the flightcrew/airplane viewpoint.

A more detailed discussion of the operational design of the ADEDS is provided in section 3.2.

In conclusion, it is considered appropriate to make some observations regarding the ADEDS task from the viewpoint of what should be done differently or additionally for follow-on programs. There are two primary items that are identifiable as recommended elements of follow-on programs:

1) The navigation computer should include an algorithm for providing ILS computation to supplement INS updating by VOR/DME during approach and landing. This capability would offset the navigation system degradation seen during ADEDS flight test approaches where adequate VOR/DME signals were not available during the final low altitude approach and landing. This signal would not be used by the autoland system.

2) The operational design of a 1980 to 1990 system should include a data link system. This portion of the ground-air and airborne system interface is considered a key element to the ultimate realization of the full potential of an advanced technology system for commercial airplanes. Future programs of this type should include provisions for the full evaluation of data link.

Additional comments regarding suggested considerations for inclusion in any follow-on effort are included in section 3.0 of this report.

A summary recommendation regarding follow-on ADEDS-type programs would be that such programs be based more closely upon an operational configuration of hardware, including basic consideration to the projected ATC environment and operational procedures. The ADEDS flight test and simulation efforts have provided valuable data toward the definition of such a system. The ADEDS equipment will continue to be flown in the NASA Research Support Flight System at Langley Research Center during the next several years. This additional opportunity to further isolate specific design and performance criteria for the operational system, particularly the ATC portion, should be strongly considered as a portion of the FAA participation in this program to the continued development of commercial aviation advanced system operational concepts that will provide improvements in traffic density, noise abatement, and economy with (as a minimum) no degradation in safety standards.

2.0 FLIGHT TEST REVIEW

The following paragraphs provide a more detailed review of the ADEDS flight test program. This review includes: (1) a summary description of each flight profile and related system performance comments, (2) a navigation system performance summary, (3) an INS performance summary, and (4) a display system performance summary. Differences in times between the following flight descriptions and those given by table 1-1 are a result of the inclusion of taxi and holding for takeoff clearance in the following descriptions.

2.1 FLIGHT SUMMARY

Flight 5-1, January 8, 1974

This was the initial flight dedicated to ADEDS engineering acceptance testing. The first flight on December 19, 1974 was primarily for the purpose of checking the basic airplane systems. The airplane had not flown since mid-August 1973 and during this time, an engine was changed on the airplane.

Departure from KBFI was via standard SID BEN13R. Prior to autoland testing at KPAE, navigation system accuracy, display symbology quality, and various airplane control modes were evaluated. The initial approach to KPAE was via standard STAR CAN16 with transition to autoland for a touch and go. A total of three touch-and-go autolands were accomplished, with a fourth being aborted.

The en route segment from KPAE to KBFI was flown 4D coupled with an autoland being accomplished at KBFI.

Flight 5-2, January 11, 1974

The purpose of this flight was to continue the ADEDS acceptance testing. Departure from KBFI was via noise-abatement SID SUM13R. En route to KMWH, 2D, 3D, and 4D guidance options were checked as well as the autopilot modes for TK, ALT, FPA, and CAS select CWS. A 4D transition to autoland was made at KMWH via curved, descending, decelerating STAR EPH32R. A racetrack course was entered for the performance of three touch-and-go autolands. The return to KBFI included checking various system modes as performed on the en route segment to KMWH. In addition, a holding pattern was executed at the Ephrata VOR. The approach to KBFI was via two-segment, straight, decelerating STAR ENU31L, with transition to autoland to 200 ft where the pilot disconnected and completed the landing in the manual mode.

System Performance Comments

Navigation

- NCU, OK.
- NCDU 002. Keyboard hangup prior to taxi, cycling of key "H" cleared it.
- NCDU 003. Keyboard hangup after power transient. Recycling 400 Hz and 28 V twice cleared it.

- INS, SN 406, OK.

- INS, SN 094, 7.5 nmi/hr. Navigation error caused aborted autoland at Moses Lake and necessitated landing to realign.

The navigation software performance was excellent (<0.1-nmi error at KBFI), but update mode annunciation problems occurred during part of the flight; i.e., IXX when DME was good; also, impossible mode IVV was seen on the MFD. Navigation mode was therefore uncertain on the way to KMWH. After the stop at KMWH for INS No. 1 realignment, the IDD, IDX modes worked OK on the flight back. IDV was seen occasionally.

Displays—Numerous transmission errors indicated by the PCU and zero data were again detected on EADI bus, causing flickering stroke symbology. Jump in the MFD picture indicated periodic bad transmission.

All EADI functions looked reasonable except for the flickering caused by the EADI bus I/O problem. Star and circle had gliches when limited. Runway symbology was still bad since no corrections had been added since the last flight.

A 1-sec lag filter was added to the MFD ACNORM at KMWH. Thereafter, trend vector looked good. New annunciation of NAV mode and GS was acceptable but too bright. Alt Range symbol disappeared off the bottom of the screen.

Flight 5-3, January 18, 1974

The purpose of this flight was to continue testing, leading to engineering acceptance of the ADEDS. Departure from KBFI was via noise-abatement SID SUM13R. Following completion of the SID, transition to a square test pattern was executed for navigation system accuracy checks. This pattern was followed by a figure 8 pattern (sid octal) flown over the Seattle area at 21,000 and 31,000 ft with DME constant radius turns. Testing during the above flight profile included 2D, 3D, and 4D modes plus variations of autopilot CWS modes, including altitude hold, track select, flightpath angle select, and computed airspeed select. The ADEDS testing included navigation accuracy checks, turn commands with 179° track error, programmed groundspeed changes, curved trend vector, altitude/range limiting, and navigation system autotuning.

A 4D approach was made to KPAE via curved, descending, decelerating STAR EDM16 with transition to autoland for a touch-and-go landing. Due to weather conditions, the remainder of this test was canceled and a direct flight to KBFI was made.

System Performance Comments

Navigation

- Bombed computer memory occurred when ground power lost during bus transfer.

- Computer autotune outputs were suspected of being in error.

- No NCDU problems; TV monitor of the pallet NCDU occurred for the first time.

- GUID software offset XTKE in 2D may be due to ICPS.

- Autothrottle overboosting occurred due to not compensating for pilot's hand on the throttle.

- VGSDOT software patch for differentiating GS in NCU was unsuccessful.

- Autotuning and Nav update from station 2 could not be achieved, probably because of frequency checks not being valid. IDV mode was achieved using manual tuning from the cockpit.

- Early in the flight, DME data were being received from both DMEs, but later No. 2 data were not received.

- The flight was flown most of the time in IDX with SEA manually tuned.

INS

- Disastrous results. Schuler errors that resulted in residual ground speeds of 8 kt (SN 406) and 23 kt (SN 094) caused autopilot trips.

- INS No. 2 (SN 406) again accepted wind angle as runway heading.

Nav Checks

Time	WPT	C-4000 DME		REF DME
13:24	CHARLY	SEA	46.88	47.03
		BLI	71.49	71.10
	TUMWR	SEA	38.55	38.58
		OLM	5.45	5.50
	BROOK	OLM	28.81	28.79

	LAT	LON		
KPAE	N 47°55.4′	W 122°17.0′		
KBFI	N 47°32.3′	W 122°17.1′	N 47°32.1′	W 122°18.3′

Displays

- No interface problems apparent during the entire flight. Bus 3 data were being lost prior to taxi. Proved to be data dependent because OK in NCDU test mode.

- Prior to flight test, jitter appeared on MFD, but it cleared up. Jitter was induced after a power transient.

- EADI. FPA and star and circle were noisy in X dimension during turbulence; filter was required.

Unresolved sum check error in bank 4 must have been due to an error on the punched tape. (Sum check differed by 00000400 between listing and location 734.)

- EADI runway centerline limiting again was no good. Runway was not seen in the limited condition.

Flight 5-4, January 23, 1974

Departure from KBFI was via noise-abatement SID SUM13R through 11,000 ft en route to a cruise altitude of 17,000 ft to KMWH.

En route, basic INS, navigation accuracy, and autotuning checks were made. This was followed by a reversionary navigation mode check and autothrottle checks and adjustments.

Following a series of CWS checks, adjustments were made in flight to further reduce column activity noted on previous flights. Limit checks were made on wheel and column detents and coupled autopilot bank angle. Autothrottle limit checks were performed for both maximum EPR and V_{MO}/M_{MO}.

A 4D approach was made to runway 32R at KMWH, using 3D-coupled path modes and manual throttle control. This control was a curved, descending, decelerating path beginning at 11,000 ft. The R-Nav to ILS transition was successfully accomplished, and automatic flare and touchdown were accomplished with a time error of less than 1 sec. Variations in wind direction and velocity during this approach were severe, ranging from 60+ kt tailwind component at 11,000 ft, through a 40+ kt headwind component at 4,000 ft during the descent, to a 5 kt crosswind at touchdown.

Three additional touch-and-go autolands were executed with two of these going through touchdown. The third was terminated at the middle marker due to tower instructions for traffic avoidance. The second approach encountered 747 wake turbulence at 60 ft AGL; the autoland system corrected for the vortex disturbance and flared to a successful touchdown slightly to the right of centerline.

The return to KBFI was made 4D coupled. A curved, descending, decelerating approach was made to runway 13R. Coupled mode operation was terminated at the outer marker due to low ceilings and turbulence.

System Performance Comments

Navigation

- A software patch was necessary to protect against a faulty power interrupt routine whereby the power interrupt was controlled by mask bit 22 (time interrupt) instead of mask bit 24 in the interrupt mask word LOC 23.

- Frequency commons for autotune were deliberately shorted together to ensure the autotune function was operative. An ECR was incorporated prior to flight to reduce the frequency common sink resistor to 1 K instead of 3.3 K. A problem still existed with the relay contact resistance in the airplane accessory box.

- Key "H" on NCDU SN 003 was replaced prior to flight. No further problems were experienced.

- Top two rows of keys on NCDU SN 002 were much less brightly illuminated than the rest of the keyboard.

- IDD logic had a hole in it. A 10-sec delay between switching DME No. 2 stations was patched in for this flight. The first 2-1/2 hr of flight were OK in IDD and ADD modes. The problem occurred when IXD mode was annunciated even when DME No. 1 was good; i.e., the same station was accepted as DME No. 2. The mode later switched to IDX but never to IDD.

- Other software-related incidents included a 9° heading change when ADD was selected. Airplane compass was suspected. Also, the Yakima (YKM) DME was frequently rejected by autotune for no apparent reason.

INS—Three new INS systems were used. SN 748 modified to provide acceleration resolution of 1/64 ft/sec replaced the rejected system SN 039. Two unmodified INS, SN 753 and 766, were used in positions A and C, respectively. Performance summary was as follows:

	INS SN	Δ LAT (min)	Δ LON (min)	Δ GS (kt)
Nav time: 7 hr	748	0.6	1.0	3
Flight time: 3 hr	753	1.5	2.6	1
	766	0.1	0.2	3

Displays

- Few errors in transmission were detected in flight. After 2 hr 40 min of flight, the PCU had detected the following bad transmissions:

MFD	bus 1	10 errors
MFD	bus 2	12 errors
EADI	bus	0 errors

- The blinking EADI symbology experienced on previous flights had occurred recently only with the waypoint TAG. This was isolated as a display problem.

- The EADI FPA symbol was in error when on the runway and shortly after takeoff. This was probably due to errors in the HDOT calculation.

- The MFD time box moved off the path during the entire leg from APDLN to SIMCE, and an extra line appeared on the other side of the path.

- Conics on the MFD flight plan path were occasionally wrong.

- MFD outer marker symbol angle was intermittently in error.

- No flare discrete was apparently received because no blinking of FPA was observed on the EADI.

- EADI runway symbology was wrong in four ways:

    1) Step position changes when turning

    2) Centerline errors when limited

    3) Runway outline errors when limited

    4) Runway centerline appeared later than runway

Flight 5-5, February 5, 1974

The purpose of this flight was to continue engineering acceptance testing of ADEDS. Departure from KBFI was via standard SID WAT13R en route to the test location over the North Cascade mountains. During the first circuit around the rectangular test path, the autothrottle operation was unsuccessful. This problem was caused by the No. 1 throttle sticking at approximately 1.4 EPR for about 3 min. During this period, problems were also encountered with the display system memory parity errors. One additional circuit of the test path was made after clearing the throttle condition, but continued display problems were of such a nature that further testing was cancelled. Further autoland tests were also cancelled due to the unknown cause of the throttle problem.

The return to KBFI was direct.

System Performance Comments

Navigation

- Changing of the SPBP transmitter on February 4, 1974, apparently cured all MFD I/O problems.

- Two NCDU keyboard hangups were experienced prior to flight and cured by cycling power.

- Problems with the basic airplane throttle system aborted all checkout of autothrottle functions.

- Nav error at the end of flight was excessive.

    1) 0.25 nmi XTKE at touchdown

    2) $\left.\begin{array}{l}\Delta \text{LAT}-0.3' \\ \Delta \text{LON}-0.8'\end{array}\right\}$ at the ramp

This error is suspected to be due to IDV mode operation for a short while during the approach.

- Baro inertial loop. HDOT errors on the runway caused up to 10° of FPA error on the EADI. The symptoms are as follows:

  1) Acceleration to "Takeoff" causes negative FPA.

  2) Deceleration at "Landing" causes positive FPA.

  3) Unaccelerated taxiing does not cause error.

  4) VACCEL in the C-4000 statically agrees with ICPS analog $\ddot{H}$ from the INS; i.e., LOC 177 0.25 ft/sec^2 = 20 mV at ICPS

  5) HDOT ramp of 3 ft/sec^2 have been recorded while VGSDOT max is 5 ft/sec.

  6) Traces of VACCEL from the C-4000 are noisy and do not follow analog recordings at the ICPS.

  Tentative conclusion is that the C-4000 A/D converter may be the cause.

- Runway centerline symbology for the EADI is in error when the slope approaches zero.

- Star and circle had errors in the limited condition, probably due to overflows.

INS—All three systems performed extremely well. Performance summary was as follows:

		INS SN	Δ LAT (min)	Δ LON (min)	Δ GS (kt)
Nav time:	2.75 hr	406	-0.6	+1.0	1
Flight time:	1.9 hr	748	-0.4	+0.21	2
		766 (unmodified)	-0.1	+0.1	0

Displays

- Memory parity errors caused several losses of displays and eventually caused permanent loss of track tape on the MFD and displacement of FPAC on the EADI.

- TV worked OK throughout the flight.

- The new LOC/GS deviation symbol was used for the first time.

- No software problems.

Flight 5-6, February 8, 1974

Departure from KBFI was via departure turn SID BUR13R en route to KPAE where a curved, descending, decelerating STAR EDM16 was used for approach, and then transition to a manual flight director approach was accomplished, followed by a touch and go. En route to a test path in the North Cascades, autopilot and navigation mode checks were performed; then, for the approach to KMWH, curved, descending, decelerating STAR SIP32R was used, followed by transition to an autoland touch and go. Following two racetrack course autolands, a full stop was made for refueling. This marked the end of the engineering acceptance testing and the beginning of the operational evaluation testing for ADEDS.

Using flight director guidance, the following sequence of SIDs and STARs were flown at KMWH: close-in turn SID POW32R–straight, decelerating STAR CON32R, standard SID POT32R–curved, descending, decelerating STAR SIP32R. Departure from KMWH was via two-segment SID COR32R using flight director guidance, and the approach to KBFI was via two-segment, straight, decelerating STAR ENU31L.

System Performance Comments

Navigation

- NCDU SN 002 had intermittent problem with "K" key.
- Active NCDU was transferred to the cockpit by wiring change in the XI matrix box.
- DME No. 1 autotuning was suspected. DME No. 1 and No. 2 frequency commons were currently tied together at the matrix. The No. 1 DME was suspected and apparently failed during flight.
- The wind calculation had 11-kt resolution and did not switch over to CAS.
- The MFD trend vector had an erroneous line.
- Runway symbol loaded too narrow.
- The MFD ratcheted when turning on the ground.
- C-4000 bulk data must be changed so that all waypoints are referenced to VORTAC.

INS–Velocity inconsistencies up to 30 kt were detected in flight in the No. 2 system SN 748. This adversely affected NCU navigation and caused autopilot first failure indications.

Time	HDG	INS No. 1	INS 2 - 1	INS No. 2	INS 2 - 3	INS No. 3	NCU	NCU-INS NO. 2
				Velocity (kt)				
11:57	270	467	-29	438	-28	466	–	–
12:02		400	0	400	-1	401	–	–
12:03		393	-7	386	-8	394	369	-17
12:05	160	449	0	449	0	449	445	-4
12:10		354	-3	351	-6	357	355	+4
12:13.30		390	-9	381	-7	388	383	+2
12:17		384	-12	372	-7	379	–	–
12:19		365	-15	350	-14	364	356	+6
12:20	116	361	-16	345	-14	359	354	+9
12:22	95	349	-16	333	-17	350	347	+14
12:24	95	304	-14	290	-15	305	306	+16
12:26		246	-9	237	-6	243	246	+9
12:29		215	-7	208	-6	214	198	-10
12:31		210	0	210	0	210	203	-7
12:33		193	-7	186	-10	196	197	+11
12:34		196	-5	191	-3	194	–	–
12:35		175	-5	171	-2	173	172	+1
12:36		174	+1	175	+1	174	–	–
12:37		188	+1	189	-1	190	187	-2
12:38	342	136	+1	137	+1	136	–	–
12:43		172	-3	169	-1	170	170	+1
12:48		192	-3	189	-5	194	189	0
12:50	283	183	-11	172	-9	181	173	+1
12:52		158	-10	148	-9	157	150	+2
12:54	350	155	0	155	-7	162	–	–
12:56	342	128	-3	125	-4	124	128	+3
13:05	162	132	+1	133	+2	131	132	-1
13:06	275	145	-8	137	-6	143	–	–
13:07	340	158	-2	156	-3	159	157	+1

INS No. 1 (SN 406) and INS No. 2 (SN 748) were interchanged at KMWH. No large discrepancies in GS were noted thereafter, but a large (>1 nmi) navigation error was noticed during approach to KBFI.

Terminal accuracies of the INS were as follows:

	INS SN	Δ LAT (min)	Δ LON (min)
KBFI to KMWH			
Nav time: 4.7 hr	406	-3.8	+0.5
Flight time: 2.3 hr	748	-1.4	+0.2
	766	+1.1	+4.0
	NCU	-0.3	+0.2

	INS SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
KMWH to KBFI				
Nav time: 3.0 hr	406	-0.6	+0.2	4
Flight time: 2.5 hr	748	-1.3	-3.7	2
	766	+2.1	-1.5	1
	NCU	-0.6	-0.2	0

Displays

- No software problems
- Memory parity problems throughout the flight resulted in EADI mode control loss, EADI pitch and roll invalid indication, and total display loss.
- Power supplies were suspected of improper operation.

Flight 6-1, February 13, 1974

Departure from KBFI was via departure turn SID BUR13R, followed by a 4D coupled flight to KMWH. The approach to KMWH was via curved, descending, decelerating STAR SIP32R from which a transition to an autoland for a touch and go was successfully accomplished. This was followed by a racetrack course flown for three additional autolands. The final autoland was a full stop for preparation for ADEDS evaluation flights from KMWH.

The initial ADEDS evaluation flight departure was via departure turn SID GRA32R with the approach via straight, decelerating STAR CON32R. This flight was accomplished using vertical plus waypoint guidance. The second flight departure was via SID POW32R, a close-in turn, using vertical plus waypoint guidance. The approach was via STAR SIP32R, a curved, descending, decelerating path, using vertical plus waypoint guidance. The third flight departure was via SID GRA32R, a departure turn path, using path perspective command guidance. The approach was via STAR CON32R, a straight, decelerating path, using path perspective command guidance. The departure for the fourth flight was via SID EPH21, a close-in turn, using path perspective command guidance; and the approach was via STAR SUL32R, a two-segment approach, using path perspective command guidance.

The departure from KMWH for KBFI was via SID POW32R, a close-in turn, in the coupled mode. The en route segment to KBFI was 4D coupled and the approach to KBFI was aborted by ATC. This was followed by reclearance for an autoland into KBFI.

Results for this flight were significantly enhanced over the previous two by the installation of improved display memory electronics boards that provided proper memory operation without parity errors encountered on previous flights.

System Performance Comments

Navigation

- Due to a bad connection somewhere, a problem occurred with the MCU prior to flight.
- There were no problems in flight.
- The active NCDU was in the cockpit.
- EADI. Pitch flight director gain was reduced by one-half at KMWH.
- Deficiencies observed during flight were as follows:

    1) EADI. Star position jumped when limited and in a turn.

    2) EADI. FPA symbol had a lag at takeoff.

    3) EADI. Flight director and circle command were noisy (suspected because of unmodified INS resolution).

    4) EADI. Runway:

        a) Centerline upwards

        b) Runway X, Y limits too small

        c) Runway outline error during takeoff when symbol should have disappeared

    5) MFD. Track angle ratcheting occurred when turning at high rate on the ground. Update rate to the display was approximately 1/sec; it should be 20/sec.

    6) Nav. Position changes on the ground were caused by INS Schuler velocities.

INS

- SN 094 had excessive Schuler velocity errors and a 0.4 true heading error with respect to the other INS.
- SN 766, unmodified, had adverse effects on EADI symbology.

The systems were realigned at KMWH. Performance summary was as follows:

	INS No.	Δ LAT (min)	Δ LON (min)	Δ GS (kt)
KBFI to KMWH				
Nav time: 4.0 hr	1	-1.9	-1.7	1
Flight time: 3.0 hr	2	+0.5	+0.9	2
	3	-0.7	-1.3	7
	NCU	-0.1	-0.7	0
KMWH to KBFI				
Nav time: 2.6 hr	1	-1.1	-2.2	2
Flight time: 2.3 hr	2	+0.6	-2.0	1
	3	-1.1	+0.4	8
	NCU			0

4D time error summary was as follows:

Evaluation (MWH)	
SID GRA32R	-:01
STAR CON32R	+:08
SID POW32R	:00
STAR SIP32R	+:01
SID GRA32R	-:06
STAR CON32R	+:02
STAR SUL32R	:00
SID POW32R	-:05

Displays

- New memory sense amplifiers were installed.
- No memory parities were detected in flight, but there was one occurrence prior to flight.
- Numerous Nav interface errors were detected. (Note: there had been none on previous flights.)
- Intermittent problems with tag jumping occurred prior to flight.
- No software problems occurred.
- The new manual control ILS symbol (black cross) was mechanized.

Flight 6-2, February 14, 1974

Departure from KBFI was via departure turn SID BUR13R en route to KPAE where an approach was made via curved, descending, decelerating STAR EDM16. Both of these flight segments were flown using vertical-deviation-only guidance. Operational evaluation flights were then flown out of KPAE. Departure for the first flight was via standard path SID LOF16 using vertical-deviation-only guidance and an approach using STAR MOU16, a two-segment path, with vertical-deviation-only guidance. Departure for the next flight was via close-in turn SID GLE16 with vertical-deviation-only guidance, and the approach was via standard path STAR ARL16. The fourth flight's departure was via standard path SID LOF16 using path perspective command guidance. The approach was via curved, descending, decelerating STAR EDM16 using path perspective situation guidance.

Departure from KPAE for KBFI was via close-in turn SID GLE16 using path perspective situation guidance. The en route portion of the flight to KBFI was 4D coupled with the automatic coupled approach via two-segment, straight, decelerating STAR KIT13R with transition to an autoland.

System Performance Comments

Navigation—No hardware problems existed.

- The bad INS SN 748 and the length of time in IXD mode due to inadequate DME coverage contributed to large errors at touchdown (XTKE = 0.35R, 1.15R, 0.46L, 0.71L, and 0.63R). Several software changes will be incorporated to alleviate this:

  1) Decrease geometry restriction for station 2 to 30° > bearing > 150° (was 45° and 135°).

  2) Increase the second station search to four stations (was two).

  3) Retain velocity correction terms for 5 min (was 15 sec).

  4) Use INS SN 406 in No. 2 position.

  5) Add Whidbey Island (NUW) to bulk data.

- Wind calculation was in error on the ground and at low speed due to TAS stopping at 160 to 180 kt. (Software limit is set to 150 kt.) It was suggested that entering a SID on the NCDU will clear out ATC and FLT PLN will be incorporated.

INS

- INS SN 748 showed large groundspeed discrepancies during turn as experienced on flight 6-1. Maximum observed error was 17 kt at 90° heading. This system was rejected after this flight.

- INS SN 094 had an 8-kt groundspeed error during a stop at KPAE and showed up to 9-kt discrepancies in flight.

- Performance summary was as follows:

	INS No.	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
Nav time: 4.5 hr	1	-0.4	+0.1	1
Flight time: 2.3 hr	2	-0.9	-0.9	1
	3	-0.5	+0.3	8
	NCU	-0.3	-1.2	0

4D time error summary was as follows:

En route	
KBFI to KPAE	+:01
KPAE to KBFI	+:24
Evaluation (KPAE)	
SID LOF16	:00
SID LOF16	-:06
STAR EDM16	+:10

Displays

- Problems at power-on delayed the flight; they were eventually cured when memory was reloaded.
- No new problems occurred.
- There were no software problems after reload.
- FPA on the EADI was bad on the ground.
- HRAD limit was 1 ft and will change back to 5 ft.
- SCMD (Acceleration Command) was noisy at times.
- DA errors due to bad navigation were obvious on the EADI.

Flight 6-3, February 15, 1974

Departure from KBFI for KMWH was via departure turn SID BUR13R in the automatic mode. The en route portion of the flight was performed 4D coupled with the approach to KMWH via curved, descending, decelerating STAR EPH32R, followed by successful transition to an autoland.

The first ADEDS evaluation flight departure was via close-in turn SID POW32R using flight director guidance. The approach was via two-segment STAR COR32R, also using flight director guidance. The second operation evaluation flight departure was via departure turn SID GRA32R using flight director guidance, followed by en route to KPAE 4D coupled. The approach to KPAE was via standard path STAR ARL16 using flight director guidance. A touch-and-go autoland was made at KPAE followed by a 4D-coupled flight to KBFI, with transition to autoland.

System Performance Comments

Navigation

- Cell 377 cannot be used for software as it is written into by DMA.
- No software problems were reported.
- Navigation accuracy was OK since the INS No. 2, SN 748, nad been replaced by SN 406.
- XTKE at touchdown were 0.13L, 0.06L at KMWH, 0.35L at KPAE and 0.45R at KBFI.

No software changes occurred since last flight except the localizer and glide slope data in the NCU were recorded.

INS–Miscellaneous GS difference observed in flight was 4 kt. Performance summary was as follows:

INS No.	SN	Δ LAT (min)	Δ LON (min)	Δ GS (kt)
1	766	0.1	0.1	1 (peaked at 2)
2	406	-4.3	-1.0	2 (ramped to 6 after 1 hr)
3	094	-1.0	-1.7	2 (peaked at 6)

Displays–There was no change in status. The following problems were still occurring:

- Memory parity errors occasionally
- Displaced EADI at turn-on
- Intermittent loss of calligraphics in EADI
- Unstable text position (Y-axis jitter) on the MFD at initial turn-on
- Symbols not closing correctly

Flight 6-4, February 18, 1974

Departure from KBFI was via departure turn SID BUR13R using flight director guidance. The flight to KPAE was coupled via radar vectoring with the approach via standard STAR CAN16, terminating in a transition to an autoland and full stop. Due to weather conditions, additional testing was cancelled, and a direct flight from KPAE to KBFI was made 4D coupled with an autoland at KBFI.

System Performance Comments

Navigation System

- There were no hardware problems.
- Navigation performance was improved using station NUW. XTKE errors at touchdown were 0.17R and 0.08L.
- Mode panel 3D amber flashing was intermittent.
- EADI pitch flight director was noisy at low speeds.
- LAND mode annunciation came up wrong on NCDU.
- Request was made that NCDU NAV DATA 1 page errors not be blanked at the end of the path.

INS—SN 094 continued to show large Schuler errors. Performance summary was as follows:

	INS No.	Δ LAT (min)	Δ LON (min)	Δ GS (kt)
Nav time: 2.5 hr	1	0.4	0.7	1
Flight time: 0.81 hr	2	-0.3	0.7	2
	3	0.4	1.4	11
	NCU	0	0	0

Flight 6-5, February 20, 1974

Departure from KBFI en route to KMWH was an automatic departure turn SID BUR13R. En route to KMWH numerous checks were made on autopilot modes during coupled flight. The approach to KMWH was via curved, descending, decelerating STAR EPH32R with automatic transition to an autoland. A racetrack course was established to perform three additional autolands. After the last autoland, a full stop was made in preparation for the following ADEDS evaluation flights.

The first flight departure was via noise abatement SID DOU32R using vertical-deviation-only guidance, and the approach was via standard STAR WIN32R using flight director guidance. The second flight departure was via noise-abatement SID DOU32R using path perspective situation guidance, and the approach was via standard STAR WIN32R using path perspective situation guidance. Departure for evaluation flight three was via close-in turn SID MAE14L using vertical plus waypoint guidance, and the approach was via curved, descending, decelerating STAR SIP32R using vertical plus waypoint guidance. Departure for flight four was via standard SID POT32R, and the approach was via two-segment STAR COR32R. Both of these used flight director guidance.

Departure from KMWH for KBFI was via noise abatement SID DOU32R using flight director guidance. The en route segment was flown 4D manual with the approach to KBFI via curved, descending, decelerating STAR TIG13R with transition to autoland for landing at KBFI.

System Performance Comments

Navigation

- No hardware problems occurred.
- Navigation was satisfactory with 30° bearing limitation, and 10-min velocity correction retention.
- Four-station search was still not operative.
- Recorded XTKE at touchdown were 0.15L, 0.24L, 0.15L, 0.10L, 0.05L, and 0.14L.
- Nav autotune problem developed twice with IDX mode, and Retune Navaid 2 message when station 2 was good. Manual tuning via NCDU of the same station cured the problem. Also, IXX mode was achieved instead of IDX when overflying station 2.
- MFD ratcheting on ground was OK with new INS software giving true heading 5°/sec output rate.
- Autothrottle was very active when flying manually.

INS–New software (TH at 5°/sec) was loaded to all three systems, and no new problems developed. Systems were realigned at KMWH. Performance summary was as follows:

	INS No.	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
KBFI to KMWH				
Nav time: 4.5 hr	1	-0.7	+6.1	4
Flight time: 4.1 hr	2	-1.3	+1.6	2
	3	-0.6	-2.0	5
	NCU	-0.1	-0.4	0

	INS No.	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
KMWH to KBFI				
Nav time: 2.0 hr	1	0.4	-1.2	1
Flight time: 1.5 hr	2	0.3	0.2	1
	3	0.4	-1.7	3
	NCU	0.1	0.2	0

4D time error summary was as follows:

En route:	
KBFI to KMWH	+:03
KMWH to KBFI	+:02
Evaluation:	
SID DOU32R	+:01
STAR WIN32R	+:05
SID DOU32R	-:43
STAR WIN32R	+:03
SID MAE14L	+:01
STAR SIP32R	+:08
SID MAE14L	+:01
STAR SIP32R	+:12
SID POT32R	-:19
STAR COR32R	+:06

Displays

- Startup symbology jitter—parity errors and brief shutdown in flight occurred.
- All EADI symbols using pitch angle in the display system showed intermittent jitter. A/D problems were suspected.
- The pilot did not like the scale displays of LOC and GS, but it will be retained for further evaluation.
- EADI runway symbology repeatedly went wrong in a takeoff situation.

Flight 6-6, February 21, 1974

Departure from KBFI was via an automatic SID BUR13R with the en route segment to KMWH being flown 4D coupled with the automatic approach to KMWH via curved, descending, decelerating STAR EPH32R. An autoland was made with a full stop in preparation for performing the following ADEDS evaluation flights.

The initial flight departure was close-in turn SID POW32R, and the approach was via two-segment STAR COR32R with both segments using vertical-deviation-only guidance.

The second flight included the same SID/STAR combination, but path perspective situation guidance was used. Similarly, the third flight included the same SID/STAR combination, but path perspective command guidance was used. The fourth flight departure was via departure turn SID GRA32R using flight director guidance, and the approach was via two-segment STAR CON32R also using flight director guidance. The fifth flight departure was via close-in turn SID POW32R, and the approach was via two-segment STAR COR32R with both segments using flight director guidance. The sixth flight included the same SID/STAR combination as flight five, but vertical plus waypoint guidance was used. The final evaluation flight departure was via noise-abatement SID DOU32R, and the approach was via curved, descending, decelerating STAR SIP32R with both segments using flight director guidance.

The departure for KBFI was an automatic noise-abatement SID DOU32R with the flight to KBFI 4D coupled with the approach via curved, descending, decelerating STAR TIG13R with transition to an autoland at KBFI.

System Performance Comments

Navigation

- New mechanization of higher gains and 3-sec lag made flight director guidance acceptable.

- Navigation errors at touchdown were 0.28L, 0.01L, 0.17L, 0.30L, 0.03R, 0.03R, 0.12L, and 0.01L at KMWH and 0.07P at KBFI. This was exceptional considering that EPH was off the air part of the time.

INS–Performance summary was as follows:

	INS No.	SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
Nav time: 6.6 hr	1	766	1.8	2.6	2
Flight time: 6.1 hr	2	406	-6.0	-1.2	3
	3	094	1.6	0.1	8

4D time error summary was as follows:

En route	
KBFI to KMWH	+:16
KMWH to KBFI	-:46
Evaluation (KMWH)	
SID POW32R	-:20
STAR COR32R	+:04
SID POW32R	-:36
STAR COR32R	+:08
SID POW32R	-1:01

STAR COR32R	+:19
SID GRA32R	-:22
STAR CON32R	:00
SID POW32R	:00
STAR COR32R	+:07
SID POW32R	-:24
STAR COR32R	-:05
SID DOU32R	:00
STAR SIP32R	+:16

Displays—There were no new problems.

Flight 6-7, February 22, 1974

This flight provided two demonstration flights for representatives from the FAA and from Boeing management. Each flight departure from KBFI was an automatic departure turn SID BUR13R. The en route segment to KPAE was 4D coupled with an automatic approach via curved, descending, decelerating STAR EDM16, ending in an autoland transition and landing. The departure from KPAE was coupled via close-in turn SID GLE16 with the en route segment to KBFI 4D coupled. The automatic approach to KBFI was via curved, descending, decelerating STAR TIG13R with transition to an autoland at KBFI.

System Performance Comments

Navigation

- Problem occurred again when Retune Navaid No. 2 message came up and locked Nav in IXX until No. 2 was manually tuned.
- Other shortcomings were noticed and changes will be made to correct them:

  1) EADI. FPAC went off screen in "Takeoff"; will limit to 10°.

  2) MFD. Alt Range symbol was too noisy; 3-sec filter will be added.
- Nav errors at "Touchdown" were 0.14L and 0.11L at KPAE and 0.07L and 0.02R at KBFI.
- Test instrumentation reported intermittent ARINC clock output fluctuation.

INS—Terminal errors were as follows:

	INS No.	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
Flight A				
Nav time: 1.8 hr	1	0.3	+0.1	1
Flight time: 1.2 hr	2	0.1	+0.7	2
	3	-0.3	+0.2	5
	NCU	+0.1	0	—

	INS No.	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
Flight B				
Nav time: 2.0 hr	1	+0.4	+0.7	1
Flight time: 1.2 hr	2	0.3	+0.9	1
	3	0.2	-0.2	3
	NCU	0	0	–

4D time error summary was as follows:

En route

KPAE to KBFI	-:07
KBFI to KPAE	:00
KPAE to KBFI	-:03

Displays—Many parity errors in flight, and intermittent EADI problems:

- Pitch jitter—A/D converter suspected
- Circle symbol not clear
- EADI left-hand side blank

Flight 6-8, February 25, 1974

This was a demonstration flight including one flight to KPAE and return to KBFI. The flight details are the same as those given for flight 6-7.

System Performance Comments

Navigation

- The smoothed Altitude Range symbol froze at ±0.
- Bulk data changes were necessary to reference all KPAE GRP's to NUW (Whidbey Island)
- Unexplained errors in touchdown time were reported.
- EADI runway (DA unfiltered) and potential gamma (10° limit) changes were OK.
- Navigation XTKE's at touchdown were 0.15L and 0.05L at KPAE and KBFI, respectively.

INS—Performance summary was as follows:

INS No.	SN	Δ LAT (min)	Δ LON (min)	Δ GS (kt)
1	766	1.0	1.2	2
2	406	-0.3	0.5	1
3	094	-0.3	-0.6	4
NCU		0	0	0

4D time error summary was as follows:

En route
KBFI to KPAE -:04
KPAE to KBFI :00

Displays

- Numerous parity errors occurred, and a tape reload was necessary.
- The INS invalid cross on the EADI occurred intermittently when the INS valid was OK.

Flight 6-9, February 26, 1974

The departure from KBFI was via noise-abatement SID SUM13R using flight director guidance. En route to KMWH, the display system developed major problems that precluded evaluation of any flight conditions. The approach to KMWH was an automatic approach via curved, descending, decelerating STAR EPH32R. Efforts to correct the display system problems were unsuccessful, and the decision was made to return to KBFI. The departure was via noise-abatement SID DOU32R and the approach to KBFI was via two-segment, straight, decelerating STAR KIT13R. The return flight was flown 4D coupled and an autoland was accomplished at KBFI.

System Performance Comments

Navigation

- Autotune No. 1 station tuning not reliable; suspected that the tuning problem had not been solved by changing RNI cards in the NCU
- IXD mode and station search frozen on OLM
- NCDU keyboard hung up; ATC CLR key sticking suspected
- Takeoff from KMWH with N0, E0 position, and no GMT because of operator errors (twice)

- Versine function and new mechanization of Altitude Range

- Navigation XTKE at touchdown; 0.21L at KMWH and 0.15R at KBFI

INS—Realignment took place at 90° heading at KMWH. System performance summary was as follows:

	INS No.	Δ LAT (min)	Δ LON (min)	Δ GS (kt)
Nav time: 2.2 hr	1	-0.1	+0.3	1
Flight time: 0.7 hr	2	-1.0	+0.1	1
	3	-1.2	-2.6	2
Nav time: 1.2 hr	1	0.3	-0.9	1
Flight time: 0.8 hr	2	0.4	+0.1	1
	3	0.4	-1.3	4

Displays—The display system was down most of the way to KMWH. Problems were:

- Memory wiped by a hydraulic switching transient during ground startup

- Unable to reload

- Jittery EADI roll

- A glitch in MFD Alt Range symbol

Flight 6-10, February 27, 1974

The departure from KBFI was coupled via departure turn SID BUR13R en route to a test path from Port Angeles to Portland to Olympia and terminating at KPAE. This test path was flown to support engineering acceptance of fixes incorporated as a result of problems encountered during flight 6-9. The test conditions included 4D-coupled flight with various mode checks and one manual and two autolands at KPAE. Following the completion of this acceptance testing, the operational evaluation testing continued.

There were two evaluation flights flown. The departure for the first flight was via close-in turn SID GLE16 using flight director guidance. The approach was via straight, decelerating STAR EDI16 using vertical-deviation-only guidance. The departure for the second flight was via close-in turn SID GLE16 using vertical plus waypoint guidance, and the approach was via straight, decelerating STAR EDI16.

The departure from KPAE for KBFI was via standard path SID LOF16, and the approach to KBFI was via curved, descending, decelerating STAR TIG13R followed by an autoland. This flight was 4D coupled.

System Performance Comments

Navigation—DME No. 2 frequently dropped out during this flight, both in NCDU tuning and manual tuning modes.

Software problems noticed were:

- After a REJ, REJ of a provisional clearance, 4D could not be obtained.
- MFD. ADIZ line was on 4 nmi/in., but not on 2 or 8. Pilot objected to alphanumeric overwriting.
- Autotune was not searching for new No. 1 when geometry went bad, and did not go to IDX when No. 2 went bad and No. 1 was good but with bad geometry.
- Navigation drift occurred on the ground when GS was less than 5 kt.
- SEL mode waypoint entry locked out PPOS waypoint entry on the ATC CLR mode.
- Autotune. When a No. 2 had been manually tuned through the NCDU and then rejected, it did not update at the next leg midpoint.
- SEL page had ?? on line 5.
- Navigation XTKE at touchdown were 0.01R, 0.1L, 0.32L, 0.80L, and 0.065 at KPAE, and 0.04R at KBFI. There was no apparent reason for the 0.80L because most of the path was IDD. The only difference was that OLM and BLI and OLM and NUW were used; normal autotune uses SEA and NUW on these approaches.
- 4D guidance time error, estimated time-of-arrival, and GMT appeared to be inconsistent at the end of the path.

INS—SN 094 had an 18-kt groundspeed error during the third stop at KPAE and had to be realigned. Performance summary was as follows:

	INS No.	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
KBFI to KPAE				
Nav time: 5.9 hr	1	1.8	0.1	4
Flight time: 5.3 hr	2	3.0	-0.4	3
	3	-0.4	-2.4	18

ICPS

- Path offset occurred and gradually cured itself.

- VEL CWS was judged unacceptable in roll because of wheel movements not initiated by the pilot. Path following in pitch was difficult because of response lags. Pitch sagged after small inputs.

- Flight director was unusable in pitch and too active in roll.

4D time error summary was as follows:

En route
KPAE to KBFI +:37

Evaluation

SID GLE16	-:10
STAR EDI16	-1:34
SID GLE16	:00
STAR EDI16	-:18

Displays– The following problems were noticed:

- EADI. Roll jitter

- MFD. Conic jitter, closure problems, and bright spots

- PCU. Load problem when changing program at KPAE

- EADI. Pitch jitter (power supply problem)

Flight 6-11, March 4, 1974

Departure from KBFI was via noise-abatement SID SUM13R using path perspective situation guidance. En route to KMWH, numerous outer-loop autopilot modes were checked during coupled flight. The approach to KMWH was via curved, descending, decelerating STAR SIP32R. Two low approaches and three touch-and-go landings were made from a racetrack course. Following the last landing test, a full stop was made in preparation for the performance of two ADEDS evaluation flights.

Departure for the first flight was via noise-abatement SID TAN14L using vertical-deviation-only guidance, and the approach was via standard STAR WEN14L, also using vertical-deviation-only guidance. The second flight included the same SID/STAR combination but path perspective command guidance was used. The departure from KMWH was via noise-abatement SID DOU32R, with the remainder of the flight including the two-segment, straight, decelerating STAR KIT13R, and landing at KBFI was in the automatic mode.

System Performance Comments

Navigation

- EADI. "Star and Circle" portion jumps observed at 13.54:51, apparently due to loss of pitch from the ICPS.
- EADI. Acceleration command symbology jumped intermittently at 17.13:30.
- EADI. Runway symbology blew up after crossing the approach threshold.
- MFD. Alt/Range symbol computation was wrong.
- MFD. One turn-point tick mark was missing.
- GUID. Vertical path capture would not occur.
- NCDU. New mechanization of ETA and TE on last legs was OK but did cause jump in ΔTE of up to 20 sec.
- NAV. Errors at touchdown at KMWH were:
  0.11R (rwy 32), 0.0 (rwy 21), 0.1L (rwy 21), 0.15R (rwy 32), 0.50R (rwy 32), 0.88R (rwy 32), 0.77R (rwy 32), and 0.48R (rwy 32).

The error at KBFI was 0.14R (rwy 16).

INS–Performance summary was as follows:

	INS SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
Nav time: 6.3 hr	766	0.1	3.2	2
Flight time: 3.4 hr	406	7.1	-2.9	4
	094	2.9	0.8	11

4D time error summary was as follows:

En route	
KBFI to KMWH	-:10
KMWH to KBFI	-1:01
Evaluation	
SID TAN14L	-:22
STAR WEN14L	+:17
SID TAN14L	-:03
STAR WEN14L	+:05

Displays

- MFD. Curved Trend Vector segments were disassociated, giving the appearance of a crooked line.

- MFD. Path conics were intermittently wrong, i.e., double arc length (could be a Nav software problem).

- EADI. Attitude invalid cross was still inhibited because it appeared when it should not.

- MFD. Tag jumping problem persisted and will continue until a new power supply is obtained.

Flight 6-12, March 5, 1974

Departure from KBFI was via departure turn SID BUR13R. The departure and en route segments to KPAE were flown 4D coupled. The approach to KPAE was via two-segment SID MOU16 using flight director guidance. Following this approach and transition to autoland, one additional autoland was accomplished, ending in a full stop in preparation for ADEDS evaluation testing.

The departure for the ADEDS evaluation flight was via standard SID LOF16, and the approach was via two-segment STAR MOU16 with both segments using flight director guidance. The flight from KPAE to KBFI was coupled with the departure via close-in turn SID GLE16 and the approach to KBFI via curved, descending, decelerating STAR TIG13R. The landing at KBFI was manual.

System Performance Comments

Navigation

- Roll input was lost from the ICPS (ICPS software error). No pitch glitches occurred as in flight 6-11.

- MFD. Alt Range pitch worked OK.

- GUID. VNAV capture logic error was found and corrected.

- EADI. Acceleration command jumped only when reaching M_{MO} and V_{MO} limits.

- Nav. XTKE at touchdowns were 0.02, 0.01, 0.12R, and 0.01 at KPAE and 0.06L at KBFI.

- MFD LAT line 45N appeared on 8 nmi/in. when it should not.

- AUTOTUNE did not define NAVAID No. 1 on a PPOS-SEA-PDX clearance and also did not update to PDX at midpoint.

- NCDU ATC CLR. Entry of a PTA in ATC CLR did not work correctly; 13.30 came up at 13.03.

- NAV XTKE errors at touchdown were 0.0, 0.0, at KPDX, 0.30R and 0.20R at KSEA and 0.08L at KBFI.

INS—Groundspeed discrepancies of 28-kt occurred on SN 094 in flight. Performance summary was as follows:

		INS SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
KBFI to KPAE					
Nav time:	3.2 hr	766	0.3	1.6	2
Flight time:	2.9 hr	406	-0.2	1.6	2
		094	-0.4	6.9	20
KPAE to KBFI					
Nav time:	2.2 hr	766	-0.1	-0.4	3
Flight time:	1.8 hr	406	-1.2	-0.1	3
		094	-1.7	-2.0	8

4D time error summary was as follows:

En route	
KBFI to KPAE	+1:06
Evaluation (KPAE)	
SID LOF16	+:01
STAR MOU16	+:10

Displays—No new problems occurred.

Flight 6-13, March 6, 1974

Departure from KBFI was via departure turn SID BUR13R using path perspective situation guidance. The en route segment to KMWH was 4D coupled and included evaluation of several ADEDS display modes and autopilot functions. The approach to KMWH was via standard STAR ROY21 using path perspective situation guidance. The transition to autoland was completed successfully, but the autoland was aborted at approximately 350 min due to poor trim of the airplane.

Following a full stop, an ADEDS evaluation flight was performed. The departure for this flight was via close-in turn SID EPH21, and the approach was via curved, descending, decelerating STAR EPH32R. Both segments of this flight used path perspective situation guidance.

Prior to departure for KBFI, three additional autolands were performed. The departure from KMWH for KBFI was via standard SID POT32R using path perspective situation guidance. Following a 4D-coupled flight to KBFI, an approach via curved, descending, decelerating STAR TIG13R was made to KBFI using path perspective command guidance. The ensuing autoland was discontinued and the touchdown was manual.

System Performance Comments

Navigation

- EADI. Intermittent pitch glitches just after takeoff
- MFD. Time box position indeterminate when PTA put in was earlier than the start of the path
- MFD. Erroneous path lines noticed at a time when there was bad geometry
- NAV. Large Nav errors (> 1 nmi) in IXD over KMWH
- NCDU. Large TE jump when went to last leg, i.e., TE 0-42-24, 23, etc.
- TEST. Output ARINC 561 clock frequency with 10% instability variation
- MFD. Alt Range not correct

INS—Performance summary was as follows:

	INS SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
Nav time: 4.6 hr	766	-0.8	-1.1	2
Flight time: 3.1 hr	406	-0.8	0.1	3
	094	-2.1	-4.3	10
	NCU	0	0.4	0

4D time error summary was as follows:

En route	
KBFI to KMWH	+:10
KMWH to KBFI	-:05
Evaluation (KMWH)	
SID EPH21	+:06
STAR EPH32R	+:06

Displays

- EADI extraneous test pattern data appeared intermittently.
- Input buffer overflow indicated by halting once in flight.

Flight 6-14, March 7, 1974

Departure from KBFI was via departure turn SID BUR13R in the 4D-coupled mode. The en route flight was 4D coupled, and the approach to KMWH was via curved, descending, decelerating STAR SIP32R. After a full stop, two autolands were performed, followed by a departure for KBFI via close-in turn SID TUM32R for a 4D-coupled flight to KBFI via curved, descending, decelerating STAR TIG13R with transition to an autoland.

This flight included demonstrations for the USAF representatives who had arrived at Boeing aboard the "Speckled Trout." Following this flight, the ADEDS engineers were given a demonstration flight aboard the "Speckled Trout" similar to the one described above.

System Performance Comments

Navigation

- MFD Alt Range symbol was fixed in flight.
- Nav IDV mode was mechanized with a 20 nmi maximum range limit.
- Nav errors XTKE were 0.47R and 0.1 at KMWH, and 0.14 at KBFI.

INS—Performance summary was as follows:

	INS SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
Nav time: 3.0 hr	766	1.0	-0.9	2
Flight time: 2.5 hr	406	-0.4	-0.3	2
	094	-1.0	-0.9	4
	NCU	0.2	0.4	0

4D time error summary was as follows:

En route

KBFI to KMWH	+:07
KMWH to KBFI	:01

Displays—There were no new problems.

Flight 6-15, March 8, 1974

The departure from KBFI was via departure turn SID BUR13R using path perspective situation guidance. Velocity CWS was evaluated en route to KMWH with the approach being made via curved, descending, decelerating STAR SIP32R, using vertical plus waypoint guidance. Following a full stop, an ADEDS evaluation flight was flown with the departure via departure turn SID GRA32R. The approach was via straight, decelerating STAR CON32R. Both segments of this flight used path perspective command guidance.

Following this flight, six autolands were accomplished to evaluate intentional fault insertion in the fail operational autoland system.

Following completion of this testing, additional ADEDS evaluation flights were accomplished. Departure for the first flight was via departure turn SID GRA32R using vertical-deviation-only guidance, and the approach was via straight, decelerating STAR CON32R using path perspective command guidance.

Departure from KMWH for KBFI was via close-in turn SID TUM32R, and the approach to KBFI was via curved, descending decelerating STAR TIG13R. Both segments of this flight used vertical-deviation-only guidance. The autoland to KBFI was terminated at 160 ft because of second failure occurrence, and a manual landing was completed.

System Performance Comments

Navigation

- IDV and IVD modes were used with a 20-nmi range limit, but results were not encouraging. XTKE errors at touchdown with primary preceding modes are shown below:

  1) KMWH rwy 32R—0.06L (IDD), 0.03L (IVD), 0.28L (IXD), 0.56L (IVD), 0.7L (IXD), 0.35L (IXD), 0.49R (IDX), 1.05R (IDV), and 0.03L (IDD).

  2) KBFI rwy 16R—0.0 (absolute zero position errors observed on EADI runway symbol)

- IVD mode acquisition was intermittent for reasons unknown, i.e., toggling IVD, IXD, or could not get IVD when should have.

INS—All systems performed well. A realignment was done at 90° heading at KMWH. Performance summary was as follows:

		INS SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
KBFI to KMWH					
Nav time:	4.0 hr	766	0.4	+1.6	1
Flight time:	3.0 hr	406	-0.6	+0.4	1
		748	0.8	+0.1	1
KMWH to KBFI					
Nav time:	2.0 hr	766	0.5	-1.9	2
Flight time:	1.6 hr	406	-0.1	0.5	0
		748	-0.4	0.4	1
		NCU	0	-0.1	0

4D time error summary was as follows:

En route	
KBFI to KMWH	+:16
KMWH to KBFI	-:02
Evaluation (KMWH)	
SID GRA32R	-:02
STAR CON32R	+:03
STAR CON32R	-:06

Displays

- MFD. Occasionally path vector conics came up as double length on the display (could be an NCU software problem).
- MFD. When path conics were partially offscreen, disconnected lines were displayed.
- EADI. The display was too dim even at maximum brightness. Other problems persisting included character Y position jitter, extraneous data on EADI, EADI attitude invalid cross, and MFD vector discontinuous lines.

Flight 6-16, March 11, 1974

This was a demonstration flight for representatives from ALPA. The flight to KPAE and return were accomplished in the automatic mode. The departure from KBFI was via departure turn SID BUR13R with the 4D-coupled flight to KPAE terminated via curved, descending, decelerating STAR EDM16 with transition to an autoland for a touch and go. The departure from KPAE was via close-in turn SID GLE16, and the 4D-coupled flight to KBFI was terminated via curved, descending, decelerating STAR TIG13R with transition to an autoland.

System Performance Comments

Navigation—XTKE error at KBFI was 0.15R (rwy 32R). XTKE errors at KPAE were 0.05L (rwy 16) and 0.20L (rwy 16).

INS—Performance summary was as follows:

	INS SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
Nav time: 1.5 hr	766	0.4	0.3	2
Flight time: 1.1 hr	406	-0.3	0.4	1
	748	-0.1	0.5	2

Displays

- EADI and MFD. Symbol distortion (open circle) problem reappeared prior to flight.

- MFD. First character of waypoint name was missing and the star symbol was distorted intermittently prior to flight.

Flight 6-17, March 11, 1974

Departure from KBFI was coupled via departure turn BUR13R en route to KMWH. Attitude CWS and 4D-coupled modes were evaluated en route with the coupled approach to KMWH via curved, descending, decelerating STAR EPH32R with transition to autoland. After a full stop, the following ADEDS evaluation flights were accomplished.

The first flight departure from KMWH was via noise-abatement SID TAN14L, and the approach was via standard STAR WEN14L, with both segments using vertical-deviation-only guidance. The departure for the second flight was via noise-abatement SID TAN14L, and the approach was via standard STAR QUI14L, with both segments using path perspective situation guidance. Departure for the third flight was via close-in turn SID TUM32R, and the approach was via curved, descending, decelerating STAR SIP32R, with both segments using path perspective situation guidance.

The departure from KMWH for KPAE was via noise-abatement SID DOU32R and the approach to KPAE was via two-segment STAR MOU16, with both segments using path perspective situation guidance. One evaluation flight was flown at KPAE with the departure via close-in turn SID GLE16 and the approach via two-segment STAR MOU16, with both segments using path perspective command guidance.

The departure from KPAE for KSEA was via noise-abatement SID BRE16, where two touch-and-go autolands were accomplished, followed by a direct flight to KBFI where a manual landing was made.

System Performance Comments

Navigation

- Station overflight (< 1.8 nmi) fix was patched in at KMWH after large errors following overflight of EPH.

- XTKE errors at KMWH were 0.09L (rwy 32), 0.85R (rwy 14), 0.47R (rwy 14), and 0.0 (rwy 32).

- XTKE errors at KSEA were estimated 0.1R (rwy 16L) and 0.1R (rwy 16L).

- NCDU looked good under night light conditions (white on black keyboard only).

INS SN 748 developed a large westerly velocity error on the JUNCN-ALTE leg at a heading of 90°. Error was steady at -15 kt. Subsequently, errors up to -32 and -27 kt were observed at headings of 90° and 270°. Thereafter, velocity and position errors were oscillatory, presumably with a Schuler period. Also, 10-kt error developed during turn from 270° to 180° at MOUVW between KMWH and KPAE after realigning with a 90° heading. Performance summary was as follows:

	INS SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
KBFI to KMWH				
Nav time: 3.1 hr	766	0.5	0.7	2
Flight time: 2.8 hr	406	-0.1	0.4	2
	748	-0.6	1.2	19
KMWH to KBFI				
Nav time: 2.6 hr	766	1.0	-2.3	2
Flight time: 2.2 hr	406	0.4	0.9	3
	748	-0.3	-0.3	5
	NCU	0	0.4	0

4D time error summary was as follows:

En route	
KBFI to KMWH	+:18
KMWH to KPAE	-1:13
Evaluation (KMWH)	
SID TAN14L	-:01
STAR WEN14L	+:25
SID TAN14L	:00
STAR QUI14L	+:05
SID TUM32R	-:01
STAR SIP32R	+:22

Displays

- PCU. Parity error occurred at KMWH after power switching.
- MFD. Blueness was pronounced under bright light conditions.

Flight 6-18, March 12, 1974

The departure from KBFI was via noise-abatement SID SUM13R using path perspective command guidance. The en route segment of the flight to KMWH was 4D coupled with the approach via straight, decelerating STAR CON32R, with a manual approach and landing. Time error at the middle marker of the landing approach was -:07 sec. Four autolands were performed from a racetrack course to obtain metric camera data for space position data. Following this effort, a full stop was made in preparation for the following ADEDS evaluation flights.

The first flight departure was via close-in turn SID MAE14L, with the subsequent approach via curved, descending, decelerating STAR SIP32R. Both segments of this flight used path perspective situation guidance. Departure for the second flight was via noise-abatement SID TAN14L, and the approach was via curved, descending, decelerating STAR SIP32R, with both segments using vertical-deviation-only guidance.

The departure from KMWH en route to KBFI was via close-in turn SID TUM32R, using vertical-deviation-only guidance. The return flight was to be 4D coupled per a planned profile, but severe weather precluded adhering to the ATC coordinated flight plan. The approach to KBFI was via curved, descending, decelerating STAR TIG13R, using vertical plus waypoint guidance.

System Performance Comments

Navigation

- GUID problems occurred with 3D; left the path for no apparent reason over ELN; two occurrences in ALT HOLD and one in G3D.
- Nav patches were put in to improve single DME update mode, i.e., bearing within ±15° of cardinal points N, S, E, W; 15° bank cut off; 2 nmi minimum range.
- Nav took patches, except bank angle limit, out after the GUID 3D problem, but had a similar problem in ALT HOLD.
- Nav XTKE with patches were 0.05R (rwy 32), 0.1L (rwy 32), and 0.0 (rwy 32) at KMWH.
- Nav XTKE without patches were 0.0 (rwy 32) and 0.1L (rwy 32) at KMWH and 0.12L (rwy 13) at KBFI.

INS—There was no abnormal INS performance. Performance summary was as follows:

	INS SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
Nav time: 6.1 hr	766	1.6	1.7	2
Flight time: 5.5 hr	406	-1.2	0.3	2
	748	1.2	1.1	1
	NCU	0.2	-0.4	0

4D time error summary was as follows:

En route KBFI to KMWH -:07

Displays—There were no new problems.

Flight 6-19, March 13, 1974

This flight included demonstrations for Boeing corporate officers. The departure from KBFI was via departure turn SID BUR13R, and the approach to KPAE was via STAR EDM16 with transition to autoland. Departure from KPAE was via close-in turn SID GLE16, and the approach to KBFI was via curved, descending, decelerating STAR TIG13R, with transition to an autoland. The second flight to KPAE used the same flight path as the first, but departure from KPAE on the second flight was via noise-abatement SID SAM16, with the subsequent approach to KBFI again via TIG13R, with transition to an autoland. All of the above en route flight segments were flown 4D coupled.

System Performance Comments

Navigation

- XTKE errors at touchdown were 0.16L and 0.01R at KPAE (rwy 16) and 0.02L and 0.06L at KBFI (rwy 13).
- The DMEs dropped out momentarily after small accelerations (<0.1 g) in the direction of the DME station.

INS—Performance summary was as follows:

	INS SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
Nav time: 3.2 hr	766	0.4	0.5	2
Flight time: 2.4 hr	406	-0.2	0.6	3
	748	0.4	0.1	
	NCU	0.1	0	

Displays—There were no new problems. Pitch on EADI was extremely jumpy.

Flight 6-20, March 13, 1974

The departure from KBFI was via departure turn SID BUR13R, with the approach to KPAE via curved, descending, decelerating STAR EDM16. During this flight segment, problems were encountered with the navigation system that precluded additional planned testing. Three autolands included two touch-and-go landings and one go-around. The departure to KBFI was direct, with a manual flight director landing. During this flight, additional problems were encountered with autothrottle control and outer-loop autopilot modes, including altitude engage and horizontal and vertical path engage.

System Performance Comments

Navigation—Many problems occurred—bad assembly suspected.

- EADI. Waypoints advanced by one.
- MFD. Time box and NCDU TE had opposite polarity.
- NCDU. Response to new PTA was incorrect.
- GUID. Violent pitch ups occurred in altitude hold (Nav or ICPS problem, cause unknown).
- Nav. New program with Nav fixes:

  1) Roll ±15° cutoff

  2) 2 nmi minimum

  3) Single DME cardinal bearings ±15° update only

- XTKE at touchdown were 0.0R, 0.20L and 0.37L at KPAE (rwy 16) and 0.17L (tuned to NUW instead of SEA) at KBFI (rwy 13).

INS—No problems occurred. Performance summary was as follows:

	INS SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
Nav time: 3.1 hr	766	0.3	0.3	1
Flight time: 1.1 hr	406	-0.8	0.3	1
	748	0.1	0.2	3
	NCU	-0.2	-0.3	

Displays—There were no new problems.

Flight 6-21, March 14, 1974

Departure from KBFI was via departure turn SID BUR13R using path perspective situation guidance, and the approach to KPAE was via curved, descending, descelerating STAR EDM16, using the flight director guidance option. This was a 4D flight, and the error at KPAE was -:06 sec. A transition to autoland was accomplished successfully and a touch-and-go-landing was made, followed by a racetrack course for one additional autoland, then followed by a full stop.

Departure from KPAE for KMWH was via noise-abatement SID SAM16 using path perspective command guidance. The flight to KMWH was 4D with the approach via two-segment STAR COR32R. The time error for this flight to KMWH was +:13 sec at touchdown.

Departure from KPAE for ADEDS evaluation flight one was via departure turn SID GRA32R, and the approach was via straight, decelerating STAR CON32R, with both segments of the flight using path perspective command guidance. Departure for the second flight was via close-in turn SID TUM32R, and the approach was via curved, descending, decelerating STAR SIP32R with path perspective command guidance used for both segments.

At this time, two autolands were accomplished for evaluation of changes made in the system to correct problems observed during the previous flight.

The next ADEDS evaluation flight departure from KMWH was via departure turn SID GRA32R, and the approach was via straight, decelerating STAR CON32R, with both segments using vertical plus waypoint guidance. The next flight departure was via departure turn SID GRA32R, using path perspective command guidance. The approach for this flight was via straight, decelerating STAR CON32R using flight director guidance.

The departure from KMWH for KBFI was via noise-abatement SID DOU32R using vertical plus waypoint guidance, and the approach to KBFI was via standard STAR TAY31L.

System Performance Comments

Navigation

- No problems occurred with PTA entry (the software from flight 6-18 was used).
- Navigation errors at touchdown were as follows:
    1) KPAE (rwy 16): XTKE 0.14L and 0.28L
    2) KMWH (rwy 32)XTKE 0.05L, 0.0L, 0.08L, 0.0R, 0.08L; following SID and STARs XTKE 0.44R (after takeoff with large navigation error), 0.6L during autoland circuits.
    3) KBFI (rwy 31): XTKE 0.02R.

Note that none of the changes for single DME mode update limitations were incorporated.

INS—SN 766 failed in flight; WARN in Nav and ATT modes; restarted in ATT mode, got WARN again. SN 094 was installed. (This system was previously rejected for excessive Schuler groundspeed errors.)

	INS SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
Nav time: 6.9 hr	406	0.8	2.1	1
Flight time: 6.3 hr	748	2.5	0.8	5
Nav time: 2.8 hr	094	1.9	4.4	3
Flight time: 2.3 hr				

4D time error summary was as follows:

En route

KBFI to KPAE	-:06
KPAE to KMWH	+:13
KMWH to KBFI	+1:40

Evaluation (KMWH)

SID GRA32R	-:16
STAR CON32R	+:01
SID TUM32R	:00
STAR SIP32R	+:01
SID GRA32R	-:01
STAR CON32R	-:05
SID GRA32R	-:06
STAR CON32R	+:15

Displays

- No new problems
- MFD time box appeared out of position momentarily on several occasions (could be NCU)

Flight 6-22, March 14, 1974

This flight was dedicated to night evaluation of a visual approach monitor (VAM) installed on the ADEDS flight test airplane (NASA 515 737-100). No ADEDS evaluation was accomplished during this flight.

Navigation—The NCU failed in flight due to a memory change, either hardware- or software-induced in bank 2. Only the NCDU keyboard was affected, but the NCU invalid could not be cleared. The memory was verified, and no evidence could be found that the problem existed in software. However, an untried combination of new banks 2 and 3 and old bank 1 was being used at the time of failure.

An old ICPS program was used.

INS—SN 748 developed large groundspeed errors (-25 kt) during a 30° bank turn to the west. Performance summary was as follows:

	INS SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
Nav time: 2.5 hr	094	1.0	0.9	8
Flight time: 1.0 hr	406	0.6	0.1	1
	748	0.4	4.0	19

Displays—Initial MFD incrementing problem was induced by software patching error.

Flight 6-23, March 15, 1974

Departure from KBFI was via departure turn SID BUR13R using path perspective situation guidance. The flight was scheduled for en route evaluation of ADEDS performance on a closed-loop flight from Seattle to Portland to Spokane and back to Seattle. Failure of the navigation computer shortly after takeoff from KBFI required aborting the flight and returning. The navigation computer software was reloaded, and tests indicated that the problem was corrected. However, by this time the weather conditions and the delay in departure time resulted in rescheduling the flight for Portland and return. The system performance was still not adequate to perform an en route test. A manual landing was made on return to KBFI.

System Performance Comments

Navigation—The new bank 1 (with PTA entry problem) was loaded.

- PTA problem occurred as before. The problem was found postflight after it was noticed that, on the final leg, TE jumped to the correct value (4:25) while the time box on the MFD stayed at approximately +0.10.

- Navigation XTKE at touchdown by KBFI rwy 31 was 0.05L.

- An old ICPS program was used. During autoland, first failure was caused by INS No. 3 groundspeed errors. When INS No. 1 failed, the autopilot did not disconnect for many seconds after INS No. 1 went invalid.

INS

- INS 748 developed groundspeed errors varying between +32 to -54 kt in flight.

- INS 094 failed in Nav and ATT modes during final approach after approximately 2.3 hr in Nav.

Performance summary was as follows:

	INS SN	ΔLAT (min)	ΔLON (min)	ΔGS (kt)
Nav time: 2.3 hr	406	-0.4	1.0	3
Flight time: 1.6 hr	748	0.2	-8.5	44

Displays

- Display was lost after takeoff; bootstrap was reloaded and then OK.

- Altitude invalid cross appeared intermittently on the EADI.

- MFD erroneous flight plan conics appeared intermittently, apparently caused by the pickup of bits in the conic length word (could be I/O problem).

2.2 DISPLAY SYSTEM PERFORMANCE

2.2.1 General

The detailed performance of the display system is described in the following sections and in appendix D. In summary:

1) Problems with the display system hardware resulted in the delay of several test flights and the early termination of two flights. The problems were, however, typical of those encountered in early test flights of developmental hardware.

2) A shortcoming of the display system was the lack of relative display brightness when operating in direct sunlight. The brightness of the LED readouts on the display system mode control panel was also judged inadequate.

3) The display system software configuration was not frozen during the flight test period. Most of the changes, listed in table 2-1, were of a developmental nature, i.e., adjustments to scaling and timing and general optimization of the software routines.

4) Problems encountered during acceptance, integration, and flight testing support the requirement for a detailed monitoring of power requirements during the design and development phase. The level provided to the ADEDS display system was not adequate.

2.2.2 Display System Hardware

2.2.2.1 Program Control Unit (PCU) and System Control Unit (SCU)

During the first flights, the program stored in memory was destroyed during the turn-on of airplane systems and transfer from ground power to airplane power. By adding a memory power supply crowbar circuit, which ensured the memory drive currents were not switching after the 5-V logic supply had reduced below a normal operating level, the display system could withstand all power interruptions except when the hydraulic pumps were switched on. The final operating procedure was to power the system down until the airplane was ready to taxi, after having conducted a preflight checkout of the display system.

Memory parity was a problem, particularly in the beginning of the flight test program. If a memory parity occurred in memory locations that did not interfere with the SCU operation, the bad memory location could be restored and the program restarted. However, if a memory location that the SCU program was using was destroyed, the SCU loader paper tape had to be reloaded. This was a problem because several minutes were required to load the tape. Approximately two-thirds into the flight test, a new memory sense and inhibit boards were installed, and there were only a few subsequent periodic memory parity problems.

TABLE 2-1.—DISPLAY SYSTEM SOFTWARE CHANGES

Change No.	Flight No.	Function	Description of change
1	2	EADI, MFD	Optimize symbol coding
2	2	EADI	Correct BITSPOT to delete unblanked vector
3	2	MFD	Eliminate jumping when new data received
4	2	MFD	Prevent hangup when more data received than can be handled in available time
5	2	EADI	Correct shape of DGAMWDGE and FPANGLE symbols
6	3	EADI	Correct pitch reference and decision height mode panel readouts
7	3	MFD	Set MFD fail bit and transmit to NCU when bad data received
8	4	EADI	Change pitch scale lines to 5°
9	4	EADI	Change pitch reference and horizon lines
10	6	EADI, MFD	Optimize symbol library to save time
11	6	EADI	New ILS symbol
12	6	EADI	Key ILS box to LAND ENGAGE from ICPS
13	6	EADI	Round off decision height
14	6	EADI	Round off radar altitude between 1,500-25,000 ft to 100 ft
15	7	EADI	Correct localizer box scaling
16	7	EADI	Simplify speed error processing in conjunction with NCU
17	8	MFD	Optimize track tape and airplane symbol
18	8	EADI	Adjust timing of EADI stroking
19	9	MFD	Adjust track tape scaling
20	12	MFD, EADI	Optimize timing
21	11	EADI	Change to ILS symbol (see change 11)
22	12	EADI	Include both ILS symbols

Shortly after installing the new memory boards, a new problem occurred which delayed the flight test for approximately 2 days. The first symptom of the problem was that the pitch map would make discrete steps in roll instead of making a smooth transition. The second symptom was that the SCU paper tape reader would not load tapes. These problems were resolved when broken wire was found in the PCU chassis wiring.

2.2.2.2 Hybrid Symbol Generator (HSG)

Several intermittent problems occurred. The most serious one was that all of the calligraphic symbology programmed to be positioned left of screen center was shifted to the right side of the display. Another problem was that symbols did not close properly. It gave the effect that a low-order bit was always a one in the +X direction.

2.2.2.3 Displays

The displays were reliable. One time the MFD did not come up because of a loose pin in the input connector to the high-voltage power supply.

2.3 NAVIGATION SYSTEM PERFORMANCE

2.3.1 General

The navigation system hardware (NCU and NCDU) performed very well throughout the flight test period. Navigation system failures/incidents No. 69 through 95 which occurred during the flight test period are included in appendix D. Only four of these related to the NCU and four to the NCDU.

The navigation computer software configuration was never completely frozen throughout the flight test period. A total of 178 changes were recorded. (See table 2-2). These changes reflect a continuing process of correcting problems, incorporating new functions and mechanizations, and optimizing software routines, which continued throughout the flight test period. Despite the large number of changes incorporated, only one flight test, the penultimate one, had to be aborted because of an NCU software problem.

2.3.2 Navigation System Hardware

2.3.2.1 Navigation Computer Unit

The four hardware problems that occurred with the NCU during the flight test period and are listed in appendix D were as follows:

- Incidents No. 69 and 86–Design problem in the power interrupt mechanization
- Incident No. 87–Spare computer No. 8 card failure
- Incident No. 88–SPBP transmitter failure
- Incident No. 91–RNI (Radio Navigation Interface) card failure

TABLE 2-2.—NAVIGATION COMPUTER SOFTWARE CHANGES

Change No.	Flight No.	Routine	Description of change	Type of change[a]
1	1	EXEC	Enable the cold start routine for power interrupts longer than 2 sec	P
2	1	GUID	Set AGCS flag to accept and process ICPS inputs	P
3	1	NCDU	Correct logic for PPOS waypoint and enable HOLD pattern left at 0	P
4	1	NAV	Correct scaling of INS velocity inputs	T
5	1	EXEC	Use pitch and roll from INS instead of ICPS and use CAS instead of TAS	T
6	2	NAV	Interchange DME 1 and 2 in listing comments	P
7	1	NAV	Interchange DME 1 and 2 processing and resynchronize runway heading output discrete	P
8	1	NAV	Correct errors in DME valid logic and compensate for 30° VOR bias	P
9	2	GUID	Inhibit HVGUID routine when GS $<$ 64 kt	P
10	2	GUID	Remove latch on ALT SEL logic and increase gains	P
11	2	MFD	Display ORIG and DEST airports when no runway is defined in ATC CLR	P
12	2	MFD	Display tuned DME 1 and 2	P
13	2	EADI	Set FPA = 0 when GS $<$ 64 kt	P
14	2	NAV	Zero DME range input cells after use	P
15	6	NAV	New autotune mechanization; see change 102	P
16	2	EADI	Modify flight director pitch; canceled for flight 3	P
17	2	NCDU	Reinitialize to INS position when ORIG entered on INIT page	P
18	2	EADI	Set DA = 0 and inhibit VNAV until GS $>$ 64 kt	P
19	3	NAV	Provide flags to inhibit automatic nav mode selection	P
20	2	MFD	Increase radial symbol brightness to maximum	P
21	2	NCDU	Make NAV DATA error functions flight plan dependent only	P
22	2	NAV	Simplify nav mode initialization using NAVFLG, NAV64K, and LLINIT	P
23	2	NAV	Change nav mode annunciation codes IDX, IXD, etc.	P
24	2	BULK	Add test DME station XXX, 108.00	P
25	2	EADI	Set VGSDOT and ACNORM to zero when INS is valid	P
26	3	NAV	Compute difference between updated and raw INS positions	P
27	2	GUID	Invert RUN/CLAMP logic to compensate for ICPS reversal	P
28	2	GUID	Enable pitch and roll synchro inputs instead of EPR	T
29	3	NCDU	Correct entry of runway in ATC CLR	P

[a]P = permanent
T = temporary

TABLE 2-2.– (Continued)

Change No.	Flight No.	Routine	Description of change	Type of change[a]
30	3	NAV	Enable frequency check when manual tuning from the cockpit	P
31	3	–	Correct assembly errors	P
32	3	NAV	Correct simulated airplane altitude computation	P
33	3	EADI	Add PITCHB of 5°	P
34	2	EADI	Patch for PITCHB and pitch and roll synchros	T
35	3	NAV	Increase accuracy of slow-loop vector magnitude routine	P
36	3	NAV	Correct IXX mode annunciation when NOSTA1 and NOSTA2 are set	P
37	3	NAV	Correct BAROSET mechanization	P
38	3	EADI	Add 1-sec lag filter to FPAC	P
39	3	MFD	Add GS and nav mode annunciation to MFD text	P
40	3	MFD	Correct interface protection mechanization for bad MFD bus 1 transmissions	P
41	3	NAV	Correct VOR mechanization for VOR 2 and change calculated bearing by 180°	P
42	3	NCDU	Inhibit LOOK UP STATUS message on line 8	P
43	3	NCDU	Correct PTA mechanization for reclearances	P
44	3	EADI	Zero VNAV at end of path	P
45	3	INS	Correct acceleration resolving errors	P
46	3	GUID	Patch of correction to EPR input processing (canceled)	T
47	3	AGCS	Method for canceling preselect modes	P
48	3	MFD	Resend MFD bus 1 when bad parity indicated by PCU mode word	P
49	3	NCDU	Correction to PTA mechanization	P
50	3	NAV	Correction to change 37	P
51	3	–	Correct assembly errors	P
52	3	NAV	New test data output variables	T
53	3	GUID	180° phase change to EPR inputs	P
54	3	MFD	Add 1-sec lag filter to ACNORM for trend vector	P
55	3	MFD	Moved GS and mode display	P
56	4	NAV	Add 4K correction to CAS to agree with cockpit display	P
57	4	NCDU	Transmit new page after power interrupt	P
58	4	NCDU	Correct error in missed approach path name in ATC CLR	P
59	4	EADI	Flash FPA symbol at flare	P
60	4	MFD	Add reciprocal of radial symbol	P
61	4	MFD	Adjust limits of altitude/range symbol	P
62	4	NCDU, MFD	Correct NAV mode annunciation	P

TABLE 2-2.–CONTINUED

Change No.	Flight No.	Routine	Description of change	Type of change[a]
63	4	EADI	Activate PITCHB of 5°	P
64	4	NCDU	Annunciate M for manual tuning on NAV DATA 3	P
65	4	EADI	Corrections to runway symbology; superseded by change 75	P
66	4	NAV	Apply range and geometry checks when manually tuned	P
67	4	GUID	Correct EPR limit calculations	P
68	4	GUID	Double precision integrators for autothrottle	P
69	4	–	New text data outputs	T
70	4	–	Correct assembly errors	P
71	4	GUID	Try differentiated GS for VGSDOT	T
72	4	GUID	Limit autothrottle sheer signal to ±16 ft/sec	P
73	4	GUID	Reduce autothrottle gains to KH = 1.5, KVDT = 1.2	P
74	5	EADI	Add 1-sec lag filter to DA to compensate for INS 1/sec computation rate of true heading	P
75	5	EADI	Correction to runway centerline; superseded by change 100	P
76	5	GUID	Modify 4D guidance to new too fast and too slow limits	P
77	5	GUID	Mode panel annunciation when IAS low-speed limit is reached	P
78	5	GUID	Modify vertical path capture logic to engage within ±1000 ft	P
79	5	GUID	Increase α limiting gain	P
80	5	GUID	Modification to prevent autothrottle overboosting	P
81	5	NAV	Fake INS valid for simulated flight	P
82	5	NAV	Increase runway discrete set time by 100 msec	P
83	5	EXEC	Correct error in power interrupt subroutine	P
84	5	–	Correct assembly errors	P
85	5	EXEC	Software fix for hardware design error in power interrupt sequence; superseded by change 103	P
86	5	NCDU	Blank windspeed when TAS < 150 kt	P
87	5	–	Modify test data output	P
88	6	BULK	Expand bulk data	P
89	5	NAV	Increase tuning time from 1 to 10 sec	P
90	5	GUID	Correction to autothrottle computation	P
91	5	GUID	Reset PCAPT after a touch and go	P
92	6	GUID	Modify autothrottle too slow to use IASREF	P
93	6	GUID	Modify EPR limit gains	P
94	6	GUID	Modify vertical capture logic	P
95	6	GUID	Stall protection in vertical guidance modes	P
96	6	NCDU	Use CAS for wind when TAS < 150 kt	P

TABLE 2-2.–CONTINUED

Change No.	Flight No.	Routine	Description of change	Type of change[a]
97	6	MFD	Add AGCS mode annunciation	P
98	6	EADI	Blank erroneous name annunciation after passing last waypoint	P
99	6	MFD	Correct error in trend vector when error exceeds screen limits	P
100	6	EADI	Correction to runway symbology	P
101	6	BULK	Expand bulk data	P
102	6	NAV	New autotune mechanization	P
103	6	EXEC	Ensure power interrupt enabled in fast loop following OUT04 instruction	T
104	6	–	New test data output	P
105	6	GUID	Reverse polarity of ICPS pitch flight director	P
106	6	EADI	Correct flashing FPA when negative	P
107	6	MFD	Correct mode annunciation	P
108	6	NAV	Alternate HDOT mechanization	P
109	7	BULK	Expand bulk data	P
110	7	NAV	Reverse autotune stations so No. 2 is path dependent	P
111	7	NCDU	Correct REJ logic in NAV DATA modes	P
112	7	MFD	Simplify speed error mechanization	P
113	7	EADI	Force VACCEL input to zero when radio altitude is less than 5 ft	P
114	7	EADI	Correction to runway centerline	P
115	7	–	Correct assembly errors	P
116	7	GUID	Reverse sign of radio altitude received from ICPS	P
117	7	NAV	Inhibit VOR update modes	P
118	7	NCDU	Increase resolution of wind calculation	P
119	7	NCDU	Delete 5-kt CAS bias inserted in change 56	P
120	8	BULK	Change all GRP references to VORTAC	P
121	8	EADI	Increase runway width to 300 ft	P
122	8	–	New test data outputs	T
123	7	GUID	Increased gain of autothrottle retard	P
124	8	GUID	Blink amber lights on mode panel when armed	P
125	8	GUID	Correction to ICPS flight director at localizer capture	P
126	8	NCDU	Correct error in runway heading format	P
127	8	GUID	Modify pitch flight director gains	P
128	9	GUID	Increase V_{MO} to 340 and M_{MO} to 0.78	P
129	9	NAV	Inhibit position update when GS $<$ 5 kt	P
130	9	EADI	Change HRAD limit to 1 ft for VACCEL = 0 (canceled)	T

TABLE 2-2.–CONTINUED

Change No.	Flight No.	Routine	Description of change	Type of change[a]
131	–	NAV	Enable VOR update modes (canceled)	T
132	10	–	New test data output	T
133	11	NCDU	Annunciate path guidance mode 2D, 3D, 4D, and LND	P
134	11	MFD	Display windspeed and direction	P
135	11	EADI	Reference speed error and acceleration command to path until IASREF is reached	P
136	11	NCDU	Freeze NAV DATA 1 errors at touchdown	P
137	11	BULK	Add NUW	P
138	11	NCDU	Set windspeed = 0 when HRAD < 5 ft	P
139	11	EADI	Corrected scaling of VNAV star and circle	P
140	17	NAV	Autotune station 1 search increased to four stations	P
141	11	NAV	Retain velocity correction terms for 5 min	P
142	11	–	Correct assembly errors	P
143	11	EADI	Correct path pointers at end of path	P
144	12	NAV	Change IDD bearing restriction to $150^\circ > \lvert Bearing \rvert > 30^\circ$	P
145	12	GUID	Change mode panel amber blinking logic	P
146	13	–	New test data output	T
147	11	NAV	Patch for autotune 2 station search	T
148	13	EADI	Flight director gain change and 3-sec filter	P
149	15	EADI	Limit FPAC to $\pm 10^\circ$	P
150	15	MFD	Add 3-sec filter to altitude range	P
151	15	EADI	Delete DA filter after INS output corrected to 4/sec	P
152	15	GUID	Add versine for ICPS vertical path command	P
153	17	NCDU	GMT not reset when new ORIG entered on INIT page	P
154	15	GUID	Modify ICPS flight director per change 148	P
155	17	NAV	Increase DME tuning time to 15 sec	P
156	17	GUID	Change autothrottle clamp logic at touchdown	P
157	17	NAV	Correct DME update flags	P
158	18	NAV	Inhibit navigation position updates when GS < 5 kt	P
159	18	NCDU	Correct errors in SEL mode and ATC CLR after REJ	P
160	18	NCDU	Make ETA = DTOGO/GS on the last leg	P
161	18	NCDU	Groundspeed error wrong scaling corrected	P
162	19	AGCS	Rescale ICPS pitch flight director	P
163	19	MFD	Make time box calculations SC and SDCC double precision	P

TABLE 2-2.–CONCLUDED

Change No.	Flight No.	Routine	Description of change	Type of change[a]
164	19	MFD	Correction to altitude range symbology	P
165	20	NAV	Correction to navaid pointer when navaid was on the path	P
166	21	NAV	Enable VOR update modes up to 20-nmi range	P
167	25B	MFD	Correct second turn mark for last two waypoints	P
168	25B	GUID	Prevent station pointer update when GS = 64 kt	P
169	23	NAV	Inhibit DME updates when range < 2 nmi	P
170	25	NAV	Calculate sin and cos of true heading in fast loop	P
171	22	GUID	Add versine to autothrottle	P
172	24	NAV	Inhibit updates in single DME modes unless bearing is within ±15° of a cardinal heading	P
173	24	GUID	Remove versine from VDC	P
174	25B	NCDU	Correct problem in debug mode when UP key was pressed	P
175	26	–	Correct assembly errors	P
176	26	GUID	VPC included in test data output	T
177	26	NCDU	Assembly errors in NCDU ETA and auto-throttle flare	P
178	26	GUID	Versine replaced to compensate for old ICPS tape	T

Incidents No. 75, 83, and 92 affected the NCU, but they were due to test equipment and not the flight hardware.

The design problem in the power interrupt system did not adversely affect NCU performance in any way, and the system withstood many hundreds of power interruptions and resumed normal operation. On the few occasions when normal operation did not resume automatically, recycling power brought the system back to normal. When the problem was diagnosed, software was modified to circumvent the hardware problem. The other three problems were fixed by substitution of new cards provided by Litton.

The NCU accumulated 2020 hr of operation during the ADEDS program; 538 of these occurred on the flight test airplane.

2.3.2.2 Navigation Control and Display Unit

Two NCDUs were used on all test flights, one mounted in the cockpit and the second mounted on top of the navigation pallet. By a simple wiring change involving moving two jumper wires in the X2 matrix box, one or the other NCDU could be made the master. Only key presses on the master NCDU keyboard had any effect; the second NCDU was a slave display. This arrangement proved to be extremely useful. The first six flights were made with the active NCDU on the navigation pallet for engineering evaluation and in-flight software troubleshooting. Halfway through the seventh flight, the cockpit NCDU was made the master system for the duration of the flight test program. Because of the better visibility of the NCDU mounted on the navigation pallet, the test instrumentation TV camera was moved to this location prior to the fourth flight.

The NCDU SN 002 had a white-on-black keyboard, while SN 003 had a multicolored keyboard. The position of the two NCDU's were interchanged several times during the flight test period. The multicolored keyboard in its present form proved to be unacceptably bright under night conditions.

The two NCDU problems listed in appendix D which occurred during the flight test period were:

- Incident No. 79–NCDU SN 003, defective key
- Incident No. 82–NCDU SN 003, design problem causing only noise on the display

Other incidents, No. 69 and No. 80, describing NCDU keyboard lockup were caused by NCU power interrupt problems (section 2.3.2.1) and were not NCDU failures. However, at least two other instances of temporary sticking of keys causing keyboard hangup were not listed as failures. Litton analysis has shown that the silver contact switches used for the NCDU keys are susceptible to temporary sticking, which can be cured by re-pressing the offending switch. During this program, after three or more occurrences involving the same switch were observed, the switch was replaced. Litton is incorporating gold contact switches in latest keyboards.

During the ADEDS program the two NCDUs accumulated estimated operating times as follows:

SN	System integration and simulation (hr)	Flight test (hr)	Total (hr)
003	4000*	500	4500
022	1500	500	2000
			6500

It is significant to note that during the accumulated total operating time of more than 6500 hr, no CRT problems or deterioration in brightness or contrast were observed.

2.3.3 Navigation Computer Software

2.3.3.1 General

The navigation computer software program of 32,000 words had been developed and checked out during system integration testing in the 8400 simulator as described by reference 5. Checkout had proceeded as far as possible in the simulator in some areas, but in other areas, in particular the MFD and EADI data processing, the checkout was incomplete because of the late availability and continuing problems with the display system hardware. Consequently, the task of software checkout during the flight test period was greater than originally intended. It had, of course, been anticipated that the real airplane environment would uncover software problems that had not been apparent in the simulator environment. It was also anticipated that mechanization changes in the ADEDS configuration would result from flight test experiences and that temporary alternate solutions to operational situations would be tried. Therefore, a software control procedure was set up to regulate software changes to the NCU and also to the display system.

The software control procedure involved the completion of a data sheet describing each change and identifying the software assembly to which it was applicable. A summary of the NCU data sheets is shown in table 2-2. A record was kept of the software assembly and the patches incorporated for each test flight. The working copies of the program listings that were kept on the airplane had all changes marked in them together with the new memory sum check values.

The major problems encountered, the fixes to those problems, and new mechanization changes made to the NCU software during flight test are discussed in the following sections under the headings of navigation software (Nav), navigation control and display software (NCDU), guidance software (GUID2D, GUID3D, and GUID4D), plus autothrottle and AGCS functions, multifunction display software (MFD), electronic attitude indicator software (EADI), and executive (EXEC), I/O, and miscellaneous functions.

*This figure is a conservative estimate of usage in the simulator between May 1972 and December 1973.

2.3.3.2 Nav Software

A software error in the INS software, causing the incoming INS velocity data to be interpreted by the NCU as half of what it should be, precipitated a navigational crisis for ADEDS on the first flight. The error was corrected by a software patch to the NCU in flight. Thereafter, navigation performance in the INS only (IXX) and the INS updated by dual DME's (IDD) was satisfactory until a DME data dropout was experienced from a crosstrack station, which uncovered a basic mechanization problem in the DME updated modes. The memory location receiving incoming DME range from the I/O must be zeroed out every time it is read; otherwise, erroneous updates result when no new input data are received, and the last frozen value in the memory cell indicates that the airplane is moving in a circle around the DME station.

As test flights continued, the crosstrack errors observed at touchdown were sometimes excessive and generally larger than the 0.1 nmi that Litton had specified for the IDD mode. The basic problem was because the DME coverage was inadequate in the areas where the majority of test flights were being conducted–Paine Field (KPAE) and Moses Lake (KMWH). In both cases, DME stations to the north or south could be received at low altitudes, but no stations to the east or west could be received. The primary runways at KPAE, KMWH, and KBFI are all essentially north-south runways. Therefore, the lack of east-west DME updates was apparent in the XTKE observed at touchdown.

In attempts to improve performance, the following mechanization changes were incorporated during the flight test period:

- Relaxing geometry restrictions to allow IDD mode with two DMEs with relative bearing difference of $>30°$ (was 45°)
- Retaining velocity correction terms in the NCU for 10 min in the event of loss of DME updating
- Inhibiting DME updates when range is less than 2 nmi
- In IDX and IXD modes only, updating when the bearing to the DME is within $\pm 15°$ of a cardinal heading
- Inhibiting all update when bank angle is greater than 15°

After the first three changes were made, it became apparent that there was no problem in the IDD mode. Analysis of 22 recorded landings at KBFI beginning with flight 12 shows a mean error of 0.08 nmi with a standard deviation of 0.05 nmi.

Operations at KMWH proved that a problem existed with a single DME update (IDX or IXD). When operating at 10,000 ft during SID and STAR pilot operations, dual DME data–usually EPH and GEG–were received and crosstrack errors at touchdown were usually small. When operating at pattern altitude of 3000 ft, only EPH DME to the north could be received, and crosstrack errors were often large (see table 2-3). The last two changes listed

TABLE 2-3.—CROSSTRACK ERROR SUMMARY

Flight No.	Airport	Runway XTKE (nmi)	Notes
1	KBFI		Gross nav errors
2	KPAE KBFI	0.19L(16), 1.54L(16), 0.56L(16) 0.21L (13R)	
3	KMWH KBFI	0.10L(32R), 0.10R(32R), 0.35R(32R) 0.02L(31L)	
4	KBFI	1.05L(13R)	IDX modes only
5	KMWH KBFI	0.10L(32R), 0.20L(32R), 0.28L(32R) 0.21L(13R)	
6	KBFI	0.25R(13R)	
7	KPAE KMWH KBFI	0.44R(16) 0.67R(32R), 1.25R(32R), 0.10R(32R) 0.46R(32R), 0.07L(32R), 0.12L(32R) 0.03L(13R)	INS 2 excessive errors
8	KMWH KBFI	0.17L(32R), 0.50L(32R), 0.20R(32R) 0.42R(32R), 0.20R(32R), 0.02L(32R) 0.23L(32R), 0.10R(32R), 0.09R(32R) 0.20L(13R)	
9	KPAE KBFI	0.35R(16), 1.15R(16), 0.46L(16) 0.71L(16) 0.63R(13R)	INS 2 excessive errors
10	KMWH KPAE KBFI	0.13L(32R), 0.06L(32R) 0.35L(16) 0.45R(13R)	
11	KPAE KBFI	0.17R(16) 0.08L(13R)	
12	KMWH KBFI	0.15L(32R), 0.20L(32R), 0.05L(32R) 0.24L(32R), 0.15L(32R), 0.10 (32R) 0.05L(32R) 0.14L(13R)	DME update geometry changed
13	KMWH KBFI	0.28L(32R), 0.01L(32R), 0.17L(32R) 0.30L(32R), 0.03R(32R), 0.12L(32R) 0.01L(32R) 0.07R(13R)	
14	KPAE KBFI	0.14L(16), 0.11L(16) 0.07L(13R), 0.02R(13R)	
15	KPAE KBFI	0.15L(16) 0.05L(13R)	
16	KMWH KBFI	0.21L(32R) 0.15R(13R)	
17	KPAE KBFI	0.01R(16), 0.01L(16), 0.32L(16) 0.80L(16), 0.06R(16), 0.05L(16) 0.04R(13R)	
18	KMWH KBFI	0.11R(32R), 0.00(21), 0.10L(21) 0.15R(32R), 0.50R(32R), 0.88R(32R) 0.77R(32R), 0.48R(32R) 0.14R(13R)	DME mode to 3.4 sec memory time

TABLE 2-3.—CONCLUDED

Flight No.	Airport	Runway XTKE (nmi)	Notes
19	KPAE	0.02(16), 0.01(16), 0.12R(16) 0.01(16)	
	KBFI	0.06L(13R), 0.08L(13R)	
	KPDX	0.00(28R), 0.00(28R)	
	KSEA	0.10R(16R), 0.10R(16R)	
20	KMWH	0.00(21), 0.11L(32R), 0.50L(32R) 1.30L(32R), 1.10L(32R)	
	KBFI	0.10R(13R)	
21	KMWH	0.09(32R), 0.47R(32R), 0.10(32R)	
	KBFI	0.14(13R)	
22	KMWH	0.06L(32R), 0.03L(32R), 0.28L(32R) 0.56L(32R), 0.70L(32R), 0.35L(32R) 0.49R(32R), 1.05R(32R), 0.03L(32R)	
	KBFI	0.00(13R)	
23	KPAE	0.21L(16), 0.05L(16), 0.20L(16)	
	KBFI	0.01R(13R), 0.15R(13R)	
	KMWH	0.09L(32R), 0.85R(14), 0.47R(14) 0.00(32R)	
24	KMWH	0.05R(32R), 0.10L(32R), 0.00(32R) 0.00(32R), 0.10L(32R)	
	KBFI	0.12L(13R)	
25	KPAE	0.16L(16), 0.01R(16), 0.00R(16) 0.20L(16), 0.37L(16)	
	KBFI	0.02L(13R), 0.06L(13R), 0.17L(13R)	
26	KPAE	0.14L(16), 0.28L(16), 0.20R(16) 0.20R(16), 0.10L(16), 0.25L(16)	
	KMWH	0.05L(32R), 0.00L(32R), 0.08(32R) 0.00R(32R), 0.08L(32R), 0.44R(32R) 0.60L(32R)	
	KBFI	0.02R(13R)	
27	KBFI	0.05L(13R)	

above were incorporated in an attempt to improve IXD and IDX mode performance. Unfortunately, the changes were not evaluated at KMWH before the ADEDS flight tests were terminated.

The last change listed above is intended to prevent the DME memory mode of operation signal loss from introducing errors into the NCU position and velocity update. The digital DME was also adjusted by Collins to the minimum setting of 3.4 sec. After this adjustment, it was noticeable that the DME frequently dropped out during airplane acceleration away from or toward the station. The bank angle limit of 15° for DME update inhibit protects against DME memory operation during turns.

The VOR DME navigation modes were not used as primary modes because the VOR tuning is independent of the DME autotune. The mode was used with mixed results, and a maximum range limitation of 20 nmi to the VOR was incorporated to limit possible introduction of navigation error due to VOR bearing error.

The backup air data/mag heading mode (ADD) was also evaluated under cruise conditions. When the mode is initiated, there is an angular jump on the MFD equal to the drift angle. This is caused by track initially becoming equal to heading when INS data are lost. The error is corrected as the DME update corrects the velocity estimates and hence track angle.

The autotune mechanization was also improved during flight test.

- Search time per station was increased to 15 sec.
- The search pattern was increased from two to four stations.

The first change allowed more time for DME lock-on to occur. The second improved the chance of finding a valid DME in the situations encountered in the Washington area where mountains limit the number of stations that can be received when operating at low altitude. Trouble experienced with the autotune system during the flight test was eventually traced to a marginal RNI card in the NCU.

2.3.3.3 Navigation Control and Display Unit Software

No major changes were made in the NCDU software from the mechanization defined in the reference 3 requirements document. Minor changes incorporated included:

- NAV DATA 1 page error displays always relate to the flight plan regardless of autopilot mode.
- WIND is calculated using CAS when TAS <150, and windspeed calculation stopped when radar altitude is <5 ft.
- NAV DATA 3 VORTAC station frequency has M annunciation when selected by keyboard entry.

- PTA computation for the last leg changed to DTOGO/GS

- After a power interrupt, a new NCDU page is always transmitted.

The last change is to protect against keyboard lockup following a momentary power interrupt.

2.3.3.4 MFD Software

It was found that a 1-sec lag filter was required for a smooth presentation of trend vector on the MFD display. Also, double precision calculation and a 3-sec lag filter were required for the altitude range symbology.

The only new features added to the MFD during the flight test period were the addition of a reciprocal line to the radial symbol and the addition of data to the bottom of the display. The latter resulted from pilot requests for data to be continuously displayed on the MFD. The data displayed are:

- Map scale

- Groundspeed

- Windspeed and direction

- Guidance mode

Very few software problems were experienced during flight test relating to the MFD display. There were occasions when extraneous lines or conics appeared, but these were quickly traced and corrected. An unresolved deficiency was latitude/longitude grid lines being displayed in erroneous positions on some map scales.

2.3.3.5 EADI Software

A great deal of development time and software debugging effort were spent on the EADI software throughout the flight test period to correct deficiencies in the basic design and to correct software mechanization errors. Not all of these efforts were successful by the time flight test was terminated. Design changes mechanized were:

- Implementing a 5° pitch bias between the airplane symbol and the 0° pitch horizon

- Adding a 1-sec lag filter to flightpath acceleration (FPAC)

- Limiting FPAC to ±10

- Incorporating in the display system flightpath angle (FPA) flashing symbol when flare is initiated by the ICPS

- Simplifying the mechanization of speed error to transfer the data processing load to the display computer

Problems were encountered with both the VNAV star and circle and the runway symbology. Debugging these problems was successful to the point that the symbology was within screen limits and the displayed formats were correct. However, in some situations when all or part of the symbology was being limited within the screen coordinates, distortions and errors in the displayed presentation would result. The problem was minor for VNAV symbology, but the runway symbology could become distorted. This problem was not solved prior to the end of flight test.

A problem with the baro inertial vertical situation calculation had a profound effect on the EADI. Large vertical speed (HDOT) computation errors resulted when the airplane was on the ground during landing and takeoff runs. Noise rectification at the NCU A/D converter caused errors in the INS vertical acceleration input to the baro inertial loop and caused the flightpath angle symbol on the EADI to be in error during takeoff and landing. The problem was circumvented in the EADI software by forcing the vertical acceleration input to zero when radio altitude is less than 5 ft.

2.3.3.6 GUID Software

No changes were made to the basic 2D and 3D guidance routines developed in the simulator. Angle-of-attack limits were added, and a versine function was temporarily incorporated until the ICPS computer program could be modified to include it.

The time guidance (4D) mechanization was not changed, but the autothrottle control function in the NCU, which had not been fully developed in the simulator, was progressively developed as the flight test continued. Gains and limits were changed, control logic was modified, double precision computation for control integrators was introduced, and a versine function was added. The final configuration was a stable smooth-working autothrottle that did not overboost and was not overactive.

The flight director output from the GUID routine was tuned to pilot requirements by gain changes and a 3-sec lag filter.

The AGCS mode panel mode logic and displays are generated in the NCU software, and the mode selections control the guidance outputs from the NCU to the ICPS and autothrottle. Only minor changes were made to the mode logic during flight test; specifically, the method of canceling a preselect mode was simplified. Changes were also made to the ALT HOLD mode capture logic.

2.3.3.7 EXEC and Miscellaneous Software

Included in this category are software changes made to the power interrupt logic, I/O functions, and bulk data. The power interrupt software was modified to compensate for the design problem that existed in the NCU hardware.

Prior to the first flight, a wiring change was installed to change over the pitch and roll synchro inputs to engine pressure ratio (EPR) for the AGCS configuration. The NCU software was modified accordingly to process the EPR inputs and to receive pitch and roll from the SPBP input bus from the ICPS.

Frequent changes were made throughout the flight test to change the output parameters on the ARINC 561 output bus for data recording purposes.

Bulk data were updated periodically; specifically, the Whidbey Island TACAN (NUW) was added to improve DME coverage in the Paine Field area. A design error was also found and corrected to make all geographic reference points (GRPs) be referenced to a VORTAC or DME. All references to VOR-only navaids were deleted.

2.4 INERTIAL NAVIGATION SYSTEM (INS) PERFORMANCE

2.4.1 General

The basic ADEDS task required the installation of one INS to provide interface data to the displays. However, to support the performance of the AGCS test, three LTN-51 INS platforms were installed on the ADEDS test airplane. The ADEDS interfaced only with the system No. 2. Modifications incorporated by Litton (section 2.4.2) in order to meet ADEDS specifications resulted in undesirable side effects to the INS performance. This problem manifested itself as velocity errors that presented basic problems for the triple autopilot sensor error detection circuitry. Even after the specified performance was relaxed as described in section 2.4.2, only INS No. 2 operated successfully, and Litton was required to provide replacement INS units to attempt to correct this problem.

The navigation system failures/incidents No. 69 through 95 (appendix D) include 15 incidents relating to the INS, and some of these incident reports cover multiple occurrences of the same problem.

2.4.2 INS Modification

It was the intention that all the INS systems used in the flight test would be identically modified per ADEDS requirements in the interest of interchangeability. The modifications included increasing the horizontal acceleration resolution within the INS from 1/8 ft/sec to 1/256 ft/sec. This hardware change was exclusively for the ADEDS display functions. All three INS were also guaranteed by Litton to have a standard accelerometer in the vertical axis. (This is an option with the LTN-51 and consequently, unless specified, no great effort is made to calibrate this output during the LTN-51 checkout phase at the factory.)

The LTN-51 systems all had modified software to accommodate the horizontal acceleration resolution change and to provide the binary output data and rates required for ADEDS and the AGCS flight control computer. These are defined in the interface document (ref. 6).

The systems modified to provide 1/256 ft/sec horizontal acceleration would not navigate satisfactorily; therefore, the modification was changed to 1/64 ft/sec. Still only one system could be made to perform properly, so Litton provided initially two, and then one, standard LTN-51 system with a patch to the ADEDS software to overcome this deficiency to AGCS requirements. The one system that met ADEDS performance was used to interface with the ADEDS.

2.4.3 Summary of INS Performance

As a consequence of the modification to provide 1/256 ft/sec horizontal acceleration resolution, the flight performance of the modified INS system was unacceptable. The problem was not detected during laboratory and ground tests, but it became apparent immediately in flight when large groundspeed discrepancies (greater than 10 kt) were observed between the three INS systems. Also, large groundspeeds were indicated when stopped on the ground after flight. The characteristic of this problem was that the system navigation errors exhibited an unexpectedly large Schuler (84.4-min period) oscillation, whereas the underlying long-term gyro drift errors appeared to be quite small.

The magnitude of the Schuler oscillation varied from system to system. SN 094, which was used extensively throughout the flight test, was an example of this problem with GS errors consistently of the order of 10 kt, as shown in table 2-4. A normal system will have a groundspeed error no greater than 5 kt after a 3-hr flight. Table 2-4, which summarizes the INS performance, shows the time in navigation (NAV) mode, the flight time, and the latitude (Δ LAT) and longitude (Δ LON) errors in minutes per flight hour. It can be seen that the long-term navigation error of the LTN-51 was well within their 2-nmi/hr 2-sigma specification, despite the Schuler oscillation problem. Rarely did the error rate exceed 1 arc min per flight hour in either axis unless the system was faulty.

Litton was unable to solve the Schuler oscillation problem with the 1/256 ft/sec acceleration, so Boeing allowed a relaxation of the resolution requirement to 1/64 ft/sec acceleration. After the modification was incorporated, one system, SN 406, performed well within specification; one system, SN 094, continued to exhibit consistently large Schuler oscillations; and the third system, SN 748, exhibited an intermittent problem whereby extremely large groundspeed errors (up to 54 kt) would appear during turns. Because of this, many of the flight tests were conducted with one unmodified INS (SN 766) in the No. 1 or No. 3 position. On one flight, use of the INS SN 776 in the No. 2 position proved that the decreased acceleration resolution caused visible granularity of acceleration dependent symbology on the EADI and MFD displays.

The failures/incidents recorded in the INS systems during the flight test period are shown in appendix D. A breakdown of the 15 failures/incidents charged to the INS system is as follows:

- Excessive velocity errors 5
- Excessive position error 1
- WARN indications 4
- Software problems 5

TABLE 2-4.–INS PERFORMANCE SUMMARY

Flight No.	NAV hr	Flt hr	INS 1 SN	INS 1 Δ LAT (minutes/ flt hr)	INS 1 Δ LON (minutes/ flt hr)	INS 1 Δ GS (kt)	INS 2 SN	INS 2 Δ LAT (minutes/ flt hr)	INS 2 Δ LON (minutes/ flt hr)	INS 2 Δ GS (kt)	INS 3 SN	INS 3 Δ LAT (minutes/ flt hr)	INS 3 Δ LON (minutes/ flt hr)	INS 3 Δ GS (kt)	Comments
1	2.5	1.7	094	0.71	0.18	3	406	0.71	0.71	7	039	0.24	4.88	9	SN 094 had WARN in NAV mode preflight
2	4.7	3.1	094	2.61	1.06	14	406	0.10	0.58	4	–	–	–	–	SN 039 rejected
3	2.6 4.1	1.9 3.4	094 –	9.58 –	3.00 –	10 –	– 406	– 0.03	– 0.71	– 5	– –	– –	– –	– –	SN 094 shut down and realigned at KMWH; rejected for excessive error
4	3.9	3.0	–	–	–	–	406	0.13	0.30	7	094	0.87	0.03	20	SN 406 and 094 rejected for GS errors
5	7.0	3.0	753	0.50	0.87	1	748	0.20	0.33	3	766	0.03	0.07	3	SN 748 modified to 1/64 ft/sec/pulse; SN 753 and 765 unmodified
6	2.75	1.9	406	0.32	0.53	1	748	0.21	0.11	2	766	0.05	0.05	0	SN 406 modified to 1/64 ft/sec/pulse
7	4.7 3.0	2.3 2.5	406 748	1.65 0.52	0.22 1.48	1 2	748 406	0.61 0.24	0.09 0.08	2 4	766 766	0.48 0.84	1.74 0.60	1 1	SN 748 had 30-kt GS error in flight
8	4.0 2.6	3.0 2.3	748 748	0.63 0.48	0.57 0.96	1 2	766 766	0.17 0.26	0.30 0.87	2 1	406 406	0.23 0.48	0.43 0.17	7 8	
9	4.5	2.3	766	0.17	0.04	1	748	0.39	0.39	1	094	0.22	0.13	8	SN 748 had 17-kt GS errors in flight and was rejected; SN 094 modified to 1/64 ft/sec/pulse
10	4.3	3.4	766	0.03	0.03	2	406	1.26	0.29	6	094	0.29	0.50	6	
11	2.5	1.3	766	0.31	0.54	1	406	0.23	0.54	2	094	0.31	1.08	11	
12	4.5 2.0	4.1 1.5	766 766	0.17 0.27	1.49 0.80	4 1	406 406	0.31 0.20	0.39 0.13	2 1	094 094	0.15 0.27	0.49 1.13	5 3	New software
13	6.6	6.1	766	0.30	0.43	2	406	0.98	0.20	3	094	0.26	0.02	8	
14	1.8 2.0	1.2 1.2	766 766	0.25 0.33	0.08 0.58	1 1	406 406	0.08 0.25	0.58 0.75	2 1	094 094	0.25 0.17	0.17 0.17	5 3	
15	1.5	1.1	766	0.91	1.09	2	406	0.27	0.45	1	094	0.27	0.54	4	

TABLE 2-4.—CONCLUDED

Flight No.	NAV hr	Flt hr	INS 1 SN	INS 1 Δ LAT (minutes/ flt hr)	INS 1 Δ LON (minutes/ flt hr)	INS 1 Δ GS (kt)	INS 2 SN	INS 2 Δ LAT (minutes/ flt hr)	INS 2 Δ LON (minutes/ flt hr)	INS 2 Δ GS (kt)	INS 3 SN	INS 3 Δ LAT (minutes/ flt hr)	INS 3 Δ LON (minutes/ flt hr)	INS 3 Δ GS (kt)	Comments
16	2.2	0.7	766	0.14	0.43	1	406	1.43	0.14	1	094	1.71	3.71	2	
	1.2	1.0	766	0.30	0.90	2	406	0.40	0.10	1	094	0.40	1.30	4	
17	3.5	3.0	—	—	—	—	—	—	—	—	094	0.13	0.80	18	SN 094 realigned at KPAE because of GS error
	5.9	5.3	766	0.34	0.02	4	406	0.57	0.08	3	—	—	—	—	
18	6.3	3.4	766	0.03	0.94	2	406	2.09	0.85	4	094	0.85	0.24	11	
19	3.2	2.9	766	0.10	0.55	2	406	0.07	0.55	2	094	0.14	2.38	20	
	2.2	1.8	766	0.06	0.22	3	406	0.67	0.06	3	094	0.94	1.11	8	
20	4.6	3.1	766	0.26	0.35	2	406	0.26	0.03	3	094	0.65	1.39	10	
21	3.0	2.5	766	0.40	0.36	2	406	0.16	0.12	2	094	0.40	0.36	4	
22	4.0	3.0	766	0.13	0.53	1	406	0.20	0.13	1	748	0.27	0.03	1	
	2.0	1.6	766	0.31	1.19	2	406	0.06	0.31	0	748	0.25	0.25	1	
23	1.5	1.1	766	0.36	0.27	2	406	0.27	0.36	1	748	0.09	0.45	2	SN 748 had -32 kt GS error in flight
	3.1	2.8	766	0.19	0.36	2	406	0.04	0.14	2	748	0.21	0.42	19	
	2.6	2.2	766	0.45	1.05	2	406	0.18	0.41	3	748	0.14	0.14	5	
24	6.1	5.5	766	0.29	0.31	2	406	0.22	0.05	2	748	0.22	0.20	1	
25	3.2	2.4	766	0.17	0.21	2	406	0.08	0.25	3	748	0.17	0.04	3	
	3.1	1.1	766	0.27	0.27	1	406	0.73	0.27	1	748	0.09	0.18	3	
26	6.9	6.3	766	Automatic shutdown; no data			406	0.13	0.33	1	748	0.40	0.13	5	SN 766 failed in flight.
							—	—	—	—	—	—	—	—	
	2.8	2.3	094	0.83	1.91	3	406	0.45	0.45	1	748	1.05	0.20	1	SN 094 failed in flight.
	2.4	2.0	094	Automatic shutdown; no data											
27	2.5	1.0	094	1.00	0.90	8	406	0.60	0.10	1	748	0.40	4.00	19	SN 748 had -25 and and -54 kt GS error on both flights
	2.3	1.6	094	Automatic shutdown; no data			406	0.25	0.63	3	748	0.13	5.31	44	SN 094 failed in flight

Six INS systems were utilized during the flight test period. These were:

1) SN 094 (modified) — Large GS Schuler errors before and after modification, changed to 1/64 ft/sec; failed twice in flight in NAV and ATT modes

2) SN 406 (modified) — Good performance after modification, changed to 1/64 ft/sec

3) SN 039 (modified) — Rejected for large navigation errors, withdrawn when unable to isolate the problem

4) SN 748 (modified) — Replaced SN 039. Intermittently exhibited large GS errors

5) SN 766 (unmodified) — Excellent performance until failed in NAV and ATT modes on penultimate test flight

6) SN 753 (unmodified) — System loaned for one flight

2.4.4 INS Software

The INS software package was modified for ADEDS in accordance with the reference 3 requirements document. These changes included magnetic variation computation and fast rate digital data outputs to the NCU and ICPS systems.

Errors were found during flight test in this modified software package. These errors included a scaling error in the velocity outputs to the NCU, which caused complete loss of ADEDS navigation capability during the first half of the first engineering test flight. Other errors in the INS acceleration outputs and true heading computation rate also compromised the NCU computation of the MFD trend vector display and the EADI symbology dependent upon drift angle. The first problem was corrected by the 3rd flight, but the true heading output problem was not diagnosed and corrected until the 12th test flight. The only other significant INS software problem involved the logic for receiving runway heading data from the NCU.

Additional software changes were made in the INS to provide interface data for the ICPS. These changes provided two identical track angle errors and one groundspeed output five times per second. Unfortunately, the groundspeed error problems experienced with the INS system frequently caused discrepancies in these functions between systems and caused nuisance first failure indications in the ICPS.

3.0 FLIGHT TEST RESULTS AND COMMENTS

3.1 FLIGHT TEST DATA

Reference 4 provides a detailed description of the instrumentation data recording and processing utilized in the ADEDS flight tests. The data acquired during the 53 hr of flight testing were subjected to different levels of processing. Data acquired during the engineering acceptance phase of the tests were processed as quick-look time history plots and printout for system troubleshooting and debugging. Data recorded during the operational evaluation phase, including demonstration flights, were processed to provide overall time history plots of each variable and, for selected variables and time intervals, were reprocessed to provide summary statistics.

Flightcrew manual notes and video recordings of the displays taken during flight were used extensively in identifying the time intervals of interest for detailed analysis. These notes identified the test condition, i.e., the procedure (path) being flown, the guidance option used, and the experimental system pilot or autopilot. A manual log was maintained of the approximate arrival times at each waypoint in order to correlate the waypoint crossing time events in the digital data and time history plots. The manual notes were also used to record events such as traffic diversions or other excursions from the planned flight profile to aid in identifying the meaningful data segments on the magnetic tape.

A review of the test logs and manual notes identified 163 such segments in the operational evaluation and demonstration flight phases. These data segments were then stripped off the flight tapes for detailed statistical processing.

The statistical processing of the data segments was performed on the EAI 8400 computer and consisted of computing the average value, rms value, and standard deviation for each of eight variables over each leg of the procedure flightpath in the data segment and identifying and posting the maximum and minimum values of each variable on each leg. Time histories of the raw data values and the rms values were concurrently plotted in order to identify dropouts, overflows, or other data quality problems resulting from onboard recorder problems or experimental system malfunction.

Using the manual notes and the time history plots, the statistical data printouts were then annotated to identify the appropriate path legs from which the samples were obtained. This was done by assigning the waypoint name representing the end waypoint of each leg to the statistical value corresponding to the processed sample. The data from the printouts were then posted to data sheets, which organized the data samples by path procedure and by waypoint for each piloted run and autopilot-coupled run. These data sheets are contained in appendix B of this report. In reducing the volume of test data to arrive at aggregate statistical measures for performance comparison and comparison of flight test results with simulation test results, only the primary guidance error variables were selected. These were crosstrack error (lateral deviation from the flight path), altitude error (vertical from the flight path), and time error (deviation from the schedule).

As noted in reference 4, the scope of the ADEDS program did not include a detailed measurement of the navigation accuracy of the system and, moreover, a nominal navigation accuracy of 0.1 nmi was specified as adequate for the flight tests. The navigation accuracy achieved during these tests was sampled during the flights and is discussed in section 2.1. For the purposes of the operational evaluation flight tests, the navigation errors affected the test results only at certain waypoints, inasmuch as these tests focused upon and measured only the tracking errors as the performance variables of primary interest. The navigation errors were thus noticeable only on flightpath legs that included waypoints fixed on the runway, such as brake-release points (BRP), lift-off points (LOP), or touchdown zones (TDZ). Because of the effect of navigation errors on the guidance errors, the results for such waypoints were not included in the performance data summaries.

In evaluating performance, a measure of the "tightness" of tracking was desired. The mean deviation from the path reference values was thus rejected as a performance measure, and the standard deviation, which reflects the variability of the data sample, was chosen. Table 3-1 summarizes the overall tracking performance observed during the operational evaluation test phase. The guidance error values listed were obtained by computing the arithmetic mean of the respective data sample standard deviation.

As a qualification on the data presented and as a recommendation for further testing of this type, it should be noted that a more meaningful measure of performance results would be obtained by using an amplitude probability distribution of the observed guidance errors. This type of data processing would provide a measure of the percentage of time that the errors exceeded given values and thus would be more useful in determining effective route widths or altitude bands usable in path oriented flight operations.

In examining table 3-1 it is apparent that the tracking performance yielded by all guidance options is comparable, i.e., less than 0.2-nmi lateral error, less than 150-ft vertical error, and less than 5-sec schedule error. Furthermore, the performance with the pilot in the guidance loop is not substantially different from the performance with autopilot and autothrottle coupling to the guidance loop. In regard to this point, it should be noted that control law modifications and other performance improvements were being made to the experimental autopilot throughout all phases of the ADEDS flight test period. While the autopilot performance does not therefore represent the performance of a completely developed system, coupled mode data were nevertheless acquired both for flight demonstration purposes and for providing a performance baseline for comparison with pilot-in-loop performance.

Table 3-2 provides a more detailed breakdown of the performance data in relation to the type of path segment from which the data were acquired. The simulation tests of reference 5 were obtained using a single, standard test path. The flight tests were performed using path configurations appropriate to weather and traffic conditions chosen from the experimental path catalog of reference 4 and supplemental test paths of appendix C of this report. In the reduction of the flight test data, the data were classified by the type of path segment or leg as shown in the description column of table 3-2.

Examination of table 3-2 reveals that the tracking performance on departure paths is, in general, less precise than the performance on arrival paths. This is, in part, because of the

TABLE 3-1.—SUMMARY COMPARISON OF PRIMARY GUIDANCE ERRORS BY GUIDANCE OPTION

Guidance error variable	Autopilot coupled mode	Manual or CWS operation				
		Flight director	Vertical deviation only	Vertical deviation with waypoint	Path perspective situation	Path perspective command
Crosstrack error (ft)	376	554	978	774	371	398
Altitude error (ft)	113	139	70	73	88	105
Time error (sec)	3.68	2.84	3.84	2.87	3.65	3.22

TABLE 3-2.—SUMMARY COMPARISON OF PRIMARY GUIDANCE ERRORS BY TYPE OF PATH SEGMENT

Leg type description	Crosstrack error (ft)		Altitude error (ft)		Time error (sec)	
	Auto	Manual	Auto	Manual	Auto	Manual
Arrival Path Segments						
1. Straight and level (or shallow descent)	167 *31	631 59	24 27	85 60	1.70 29	2.48 58
2. Straight, steep descent	— 0	604 15	18 1	167 15	8.90 1	3.47 14
3. Curved, decelerating descent	486 29	1198 16	74 12	95 14	2.82 23	4.34 15
4. Final approach fix	72 9	132 21	31 6	31 32	1.17 9	3.98 20
Departure Path Segments						
5. Initial climb legs after lift-off	299 16	248 47	106 16	75 47	2.83 15	2.44 42
6. Curved, climbing, accelerating	649 23	937 36	238 21	104 34	6.90 20	4.22 33
7. Speed-limited straight climb (below 10,000 ft)	519 24	647 48	114 24	115 46	5.43 22	2.93 42
8. Straight climb to 11,000 ft or higher	159 23	606 39	161 21	131 39	5.58 18	4.73 39
Cruise Segment						
9. En route	236 20	662 13	113 20	76 13	2.39 22	1.28 12

*Indicates sample size

nature of crew workload on takeoff and the priorities given to path-tracking tasks as opposed to airplane configuration changes, engine performance monitoring, airplane systems checklists, and communications with traffic control. In contrast, the same categories of tasks are less compressed in time during arrival and approach operations. Another general trend in the data is seen by comparing the performance on curved path segments to that on straight segments. As expected, the tracking performance decreases with paths of more dynamically complex configurations.

Of more interest is the general level of tracking precision over all the test conditions. In spite of the limited size of the data sample, the results support the feasibility of 3D and 4D path operations. Of special interest is the performance on path legs leading to a final approach fix as shown in line 4 of table 3-2. These results, obtained with an experimental system under development and with limited time for training and development of optimum procedures, should encourage further development efforts and testing toward the eventual implementation of this type of operation.

3.2 OPERATIONAL DESIGN CRITIQUE

This section summarizes the subjective reactions of two categories of observers during the course of the flight testing: flightcrews, including both Boeing engineers and flight test and training pilots as well as qualified pilots from airline, military, and other Government agency organizations; and Air Traffic Controllers from local ARTCC, Approach Control, and Tower facilities.

3.2.1 Flight Crew Comments

This section represents a consensus of comments, criticisms, and recommendations of the various qualified flightcrew members participating in the program.

3.2.1.1 Overall System Operational Concept

A primary objective of the ADEDS program was to assess the feasibility of 3D and 4D path operations for commercial transport aircraft. This type of operation is markedly different from the existing operational environment and requires changes, not only to the onboard systems, displays, and crew procedures but also to the airspace structure and traffic control facilities and procedures. Since the scope of the program did not permit the establishment of a complete, experimental airspace and airspace management system, the ADEDS flight tests concentrated on the questions of onboard system operation, pilot technique, and crew procedures, and the development of a data base for both the quantitative measures of system performance and the subjective evaluation and composite judgment of a cross section of pilots.

Fundamental questions in the area of 3D and 4D operational feasibility were related to the problem of flying an aircraft in accordance with a groundspeed and time schedule and the level of attention that the crew must devote to tracking such paths. The task of managing the aircraft trajectory to minimize lateral and vertical deviations is, of course, increased when the additional burden of maintaining along-track control or schedule keeping is added. This problem requires additional information for the crew. The content and presentation of this information to the pilot in the form of CRT display formats and symbology was the primary focus of the ADEDS program. It should be noted that there has been an increasing use of speed and arrival time control for traffic spacing in the present ATC system. The use of voice vector speed commands is commonplace for air carrier operation in terminal areas of even moderate traffic density.

The ADEDS flight tests clearly demonstrated that path-oriented operations are feasible and do not place an undue burden on the total piloting task, with path designs properly matched to ambient weather conditions. In particular, the management of thrust and speed for schedule keeping on 4D paths does not add an undue workload to the pilot. The addition of path-following features to the autopilot, of course, provides a reduction in workload during this type of operation, and coupled automatic modes may be the standard operating procedure in line operation.

During the flight test period, four types of departure paths and four types of arrival paths were flown. In general, these path configurations were conservatively configured with respect to the 737 performance envelope. As expected, the two-segment arrival paths were most sensitive to variation in pilot technique.

3.2.1.1.1 Departure Paths—The four types of departure paths flown were standard departure, noise-abatement climbs, departure turns, and close-in turns. A general impression resulting from the experience in flying the departure paths is that time control should be deemphasized, at least in the early stage of the departure, for more efficient energy management. Adherence to the 3D representation of the path presented no problems during this phase of flight, and the path operation concept presumes a network of diverging departure paths that provide adequate separation without strict time control. The thrust changes required to adhere to schedules during this phase of flight would, in general, increase fuel cost and crew workload without a corresponding advantage in separation. In other words, the departure path design should emphasize getting the aircraft to a transition altitude (10,000 to 18,000 ft) as quickly as possible with a looser tolerance on time control. The standard departure paths and noise-abatement climb departures were, in general, conservatively defined with respect to aircraft performance. The addition of the 3D path capability via the system and its displays yields much more precision in the performance of these maneuvers and, in an operational system, would lead to more detailed and timely information for use by both the flightcrew and the ATC controllers.

The curved climbing departure paths were of special interest due to their potential use for avoiding highly noise-sensitive areas or traffic conflict areas in departure operations. The system capability for defining and displaying these paths opened up new operational capabilities that could be usefully applied to many operational problem areas today. The pilot and crew tasks involved in executing these types of maneuvers are straightforward and present no unusual problems. Useful path configurations can be devised for both departure turns and close-in turns that are well within both the aircraft and flight control system performance and passenger comfort limits.

3.2.1.1.2 Arrival Paths—Four types of arrival path configurations were also flown: standard, straight decelerating, steep two-segment, and curved descent paths. As was previously mentioned, the two-segment approaches proved to be the most difficult type from the standpoint of adhering to precise time schedules. Slight changes in the gear and flap extension schedules were found to be helpful in executing the steep segments. By extending the gear at altitude and slowing the airplane to a value under the 5° flap placard prior to initiation of steep segment provided sufficient drag to permit further speed and flap adjustments with only minor excursion above the vertical profile. In line operations, the path configurations could be defined so that the aircraft is slowed to an airspeed well within the placard for higher flap settings to permit a higher rpm setting for engine anti-ice provisions.

The straight decelerating approach profiles presented no special problems. No attempt was made during these limited flight tests to tailor the path configuration to an optimum speed, thrust setting, and flap extension schedule.

The curved, descending, decelerating approach paths were of most interest and were extremely successful. The MFD map presentation provides excellent orientation for precise lateral tracking, and the EADI flight director or other vertical guidance options provide the information for vertical tracking. The execution of these types of paths, even with the added task of schedule control, is straightforward and routine.

3.2.1.2 System Mechanization

3.2.1.2.1 General—The CRT displays, as mechanized for these flight tests, were notably sharp and clear. Problems with noise and jitter early in the tests were resolved in the late stages of flight, as were the earlier problems of display reliability. The problem of contrast under high ambient light conditions, while greatly reduced by the filtering provided, still remains when the displays are illuminated by direct sunlight. Although 100 foot lamberts of brightness was considered adequate, it appears that specific study and additional testing are required prior to specifying this design criterion for production systems. The required effort should consider brightness, filtering, and type of phosphor. Investigation of the ADEDS EADI brightness problem continued after completion of the flight test. This investigation included a spectrum response check of a sample of the EADI filter glass by Boeing Aerospace. Results of this test revealed a large passband in the blue spectrum that would partially account for the bluish tint of the display. A large passband in the near infrared range was also found which would partially account for some of the degradation in high ambient light. These filter deficiencies were verified by GE and followup coordination with their filter supplier was initiated.

The mode control panels for the EADI and MFD displays were, likewise, vulnerable to washout in direct sunlight. This was especially true of the LED readouts for decision height setting and flightpath angle reference settings on the EADI mode control panel. It is, however, recognized that the ADEDS installation in the test aircraft was subject to a number of compromises and that no problems were encountered that could not be overcome in the design and installation of a production system.

A strong recommendation is made that future operational systems employing automatic, multisensor navigation systems be mechanized so that independent navigation solutions are available for reasonableness checks and appropriate annunciations or warnings in the event of malfunction of some portion of the combined navigation process. Subtle failures in the updating of the map presentation may go undetected in the present mechanization.

The ADEDS navigation system outputs the result of the combined navigation process, and while the individual sensor outputs can be examined and cross checked, the system should embody some form of automatic cross-checking and annunciation of the difference between the combined navigation solution and the individual sensor inputs. Examples of the type of reasonableness checks that could be applied are:

1) The LAT/LON outputs of the combined navigation could be differenced with the INS outputs. The differences could be compared against tolerance values and an appropriate annunciation could be executed when the difference exceeds this value.

2) The radio-navigation inputs could be processed separately to yield a position measurement in LAT/LON coordinates, which could then be differenced with the NCU outputs. Exceeding a reasonable error bound could be annunciated. The annunciation would only convey the message that the difference exists, not that one computation or the other is in error. To minimize false alarms or nuisance alerts, the excesses could be counted and the annunciation made only in the event that an arbitrary number of excesses occurred.

3.2.1.2.2 EADI–The basic EADI format, TV scene, guidance options, ILS information, and artificial runway symbol are described in the following paragraphs.

Basic EADI Format: The basic EADI format is an improvement over the existing ADI and artificial horizon instruments. This improvement is, in part, due to the increased resolution that results from the larger size of the EADI. The flightpath angle symbology adds extremely valuable velocity vector information to the format. The velocity vector in conjunction with the potential flightpath or flightpath acceleration symbol provides a thrust management capability and more precise overall operation.

The 5° bias in pitch attitude does help to decrease clutter in the center of the display; however, it tends to detract from the assessment of angle of attack. An indication of angle of attack or some parameter such as alpha margin could be added at the side of the EADI to overcome these objections.

EADI TV Scene: During the approach phase of flight, superposition of the forward-looking TV scene on the EADI provides valuable additional information that is independent of other sensors and processes. While the camera system used in the flight test exhibited some problems in picture quality (i.e., blooming of approach and runway lights under night conditions and loss of resolution during operations into severe glare conditions on the runway), this feature provides useful information for maintaining proper lateral adjustment with the runway. The estimation of the touchdown point on the runway is improved with the velocity vector information superimposed on the TV scene.

EADI Guidance Options: In addition to the basic format with flight director, four different guidance options were used in the operational evaluation test flights. The results of these test flights are summarized below.

1) The lateral and vertical guidance provided by the flight director satisfies the display requirements for 3D path operation. Although this symbology is referenced to the airplane attitude rather than velocity vector information, pilot familiarity with this format resulted in a strong pilot preference for this option.

2) The path perspective options (PPS and PPC) are both referenced to the velocity vector symbology. While this factor tended to focus pilot attention on flightpath angle and, indirectly, on thrust management symbology and cues, the interpretation of this symbology is sufficiently different that a number of adverse comments were recorded. The command version of this symbology (PPC) received slightly higher acceptance due to the nature of the control law centering of the symbology. The lack of an acceptable velocity CWS mode in the autopilot undoubtedly had an adverse effect on the evaluation of the symbology, inasmuch as the CWS mode is designed to hold velocity vector settings and thus reduce the tracking workload.

3) The two guidance options, vertical deviation only and vertical deviation plus waypoint, were designed to force the pilot to split the path-tracking task into two distinct components—lateral deviation and vertical deviation—and thus to force a continuous scanning pattern over both the EADI and MFD. As expected, the perceived pilot workload was increased and the tracking performance was adversely affected.

In summary, 3D and 4D path tracking was acceptable with all guidance options used; the differences observed between tracking performance are considered to be largely due to pilot familiarity with the symbology.

Further development effort is recommended in this area. Flightpath angle or velocity vector display is a valuable addition to the complement of information available to the pilot. This is true not only for 3D and 4D path operation but also for operation in today's environment. There were some comments to the effect that the flightpath angle information was sufficient for all pilot tasks and that the aircraft attitude information should be removed from the EADI format to reduce display clutter. While this argument has some merit, it is felt that both attitude and flightpath angle information are useful and that continuous presentation of attitude information, in particular, is required for safety-of-flight considerations. Formats that emphasize flightpath angle and also portray alpha margin or some other measure of pitch attitude should be developed and evaluated in future studies of this type.

EADI ILS Information: Reference 3 describes the mechanization selected for presentation of ILS information. The rectangular symbol is driven, at high sensitivity, by the raw localizer deviation and glide slope deviation signal from the ILS receiver and is intended to be used solely as a monitor of autoland system performance. During the course of the flight test, an alternative presentation of raw ILS data was desired. Two alternative presentations were devised with lowered deviation sensitivities that were more compatible with pilot responses.

While the limited amount of test time precluded the development of optimum presentations for manual approaches, the experience points to the usefulness of raw ILS presentations and need for separate formats for autoland and manual approaches.

EADI Artificial Runway Symbol: The artificial runway symbol is a useful display feature in the initial phases of the approach. When navigation errors are not excessive, the symbol provides useful guidance information in setting up the proper final approach path. When this symbol is superimposed upon the TV scene, however, the effect of navigation errors becomes increasingly more distracting as the range to touchdown decreases.

It is strongly recommended that the combined navigation process be modified so as to include ILS information. This would reduce the crosstrack component of navigation error on final approach to a level well within tolerance and would thus eliminate the distracting influence of the artificial runway symbology. At some point on the approach, the TV scene of the actual runway is sufficiently sharp and clear to provide all the necessary information on alignment and thus obviates the need for artificial cues. While schemes for automatic removal of artificial runway symbology could be mechanized, the provisions for manual selection of symbology are felt to be sufficient and less confusing.

3.2.1.2.3 MFD—The MFD was designed and used exclusively as a map presentation or horizontal situation display throughout the ADEDS program. The ADEDS MFD presentations were highly successful and emphasized the utility of such displays and their value in maintaining an easily interpreted orientation during flight.

As in all such CRT displays, the information density at high map scales can result in display clutter and unreadable symbology if the mechanization does not provide the selective control of symbology or for some scheme for symbol priority. The ADEDS mechanization employed a display mode control panel with pushbutton switches to provide symbology selectivity. A limited amount of automatic symbol selectivity was provided in the case of the radio navaid symbology; i.e., radio navaids that are not part of the high altitude route structure are not displayed at the 32 nmi/in. map scale.

The MFD map scales, orientation, altitude/range symbology, and radial and track select symbology are described in further detail below.

MFD Map Scales: The map scales available on the ADEDS are 1, 2, 4, 8, 16, and 32 nmi/in. While this choice of scales is more easily mechanized, a preferable system should be devised. One such scheme might be a semilogarithm scale selection such as 1, 3, 5, 9, 15, and 25 nmi/in. This would provide a less abrupt change of presentation with map scale changes.

MFD Orientation: Both track-up and north-up map presentations were provided by ADEDS. The desired orientation was selectable by a switch on the MFD mode control panel. The track-up mode was found to be the only useful orientation for execution of the flightpaths (i.e., tracks, the flightpath using manual, CWS, or select/hold modes). The north-up presentation is highly valuable for nonpilot operation such as generating, reviewing, or modifying a flightpath including momentary referral when in autopilot coupled path modes. It is desirable to have the capability for both orientations as each has its specific uses.

MFD Altitude/Range Symbology: The depiction of altitude intercept points on the MFD map presentation was highly successful and provides extremely useful information for climb and descent. A suggestion is made that the setting of the reference altitude should be made more easily, perhaps by using the autopilot altitude select knob rather than the NCDU select page. The information provided by this feature is predictive information not provided by any conventional instrumentation and removes much of the guesswork regarding the effects of thrust setting and aircraft performance upon climb and descent capabilities.

MFD Radial and Track Select Symbology: Two display features that were useful in the presentation of relative bearing information were the radial symbol and the track select symbol.

The radial symbol depicts the desired bearing relative to a navaid facility or navigation fix while the track select symbol depicts the relative bearing of the airplane's predicted track as selected using the autopilot track select knob. Both symbols provide a graphic presentation of the guidance situation, which is extremely useful and is not available with conventional aircraft instrumentation.

3.2.1.2.4 NCDU—With the advent of inertial navigation systems and an increasing implementation of (R-Nav) systems in commercial aircraft, the use of keyboard entry devices and keyboard/display units for the crew's interaction with such systems is becoming more common. The operational design of such devices and the matching of these units to crew tasks and procedures is a formidable task and represents a major challenge in the development and acceptance of advanced avionics systems.

The ADEDS keyboard/display was the navigation control and display unit (NCDU) and consisted of a 7x7 keyboard matrix together with an 8-line (24 characters per line) cathode ray tube display for alphanumeric readout. While the NCDU design fulfilled the functional and operational requirements of the ADEDS program, further design, development, and evaluation efforts would be required to simplify and clarify the crew system interactions necessary for a system in line operations.

The operational evaluation of the NCDU was burdened by several facets of the ADEDS program. First among these was the experimental nature of the program and the associated requirements for the functional flexibility to evaluate different system configurations. These requirements led to the inclusion of functional options in both display formats and navigation-guidance modes that were ideally controlled through the NCDU. The result was an extensive use of keyboard display formats and of keyboard procedures for reconfiguring the system.

Another facet of the program which tended to distort the evaluation of the NCDU is related to the artificiality of the test flights in representing a true operational environment. Typical flights consisting of takeoff, departure, cruise, arrival, approach, and landing were accomplished in 15 to 30 min as opposed to line operations where these procedures would span a longer time period. The resulting time compression led to an impression of an overly busy use of the keyboard.

The prohibitive cost of the ground support and test equipment necessary for magnetic tape or magnetic data card entry of flight plans and clearance necessitated the use of the keyboard for this purpose. For an operational system, the entry of flight plans would take place during the preflight checkout of the airplane and systems by the use of tape cassettes or other memory storage and transfer devices that minimize lengthy keystroke sequences. The keyboard would thus serve as a device for detailed review of the flight plan for verification and possible alteration. At the same time, the keyboard is the best means for modifying a flight plan if it becomes necessary in flight. The language, procedures, and display interaction developed for this program were exceptionally useful and are readily applicable to future operational systems.

While limitations of time precluded an extensive training period for all flightcrew members, the basic functional layout of the keyboard is well suited both to the experimental flight testing of this program and to the development of prototype operational systems as well. The automatic compilation of detailed flight plans from the abbreviated ATC clearance (ATC CLR) language is especially useful in reducing the amount and complexity of keyboard operations. One suggested addition to the flight plan page formats would be the inclusion of the initial heading or track angle for each leg. While this information is readily available on the MFD display, it would serve as a usefully redundant bit of information during preflight system checkout and would also be of value, if not a necessity, during malfunction of the MFD display.

The navigation data (NAV DATA) formats were normally referred to during the execution of the flightpaths and provide a continuous presentation of current status information in alphanumeric form. The number of items in this category necessitated the mechanization of three such pages, accessible by successive presses of the NAV DATA mode key. While this mechanization does provide access to all the desired information, it is desirable to provide full-time display of some of these data on other displays or instruments for immediate viewing. Examples of modifications to the display format made during the flight test period were:

1) Groundspeed—The usefulness of groundspeed as a control parameter led to the continuous readout of groundspeed, in digital form, in the lower right corner of the MFD.

2) Wind—The current measured values of wind speed and direction were also found to be useful references and were displayed on the MFD.

3) Navigation mode—The usefulness of this information was primarily for the purpose of system debugging and testing. The information was also displayed in the lower right corner of the MFD.

A primary information element requiring full-time display is information concerning the current state of the automatic tuning (autotuning) feature of the navigation system. While the frequencies and identifiers of the radio navaids being used were displayed on NAV DATA page 3, it was felt that this information should be displayed full time. Accordingly, the identifier codes for the active navaids were added to the MFD display in the course of the system flight tests. A recommendation for an operational system of this type would be to modify the panel indicators for the DME readouts to include the three-letter identifiers, and frequency of the active navaids as well as the DME distance from the navaid. Replacing the electromechanical drum-type distance readouts with bright LED panels to include I.D. and frequency information would be one way to accomplish this.

In summary, advanced navigation and guidance systems such as INS, R-Nav, or ADEDS-type systems provide new system functional and operational capabilities that have great potential benefit. Their initial impact on flightcrews, controllers, and design engineers can be described as an information explosion. Traditionally, the design of aircraft flight deck instrumentation, display, and controls has been to assign dedicated cockpit space for each function and information element necessary or useful to the conduct of flight. The magnitude of the information explosion associated with these emerging capabilities precludes the traditional design approach in incorporating the new technology. The ADEDS NCDU design is one approach to viable solutions in this area and should serve as a departure point for further study.

3.2.2 FAA-ATC Comments

The involvement of FAA Air Traffic Services personnel in the ADEDS program contributed immeasurably to the success of the flight test program. The active involvement of representatives of Seattle Air Route Traffic Control Center, Seattle Approach Control, Grant County Approach Control, and the Grant County Tower not only facilitated the coordination required for day-to-day flight test operations but also provided insight into the more general problems of air traffic management and the possibilities for improvement in aircraft operation offered by ADEDS-type equipment. The following paragraphs represent a consensus of ATC personnel who participated as observers on ADEDS test flights and/or who handled the test aircraft in the course of their duties as traffic controllers.

The flight tests of the ADEDS-equipped 737 aircraft demonstrated several areas of potential benefit to ATC operations and services. While these potential benefits would not be realized by the introduction of this type of equipment in itself, the possibilities of improvements in the use of airspace and the management of air traffic, which this type of system provides, are worthy of further study and development.

Among the potential benefits, especially in crowded terminal areas with high-peak traffic loads, is the more predictable and accurate movement of traffic and the more ordered management of traffic flow with a consequent reduction in overall traffic delay. The path-following capabilities of this type of system would permit the use of networks of nonconflicting 3D paths for the arrival and departure of suitably equipped aircraft and a consequent reduction in the burden of sequential vectoring for the total traffic load. This, of course, presumes that some substantial portion of the traffic mix is so equipped and that appropriate improvements in ATC equipment and procedures are made.

The schedule control (4D) capabilities of this type of system provide the potential for an added measure of control. The capability for determining precise time-of-arrival information and controlling the aircraft to make good a specified time of arrival adds a predictive capability to the overall airspace system, which can be used to further regulate the flow of traffic. An exploitation of this capability will allow time adjustments to be made en route with consequent savings in fuel.

The mechanization of this type of system provides a basis for incorporating data link communication techniques between the ground system and airborne traffic. This feature can be exploited in several ways that would be of benefit to ATC. The continuous downlink transmission of aircraft position, altitude, heading, groundspeed, vertical speed, and turn rate would provide the ground system with situation and predictive information of high value. These data, complementing the basic radar surveillance, would provide an extra measure of redundancy in the surveillance loop. The advanced display capabilities under development for the ground controller could be adapted to include the predictive information, thus adding a needed "lead" term to the control loop. This information could also be used by ground-based computers to provide more highly automated conflict predictions and traffic load predictions.

Uplink data transmission could include a number of information categories that would lessen the burden on voice communication channels. Examples of this type of communication include changes and amendments to clearance, detailed routing instructions, and terminal weather condition reports. The airborne system map display could be used to display the relative portion of nearby traffic from uplinked ground systems data.

REFERENCES

1. P. Wright and R. Peal, *ADEDS Flight Test Report, Vol. II, Airplane Installation,* FAA-SS-73-22-2, February 1974.

2. B. E. Bjurman, D. L. Jones, R. G. McKinstry, P. L. O'Toole, H. N. Tobie, and R. A. Peal, *Supplemental Flight Test Report,* D6-41593, Boeing Commercial Airplane Company, May 1974.

3. A. J. Martin and D. H. Cosley, *ADEDS Functional/Software Requirements,* FAA-SS-73-19, December 1973.

4. D. H. Cosley and H. E. Dale, *ADEDS Flight Test Report, Vol. I, Flight Test Plan,* FAA-SS-73-22-1, February 1974.

5. D. H. Cosley, A. J. Martin, L. P. Giroir, and R. A. Peal, *ADEDS Simulation Test Report,* FAA-SS-73-21, June 1974.

6. L. Giroir, A. Martin, V. Paulson, and R. Peal, *ADEDS Interface Description,* FAA-SS-73-20, June 1974.

APPENDIX A

ADEDS FUNCTIONAL/SOFTWARE REQUIREMENTS ERRATA

The ADEDS functional/software requirements as they existed at hardware delivery, September 1973, are provided by report No. FAA-SS-73-19, dated December 1973. This appendix lists the changes made to those requirements during integration and flight test. Wherever possible, specific sentences and words were changed and referenced to the basic release. In other instances, such as section 1.0, INTRODUCTION, the changes were so extensive that replacement of the entire section is included in the immediately following pages of this errata.

Page 1, Replace

1.0 INTRODUCTION

1.1 GENERAL

This document defines the advanced electronic display system (ADEDS) functional/software requirements. The document is divided into the following sections:

Section 1–Introduction
2–MFD Requirements
3–Bulk Data Storage
4–EADI Requirements
5–Four-Dimensional Guidance Requirements
6–NCDU Requirements
7–Navigation and Subsidiary Function Requirements
8-Advanced Guidance and Control System (AGCS)

Each section defines the functional requirements and assigns the software responsibility between the navigation computer unit (NCU) and the display system (DS), where applicable.

The General Electric Company was responsible for all DS software defined in this document. Initially, the NCU software responsibility was divided between Boeing and Litton as follows, in accordance with the ADEDS statement of work (SOW):

Boeing responsibility:	Sections 5 and 6
Litton responsibility:	Sections 2, 3, 4, and 7

During system integration, Boeing took over responsibility for sections 2 and 3 also.

The subsidiary function requirements in section 7 include all items identified in the Litton SOW. Litton will be responsible for integrating the NCU software subroutines defined in this document into the delivered ADEDS software package.

This document represents the ADEDS functional/software description at the completion of flight testing on March 15, 1974.

1.2 ADEDS SYSTEM CONFIGURATION

The ADEDS interface block diagram is depicted in figure 1-1. This diagram identifies the boxes and interfaces referred to in this document.

This document is concerned primarily with the Litton NCU software, the GE program control unit (PCU) software, and the interfaces used to transfer data between the two

Page 2, Replace

computers. These interfaces consist of the following four split-phase bipolar (SPBP) data buses utilizing a 100-kHz clock:

MFD bus 1:	NCU to PCU
MFD bus 2:	NCU to PCU
EADI bus:	NCU to PCU
PCU/NCU bus:	PCU to NCU

The data content, timing, and word formats for each of these buses are defined in this document.

1.3 NCU EXECUTIVE

1.3.1 Executive Control

The NCU executive controls two basic program loops. The fast loop contains programs that must be executed 20 times/sec. The other loop is called the slow loop. Even though all programs are executed in the slow loop before repetition, many of the programs permutate their calculations over several slow-loop cycles. During periods of high activity, the slow loop may take between 1 and 2 sec for execution. Normally it executes several times per second.

When the NCU is started, it automatically goes to actual location 12000, which contains the start of the initialization instructions. After initialization, the slow-loop programs are executed continuously except that every 50 msec an interrupt occurs. The fast-loop programs are then executed and return is made to the interrupted program in the slow loop. The wait at the end of the slow-loop program is to prevent the execution rate from being faster than 20 times/sec.

1.3.2 Power Interrupt

A power interrupt will do one of two things. If the interrupt was for less than 2 sec, the NCU program will continue at the point of interruption. If the power was off for more than 2 sec, control will return to the cold start initialization program.

1.3.3 Core Allocation and Major Programs

Table 1-1 shows the NCU memory allocation and table 1-2 lists the major NCU programs.

1.3.4 Checksum

Program instruction code and fixed data memory are checksummed in the slow loop.

Page 2a, Add

The NCU memory is divided into approximately 4K-word blocks, with one such block being checksummed for each pass through the slow loop. A checksum fail results in illumination of the NCU FAIL light. The checksum table assignment is as follows:

Bank No.	Part No.	Memory location	Table No.
1	1	726	1
1	2	727	2
2	1	730	3
2	2	731	4
3	1	732	5
3	2	733	6
4	1	734	7
4	2	735	10

Memory location 746 contains the checksum table number of the failed checksum block if such a fail exists. The program must be executing the slow-loop checksum routine for this number to be available. Multiple checksum block failure will alternately appear as the checksum fail is detected. A new checksum required as a result of a program change is initiated by zeroing out the appropriate table number memory location.

The checksum routine can be executed off line, at load time for example, by executing the checksum off-line call at memory location 1300. Off-line checksumming requires that the NCU MCU be connected and operating.

1.4 NCU AIRPLANE SIMULATOR

The NCU airplane simulator permits ground checkout and debug of many of the changes that can be implemented in the NCU programs. The simulator is a simple point-mass model that updates airplane heading and altitude from an integration of the lateral and vertical steering signals. Groundspeed is updated from either assigned path groundspeed, speed acceleration command, or by constant groundspeed command (200 kt). The simulator also includes the capability of setting the status of the DME/VOR navigation update mode.

The simulator is exercised by setting bits in a simulation flag word (SIMFLG) corresponding to the desired simulated flight condition. The bit assignment is:

SIMFLG bit
1–IC airplane
2–Fly airplane (200 kt)
3–Fly path GS
4–Fly commanded acceleration
5–Hold airplane
6–Unused
7–Good DME 1
8–Good DME 2
9–Good VOR 2

Example: SIMFLG 3038 will IC the airplane and fly it at 200 kt.

Page 2b, Add

1.5 NCU TELETYPE DEBUG PROGRAM

The C-4000 debug program is designed to aid the programmer in his checkout of system programs. It can also be used by the hardware personnel to test equipment that is interfaced with the computer.

Via the ASR teletypewriter keyboard, the C-4000 debug program provides the following functions:

1) Display and change memory locations (A:)
2) Halt program (B:)
3) Copy memory block (C:)
4) Dump memory block to teletype (D:)
5) Input and output decimal number (E:)
6) Fill memory block with constant (F:)
7) Input and output angle in degree, minute, and second (G:)
8) Punch object paper tape (P:)
9) Load object paper tape (L:)
10) Execute program (R:)
11) Search memory block for constant under mask (S:)
12) Verify memory block against copy in memory (V:)

1.5.1 Equipment

The C-4000 computer, manual control unit (MCU), teletype, and I/O interface are necessary.

1.5.2 Memory Utilization

Approximately 800 (1440_8) words are needed.

1.5.3 Debug Program Loading

The program can be loaded via the Mylar tape reader on the MCU. The procedure for filling a computer main memory using the MCU Mylar tape reader is described in section 3.2 of *C-4000 Manual Control Unit Instruction Manual,* Litton APD document 70-081.16.

Page 2c, Add

Depending on the needs of the program, the debug program can be assembled and loaded at any convenient starting address in the computer.

1.5.4 Debug Program Execution

The debug program is executed at its starting address. When the teletype switch is turned to ON and DEBUG is properly executed, teletype prints DEBUG, followed by a CR (carriage return) and an LF (line feed) to indicate the program is ON.

1.5.5 Debug Program Operation

1) Each command consists of a single-letter function code, followed by a colon (:) and one or more octal/decimal values. Values are separated by commas, and the last value used must be followed by a carriage return.

2) Values are right-justified octal/decimal integers. If no digits follow a comma, the value is made zero.

3) DEBUG will type BAD CODE if the user types a command that DEBUG cannot recognize.

4) A slash may be used to abort any input and return to start.

5) Octal value fields ignore all characters except 0, 1, 2, 3, 4, 5, 6, 7, /, *, comma, carriage return. In addition to the preceding characters, decimal value fields accept 8, 9. To cancel an incorrect value, key in *.

6) Prolonged outputs may be absorbed by activating any key on the teletype.

In the following discussion of the debug program, information produced by DEBUG is underscored, while that entered by the user is not.

1.5.5.1 Display and Change Memory Locations

A:V1 (CR)

1) Access locations in memory (starting) at location V1. DEBUG types out the address, V1, and its content, then waits for keyboard input.

2) To change the content, key in the new octal value, followed by a carriage return. The program then types out the next higher address and its content.

3) To progress to the next higher address without changing the content of the current location, key in a comma.

4) The look/change cycle continues until the operator keys a /.

Page 2d, Add

5) Example: The user wants to replace the contents at location 2000_8 and 2002_8 by 12341234 and 43214321, respectively. The present values at 2000_8 through 2003_8 are zeros.

A:2000 (CR)

<u>02000 00000000</u> 1 2 3 4 1 2 3 4 (CR)

<u>02001 00000000</u> ,

<u>02002 00000000</u> 4 3 2 1 4 3 2 1 (CR)

<u>02003 00000000</u> /

1.5.5.2 Halt Program

B:V1, V2 (CR)

1) Typically, the programmer will insert a breakpoint at some desired place in the program. When the program encounters the breakpoint, control is returned to DEBUG so that the programmer may examine the results, make corrections in the program, and continue debugging.

2) V1 is the address of the breakpoint. If V2 is 1, 2, or 3, DEBUG inserts the first, second, or third breakpoint at location V1. The original content at V1 is saved by DEBUG.

3) If V2 is zero, DEBUG restores the original content in location V1. However, if a breakpoint has not been previously set at location V1, DEBUG will type NOT USED .

4) If object program is later executed and the program reaches location V1, control is passed to the DEBUG. DEBUG prints V1 and the contents of registers A and Q, then awaits further commands. Note that breakpoint at V1 is removed, and the original content of V1 is restored.

5) Example: The user wants to insert second breakpoint at 3000_8 and first breakpoint at 3400_8.

B: 3000, 2 (CR)

<u>DONE</u>

B: 3400, 1 (CR)

<u>DONE</u>

Page 2e, Add

When program encounters 3000_8:

```
              (A)           (Q)
3000  1 2 3 4 1 2 3 4  4 3 2 1 4 3 2 1
```

The user wants to remove breakpoint at 3400_8.

B: 3400 (CR)

DONE

1.5.5.3 Copy Memory Block

C: V1, V2, V3 (CR)

1) Copy memory block at location V1 through V2 into block at location V3 through V3 + (V2 - V1).

2) If V2 does not exceed V1, only the word at V1 will be copied.

3) If V3 lies between V1 and V2, no action is taken.

4) Example: The user wants to save the memory block from 1400_8 through 3000_8 into block starting at 10400_8.

   C: 1400, 3000, 10400 (CR)

   DONE

1.5.5.4 Dump Memory Block to Teletype

D: V1, V2 (CR)

1) Dump memory block at location V1 through V2 to teletype.

2) The basic typing format is four octal words per line, preceded by the octal address of the first word printed on the line. If this address does not end with a zero or a four-digit number, appropriate spaces are inserted to maintain column integrity.

3) Repetitious words are suppressed as follows:

   a) If the remainder of the current line is identical to the word last printed, the line is terminated.

   b) If one or more subsequent lines are identical to the word last printed, the teletype goes to the next line with different words, if any.

4) Prolonged outputs may be aborted by activating any key on the teletype.

Page 2f, Add

5) Example: The user wants to dump from 4001_8 to 4010_8.

D: 4001, 4010 (CR)

04001 12341234 23452345 34563456

04004 45674567 43214321 54325432 65436543

04010 00000000

DONE

1.5.5.5 Input and Output Decimal Number

E: V1, E V2 (CR)

1) Display decimal number from location V1 with binary point set at B V2 on the teletype. V2 may be any positive or negative number.

2) To change the content, key in the new decimal value, followed by a carriage return. Control is returned to DEBUG.

3) Example: The user wants to display the decimal number at location 7000_8 with binary point set at B 12. He then wants to replace it by 90.65.

E: 7000, B 12 (CR)

07000 60.7635 90.65 (CR)

1.5.5.6 Fill Memory Block With Constant

F: V1, V2, V3 (CR)

1) Fill memory block at locations V1 through V2 with octal constant V3.

2) If V2 does not exceed V1, only location V1 will be filled.

3) Example: The user wants to clear the buffer at locations 7000_8 through 7777_8 with 0.

F: 7000, 7777, 0 (CR)

DONE

Page 2g, Add

1.5.5.7 Input and Output Angle in Degree, Minute, and Second

G: V1 (CR)

1) Convert angle in C-4000 pi-normalized format at location V1 to degree, minute, second, and hundredth of second and print it on the teletype.

2) To change the angle, key in desired angle in degree, minute, second, and hundredth of second, followed by a carriage return. DEBUG converts it to C-4000 pi-normalized format and stores it at location V1.

3) Example: The user wants to display angle at 10000_8 and replace it by -120 degrees, 30 minutes:

   G: 10000 (CR)

   10000 -90, 22, 40.1 -120, 30 (CR)

1.5.5.8 Punch Object Paper Tape

P: V1, V2 (CR) and turn on paper tape puncher

1) Punch memory words from locations V1 through V2 to a paper tape.

2) The tape format is as follows:

   a) Thirty words of "carriage-return" for a leader.

   b) Character A and starting location V1, followed by CR and LF.

   c) Contents of location V1 through V2 with space between them.

3) Example: The user wants to punch his patch program from 4000_8 to 4030_8:

   P: 4000, 4030 (CR) and turn on paper tape puncher.

   A4000

   12341234 ....

   Type HERE IS key to generate a leader and turn puncher off. Note that the punched paper tape cannot be loaded back via the MCU. It can only be loaded back through the load function described in the next section.

Page 2h, Add

1.5.5.9 Load Object Paper Tape

L: (CR) and place punched paper tape in reader and turn on

1) DEBUG will load the tape punched by P command in memory word by word starting at location received after character A.

2) When tape is completely loaded, key in / to return control to DEBUG.

3) Example: The reader wants to load patch program on the tape produced by using P command.

   L: (CR) place punched paper tape in the reader and turn on

   A4000

   12341234 . . .

   / (CR) (LF)

1.5.5.10 Execute Program

R: V1, V2, V3 (CR)

1) Run object program by performing TRA to location V1 instead of doing it through the MCU. Prior to program entry, V2 is loaded into register A, and V3 is loaded into register Q.

2) Control does not return to the DEBUG program unless a breakpoint is encountered.

3) If a breakpoint is encountered, the print format is breakpoint address, content of register A, and content of register Q.

4) Example: The user has set a breakpoint at 5000_8 and he wants to execute his program at 4000_8 with 77777777 in register A. It is assumed that 5000_8 is encountered.

   R: 4000, 77777777 (CR)

```
              (A)        (Q)
   05000   66666666   55555555   (CR) (LF)
```

1.5.5.11 Search Memory Block for Constant Under Mask

S: V1, V2, V3, V4 (CR)

1) Search memory block at location V1 through V2 for words equal to V3 under the mask V4.

Page 2i, Add

2) If no mask is specified, the entire word is tested.

3) When a match is found, the address and its content are typed out, and the search continues until V2 has been tested.

4) Example: The user found that the instruction at 5010_8 was destroyed during his checkout, so he wants to find out if there are instructions having address equal to 5010_8 in his program. He searches his entire program for 5010_8 under mask of 7777_8. It is assumed that his program starts at 2000_8 and ends at 7000_8 and there is a STORE A 5010 (bug!!) at 5010_8:

   S: 2000, 7000, 5010, 777 (CR)

   <u>05010 12005010</u>

   <u>DONE</u>

1.5.5.12 Verify Memory Block Against Copy in Memory

V: V1, V2, V3 (CR)

1) Verify memory block at locations V1 through V2 against a copy in location V3 through V3 + (V2 - V1).

2) The program types the address and content of each location in the V1 block that does not match the corresponding word in the V3 block. It also types the address and content of the corresponding word in the V3 block.

Page 2j, Add

TABLE 1-1.—NCU MEMORY ALLOCATION

C-4000 core allocation	Description
	Bank 1
0–2777	Hardware cells and program variables
3000–3377	Guidance buffer pointers and scratch (bombs 1 and 2)
3400–3766	Constants
3767–4550	Fast-loop subroutines
4554–6617	Slow-loop subroutines
6620–11761	Guidance/EADI flight director/mode panel programs
12226–14440	
12000–12225	Executive
14461–17776	Guidance buffers
	Bank 2
20000–37777	NCDU programs
	Bank 3
40000–47277	EADI/navigation programs
47300–57777	MFD programs, EPR program
	Bank 4
60000–77777	Bulk data storage

Page 2k, Add

TABLE 1-2.–MAJOR NCU PROGRAMS

Program name	Description
50-msec Programs	
NAVIG	Airplane simulation
HNAVFS	Navigation
PATHDF	Path definition
SWTPZA	Guide buffer switch
HVGUID	2D 3D path guidance
TGUID	4D time guidance
EADIFD	EADI flight director
MSPLGC	Mode select panel logic
SREADI	EADI
MFDFST	MFD (map)
NCDKEY	NCDU I/O
100-msec Programs	
NCFM	Noncritical flight modes
MSPRQ	Mode select panel readout
TESTOT	Output to flight recorder
Slow-Loop Programs	
NCDUEX	NCDU executive
ERAD	Earth's radius
HNAVSL	Navigation
BLOW	Wind calculations
MFDEXC	MFD executive
EPRLMT	EPR limit
CHKSUM	Checksum routine

Page 3, Replace

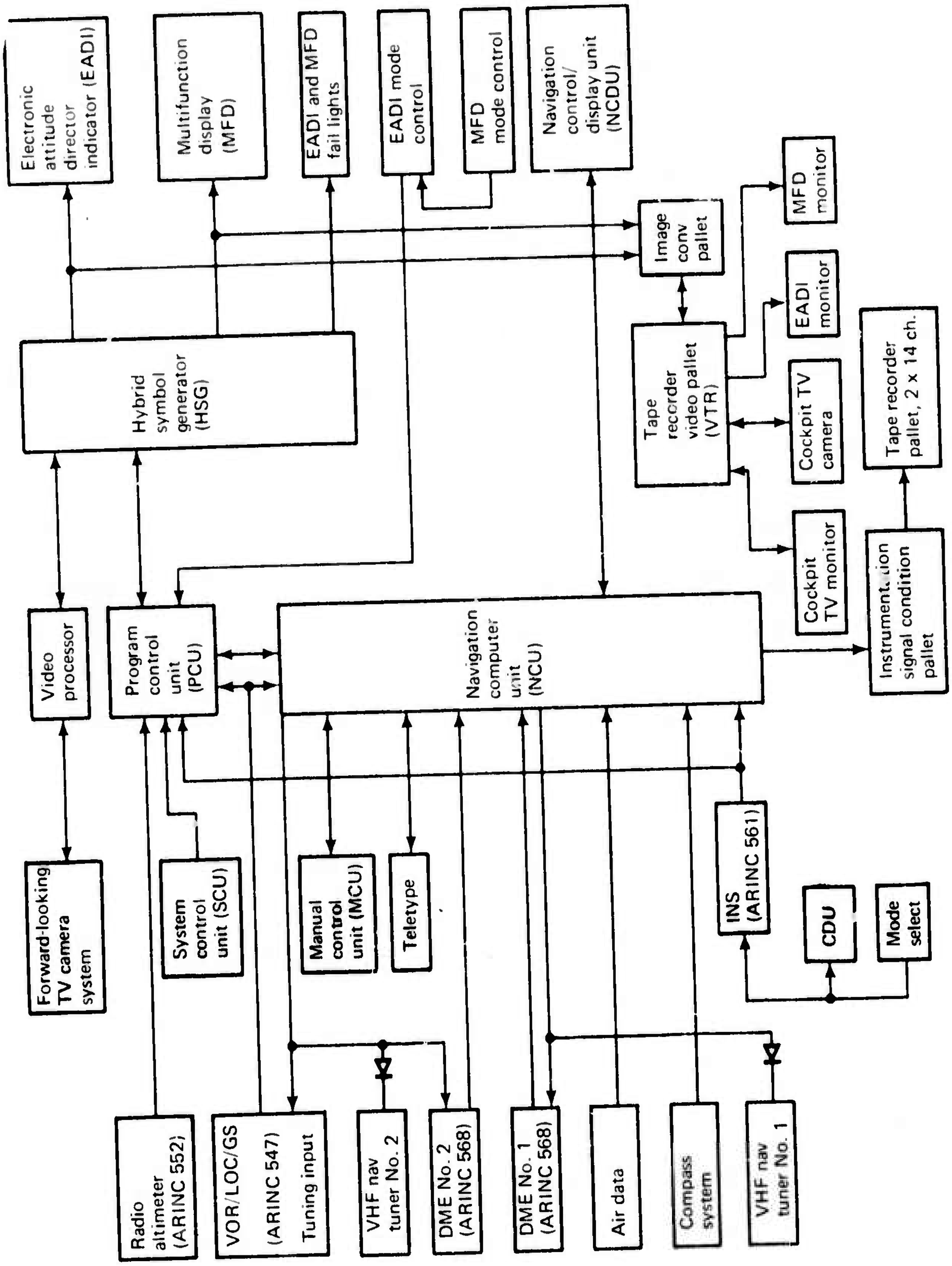


FIGURE 1-1.–ADEDS INTERFACE BLOCK DIAGRAM

Page iii, CONTENTS

Add	1.3	NCU Executive	2
	1.4	NCU Airplane Simulator	2a
	1.5	NCU Teletype Debug Program	2b

Page iv, CONTENTS–Continued

Change	4.4.11 ILS Symbology
Title	4.4.13 Horizontal and Vertical Guidance

Page v, CONTENTS–Continued

Change	6.8	NCDU Software Labels to "NCDU Debug Pages and Commands"
Renumber	6.9	NCDU Software Labels

Page vi, CONTENTS–Concluded

Add	7.3.4	Magnetic Variation	304
Add	8.0	ADVANCED GUIDANCE AND CONTROL SYSTEM (AGCS)	314b
		8.1 General	314b
		8.2 AGCS Mode Select Panel/NCU Interface	314b
		8.3 Lateral and Vertical Noncritical Flight Mode Steering Signals	314b
		8.4 Autothrottle Control Law	314b
		8.5 EPR Thrust Limit Calculations	314b
		8.5.1 Maximum Limit Thrust EPR Limit Algorithm	314c
		8.5.2 Maximum Continuous Thrust EPR Limit Algorithm	314d
		8.5.3 Maximum Cruise Thrust EPR Limit Algorithm	314d

Page viii, FIGURES–Concluded

Add	612a	SEL 3 (Select 3) Mode	281a
Add	7-3	Baro-Inertial Loop Diagram	314a
Add	7-4	Altitude Corrected for Barometric Setting	314a

Page ix, TABLES

Add	1-1	NCU Memory Allocation	2j
	1-2	Major NCU Programs	2k

Page x, TABLES–Concluded

Add	7-7	Fast-Loop Analog-to-Digital and ICP Input Conversions . . .	312a
Add	8-1	AGCS Label Definition	314e

Page xi, ABBREVIATIONS

Change	ACCNORM to "ACNORM"	Normal acceleration

Page xii,

Change	HLDTK to "HLDTRK"	Track hold

Page 1, section 1.0, INTRODUCTION

Replace entire section

Page 3, FIGURE 1-1

Replace

Page 5, section 2.1, paragraph 2, first sentence

Change to

"The MFD has a viewable area 5.5 in. wide by 7.54 in. high."

Page 5, section 2.1, paragraph 3, second sentence

Change to

"Background data were processed by the NCU at a slow rate and transmitted to the PCU once every 5 sec." Dynamic data, . . .

Page 7, section 2.2.2.4, paragraph 2

Add to RC bit 22

. . . coordinate rotation is required. "When RC = 1, the conic angle is modified to (ITAN–TK), where TK is received in the second word of MFD bus 2."

Page 8

Add to R

. . . symbol word type 1. "Positive rotation angle will produce a clockwise rotation."

Page 10, paragraph 3, third sentence

Change to

. . . for troubleshooting. "An alternative modification to the display system software that would cause the MFD display to go blank if no valid data were received over MFD bus 1 and/or bus 2 for a defined period of time was not mechanized."

Page 10, section 2.2.4

Insert new paragraph between paragraphs 2 and 3

. . . as shown in table 2-1.

"During transmission of MFD bus 1, MFD bus 2 and EADI bus 3 will be alternately transmitted until bus 1 transmission is completed. See figure 2-7."

The PCU changes . . .

Page 11, paragraph 1, last sentence

Delete

"Any change to 1 . . . at least twice."

Page 11, paragraph 1

Add (replaces deleted sentence)

"The PCU continues to set bit 30 to 1 until a good MFD bus 1 is received."

Page 12A, paragraph 1, first sentence

Add to

. . . a route line, "text annunciation," and digital . . .

Page 12A, paragraph 4, second sentence

Add to

. . . East and north position increments, "true track angle (TK)," and sin and . . .

Page 14

Add to

ACNORM = . . . vector (ft/sec^2) "smoothed with a 1-sec lag filter"

Page 14, next to last paragraph, last sentence

Change to

. . . table 2-2. "An I&R control word with IC = 00 and RC = 0" will precede . . .

Page 15, section 2.4.1 4, first sentence

Insert

. . . airplane symbol to "a point 0.45 in. below the" lower edge of . . .

Page 15, section 2.4.1.6, third sentence

Change

. . . TKESEL = HLDTK - TK "TKESEL = TK - HLDTRK."

Page 28, section 2.4.1.7.9, second sentence

Change

. . . displayed on the 8, 4, 2, and 1 . . . to "displayed on the 4, 2, and 1" nmi/in. scales. . .

Page 29, section 2.4 1.7.11, sketch

Add to

ABCDE
350
"15000"

Page 29, sentence below sketch

Add to

. . . symbol select button "but will be displayed only if WPT ALT is also selected ON by the MFD mode control unit (see sec. 2.4.1.7.13.) The display format is shown above."

Page 29, paragraph 3

Delete all of the paragraph

"Whenever a four-dimensional . . . where b = blank."

Page 31, section 2.4.1.7.14, paragraph 2, first sentence

Change to

"The NCU will generate two symbol word groups" once per second . . .

Page 31, section 2.4.1.7.14, paragraph 2, third sentence

Change

. . . R = 1, SS = 11, I_S = 10, L = 0 to "R = 1, SS = 11, I_S = 11, L = 0."

Page 31, section 2.4.1.7.14, paragraph 2, last sentence

Add to

variation). "The second symbol word group will be identical to the first except the type 3 word will be RADBRG + MAGVAR + 180°."

Page 33, paragraph 1, last sentence

Delete

"The small circles . . . two circles (10)."

Page 36, paragraph 2, fourth sentence

Change to

"The other three symbol groups include the symbol code 0010111, position in E and N coordinates to define the 30-, 60-, and 90-sec prediction circles with intensity $I_S = 10$, and R = 0, SS = 11, and L = 0." These calculations . . .

Page 36, last paragraph, first sentence

Change to

"The symbol is stroke written by the DS and is an arc segment of a circle with a 4-in. radius" extending . . .

Page 37, sixth symbol

Change

DELH = ALTC − ALTREF to "DELH = ALTREF − ALTC"

Page 37, last symbol

Change

where: $RALT = -\left(\frac{DELH}{HDOT} \cdots\right)$ nmi to "where: $RALT = f_2\left(\frac{DELH}{HDOT} \cdots\right)$ nmi"

Add immediately below "and f_2 is a 3-sec lag filter"

Page 38, paragraph 2

Change Group 1

Word type 2 Y = RALTY, X = 0, C = 1, D = 0 to
"Word type 2 Y = RALTY, X = −89, C = 1, D = 0"
Word type 3 Arc length = 90 bits; rotation angle = +90° to
"Word type 3 Arc length = 180 bits; rotation angle = 75.585°"

Change Group 2

Word type 2 Y = RALTY, X = 0, C = 1, D = 1 to
"Word type 2 Y = RALTY, X = −89, C = 1, D = 1, rotation angle = 104.414°"

Page 39, section 2.4.1.10

Replace

2.4.1.10 Mode and Scaling Annunciation

"The current map scale selected and the current guidance or select mode activated, or the current hold mode or the land mode if actuated will be displayed in the lower left-hand corner of the MFD map display. The current groundspeed, navigation mode, and wind direction and speed will be displayed in the lower right-hand corner of the MFD map display. The display format will be, for example:

Line 1	54NM/IN	GSb321
Line 2	G4D	bbb1DD
Line 3		273/b17KTS

The NCU will generate two text symbol word groups to define this annunciation and will transmit them once per second over MFD bus 1. The text word groups will be preceded by an I&R control word with TC = 1, OC = 1, RC = 0, RS = 0, and IC = 00. The text word type 1 will have I_T = 10, R = 0, and seven-bit code 0000001. Word type 2 will have C = 0 and coordinates X = –230, Y = –180 for the left-hand word group and X = +132, Y = –230 for the right-hand word group. Word type 4 will have ST = 0 and the alphanumeric codes defined below:

Line 1 (left):	XXNM/INCRLF	where XX is b1, b2, b4, b8, 16, or 32 corresponding to the map scale selected on the MFD MCU
Line 1 (right):	GSXXXCRLF	where XXX is the present groundspeed in knots
Line 2 (left):	XXX	where XXX corresponds to the current flag set by the guidance routine to indicate mode. This can be G2D, G3D, or GAD.
or:	SEL/XXX/XXX, etc.	where XXX indicates which mode or modes have been activated by the external autopilot mode panel. The MFD will display annunciations corresponding to the following mode flags set by the autopilot mode panel: TKSEL FPASEL ALTSEL IASSEL XXX can be TKA, ALT, FPA, or IAS. Line 2 will annunciate only one of the above formats, depending on whether a guidance mode or select mode is activated.

Line 2 (right): bbbXXXCRLF where XXX indicates the present navigation update mode. See section 7.1.1 for the possible update mode indications.

Line 3 (left): HOLD/XXX where XXX indicates the flightpath offset mode (OFS) or the hold at waypoint mode (WPT) if activated. The corresponding flags set by the NCDU are:

OFSSEL HLDSEL

or: LANDbSEL/IAS LAND will be displayed if the autoland mode is activated and SEL/IAS will be concurrently displayed if the IAS select mode is activated.

If line 2 contains an annunciation, line 3 will not and conversely.

Line 3 (right): XXX/YYYKTS where XXX is the present wind direction and YYY is the windspeed as calculated by the NCU.

The DS will generate the symbology using its normal text mode in accordance with the I&R control word instructions so that the coordinates are not rotated or incremented."

Page 41, section 2.4.2.2, paragraph 3, first sentence

Change to

. . . bus 2 word label "01000001 (TK) SIN/COS." The DS . . .

Page 42, paragraph 1, second sentence

Change to

. . . any of the limits " + 240 < E < -240 or + 280 < N < -280," the three . . .

Page 42, section 2.4.2.4, paragraph 1

Replace

"The straight-trend vector shall project 3 in. straight ahead from a point 0.625 in. ahead of the apex of the airplane symbol. This trend vector shall be displayed only when the aircraft's position is not limited."

Page 42, section 2.4.2.5, paragraph 1, first sentence

Add

. . . in section 2.4.1.5 " from magnetic track angle binary and magnetic track angle (BCD) data transmitted over MFD bus 2."

Page 42, section 2.4.2.5, paragraph 1, second sentence

Delete

"Track (TK) . . . map mode."

Page 42, section 2.4.2.5, paragraph 2, last sentence

Delete

"Transmission of . . . is optional."

Page 44, section 2.4.2.10, second sentence

Change to

"The X,Y coordinates in the text type 2 word will be X = −230, Y = −256 for the left-side word group and X = 132, Y = 256 for the right-side word group."

Page 44, section 2.5

Delete all of the paragraph

"This mode . . . is shown in figure 2-14."

Page 44, section 2.5.1, first sentence

Change to

"This mode is initiated by selecting the TEST mode" on the MFD . . .

Page 46, last line

Delete

"Switch 3 OFF—Track select bug"

Pages 47, 48, and 49, TABLEs 2-1, 2-2, and 2-3

Replace

Page 53, TABLE 2-6—Continued, Aircraft Symbol

Delete dimension "16"

Page 47, Replace

TABLE 2-1.—MFD BUS 1 TRANSMISSION ORDER

		Track-Up Map	North-Up Map
	0	SOT control word	SOT control word
	1	I&R control word (TC = 1, OC = 1, RC = 0, IC = 00, WF = 1, RS = 0) Text word groups I&R control word (TC = 1, OC = 1, RC = 1, IC = 11, WF = 1, RS = 0) Upright symbol word groups (R = 0) Vector word groups I&R control word (TC = 1, OC = 1, RC = 1, IC = 11, WF = 1, RS = 1) Rotated symbol word groups (R = 1)	I&R control word (TC = 1, OC = 1, RC = 0, IC = 00, WF = 1, RS = 0) Text word groups I&R control word (TC = 1, OC = 1, RC = 0, IC = 00, WF = 1, RS = 0) Symbol word groups Vector word groups
(a)		(a) EOD control word (TC = 1)	
(a)		I&R control word	
(a)		MFD2 data	
		EOD control word (TC = 0)	
		Unused data words	
(a)	507	Mode MFD 2	
(a)	508	ΔMFD 2	
	509	Mode MFD 1	
	510	ΔMFD 1	
	511	EOT control word	

Note: There may be other I&R control words within an MFD 1 or MFD 2 data block.

[a]These data blocks and words are applicable only when two MFD displays are in use.

Page 48, Replace

TABLE 2-2.–MFD BUS 2 LABEL CODES AND TRANSMISSION ORDER–TRACK-UP MAP[a]

Label MSB LSB 8 7 6 5 4 3 2 1	Function	
0 1 0 0 0 0 0 0	MFD 1 delta position E and N	
0 1 0 0 0 0 0 1	MFD 1 coordinate rotation angle (TK sin and cos)	
0 1 0 0 0 0 1 0	Track angle (TK) (magnetic)–binary	
0 1 0 0 0 0 1 1	Track angle–BCD	
0 1 0 0 0 1 0 0	Selected track error (TKESEL sin and cos)	
0 1 0 0 0 1 0 1	Selected track error (TKESEL scaled binary)	
0 1 0 0 0 1 1 0	Airplane position N and E (DM = 11)	
0 1 0 0 0 1 1 1	Track angle (true)–binary	
0 1 0 0 1 0 0 0	MFD mode word	
0 1 0 0 1 0 0 1	I&R control word with IC = 00, RC = 0, RS = 0[b]	
0 1 0 0 1 0 1 0	Vector word type 1	Curved-trend vector
0 1 0 0 1 0 1 1	2	30-sec line
0 1 0 0 1 1 0 0	2	
0 1 0 0 1 1 0 1	2	
0 1 0 0 1 1 1 0	2	
0 1 0 0 1 1 1 1	2	
0 1 0 1 0 0 0 0	Vector word type 1	60-sec line
0 1 0 1 0 0 0 1	2	
0 1 0 1 0 0 1 0	2	
0 1 0 1 0 0 1 1	2	
0 1 0 1 0 1 0 0	2	
0 1 0 1 0 1 0 1	2	
0 1 0 1 0 1 1 0	Vector word type 1	90-sec line
0 1 0 1 0 1 1 1	2	
0 1 0 1 1 0 0 0	2	
0 1 0 1 1 0 0 1	2	
0 1 0 1 1 0 1 0	2	
0 1 0 1 1 0 1 1	2	
0 1 0 1 1 1 0 0	I&R control word with IC = 00, RC = 1, RS = 1, OC = 1	
0 1 0 1 1 1 0 1	Symbol word type 1 (R = 1)	Time box
0 1 0 1 1 1 1 0	2	
0 1 0 1 1 1 1	3	
0 1 1 0 0 0 0 0	I&R control word with IC = 00, RC = 1, RS = 0, OC = 1	
0 1 1 0 0 0 0 1	Symbol word type 1 (R = 0)	30-sec dot
0 1 1 0 0 0 1 0	2	
0 1 1 0 0 0 1 1	1	60-sec dot
0 1 1 0 0 1 0 0	2	
0 1 1 0 0 1 0 1	1	90-sec dot
0 1 1 0 0 1 1 0	2	
0 1 1 0 0 1 1 1	EOD control word with TC = 0	
0 1 1 0 1 0 0 0 – 0 1 1 1 1 1 1 1	Unassigned	

[a]Single MFD display configuration

[b]The data content following the I&R control word varies in content depending on the map scale and symbol options selected.

Page 49, Replace

TABLE 2-3.—MFD BUS 2 LABEL CODES AND TRANSMISSION ORDER—NORTH-UP MAP

Label MSB LSB 8 7 6 5 4 3 2 1	Function	
0 1 0 0 0 0 0 0	Invalid	
0 1 0 0 0 0 0 1	TK (true) sin and cos	
0 1 0 0 0 0 1 0	Track angle (TK) (magnetic)—binary	
0 1 0 0 0 0 1 1	Track angle—BCD	
0 1 0 0 0 1 0 0	Selected track error (TKESEL sin and cos)	
0 1 0 0 0 1 0 1	Selected track error (TKESEL scaled binary)	
0 1 0 0 0 1 1 0	Airplane position N and E	
0 1 0 0 0 1 1 1	Track angle (true)—binary	
0 1 0 0 1 0 0 0	MFD mode word	
0 1 0 0 1 0 0 1	I&R control word with IC = 00, RC = 0, RS = 0	
0 1 0 0 1 0 1 0	Vector word type 1	Curved-trend vector—first segment
0 1 0 0 1 0 1 1	2	
0 1 0 0 1 1 0 0	2	
0 1 0 0 1 1 0 1	2	
0 1 0 0 1 1 1 0	2	
0 1 0 0 1 1 1 1	2	
0 1 0 1 0 0 0 0	Vector word type 1	Curved-trend vector—second segment
0 1 0 1 0 0 0 1	2	
0 1 0 1 0 0 1 0	2	
0 1 0 1 0 0 1 1	2	
0 1 0 1 0 1 0 0	2	
0 1 0 1 0 1 0 1	2	
0 1 0 1 0 1 1 0	Vector word type 1	Curved-trend vector—third segment
0 1 0 1 0 1 1 1	2	
0 1 0 1 1 0 0 0	2	
0 1 0 1 1 0 0 1	2	
0 1 0 1 1 0 1 0	2	
0 1 0 1 1 0 1 1	2	
0 1 0 1 1 1 0 0	I&R control word with IC = 00, RC = 1, RS = 1, OC = 1	
0 1 0 1 1 1 0 1	Symbol word type 1	Time box
0 1 0 1 1 1 1 0	2	
0 1 0 1 1 1 1 1	3	
0 1 1 0 0 0 0 0	I&R control word with IC = 00, RC = 1, RS = 0, OC = 1	
0 1 1 0 0 0 0 1	Symbol word type 1	30-sec dot
0 1 1 0 0 0 1 0	2	
0 1 1 0 0 0 1 1	Symbol word type 1	60-sec dot
0 1 1 0 0 1 0 0	2	
0 1 1 0 0 1 0 1	Symbol word type 1	90-sec dot
0 1 1 0 0 1 1 0	2	
0 1 1 0 0 1 1 1	EOD control word with TC = 0	
0 1 1 0 1 0 0 0 – 0 1 1 1 1 1 1 1	Unassigned	

Note: Data content is dependent on the symbology options selected

Page 54, TABLE 2-6–Continued, VOR Symbol

Add to

VOR Symbol (Reporting Point) "–Not Used"

Page 56, TABLE 2-6–Continued, Standard Circle Symbol

Change

Double all machine unit dimensions

Page 56, TABLE 2-6–Continued

Change

Fan Marker Symbol to "Marker Beacon Symbol"

Page 57, TABLE 2-6–Continued

Add to

GRP Symbol (Reporting Point) "–Not Used"

Page 58, TABLE 2-6–Continued

Add to

VORTAC Symbol (Reporting Point) "–Not Used"

Page 61, TABLE 2-6–Continued

Add to

Waypoint and First Cue Symbol "–Not Used"

Page 61, TABLE 2-6–Continued

Add to

Waypoint and Second Cue Symbol "–Not Used"

Page 87, TABLE 2-8

Change

MFD bus 1 subheading from 1/sec to "1/5 sec"

Page 87, TABLE 2-8

Change

Minimum computation rate column figure, fifth item, Track angle (BCD), from 1 to "20"

Page 89, TABLE 2-11

Change

MFD bus 1 subheading from 1/sec to "1/5 sec"

Page 89, TABLE 2-11

Change

Minimum computation rate column figure, last item, Altitude/range, from 5 to "X"

Page 90, TABLE 2-12, Data content, word No. 3, Bus 1

Change

Position N 240, E –60 to "Position N 240, E –144"

Page 90, TABLE 2-12, Data content, word No. 10, Bus 1

Change

Position N –360, E –60 to "Position N –360, E –144"

Page 90, TABLE 2-12, Data content, word No. 21, Bus 1

Add to

0 0 D "WF = 1"

Page 90, TABLE 2-12, Bus 2

Replace

Bus 2

Label	Data	Data content
0 1 0 0 0 0 0	ΔN, ΔE	+100, 0
0 1 0 0 0 0 1	Coordinate rotation angle	0° (sin and cos)
0 1 0 0 0 1 0	TK (magnetic)–binary	Current track (magnetic)
0 1 0 0 0 1 1	TD BCD	Current track (magnetic)
0 1 0 0 1 0 0	TKESEL sin/cos	Invalid
0 1 0 0 1 0 1	TKESEL binary	Invalid
0 1 0 0 1 1 0	Airplane position	Zero
0 1 0 0 1 1 1	Track (true)–binary	
0 1 0 1 0 0 0	MFD mode word	
0 1 0 1 0 0 1	EOD	
0 1 0 1 0 1 0 }	Unassigned	
0 1 1 1 1 1 1 }		

Page 91, FIGURE 2-1

Change

Draw vertical line between RC|RS (bits 22 and 21 immediately under control word format.

Page 93, FIGURE 2-3, Word Type 1–Code Word

Add

Immediately under control word format, bit 23 space, vertical line on each side |R|

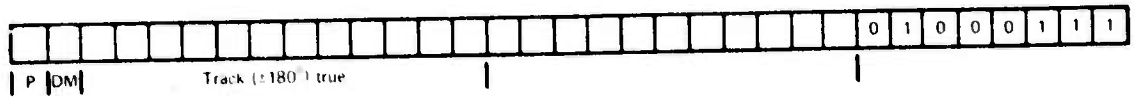
Page 94, FIGURE 2-4, third control word format from top

Add

TK (±180°) "magnetic"

Page 94, FIGURE 2-4

Insert immediately above last control word format



Page 94, FIGURE 2-4, last control word format

Change last four numbers

0 1 1 1 to "1 0 0 0"

Page 94, FIGURE 2-4, sentence at bottom of figure

Change to

"The following words (8 through 64)", will contain . . .

Page 97, FIGURE 2-7

Replace

Page 99, FIGURE 2-9

Change

GUID2D to "G2D"

Page 99, FIGURE 2-9

Add to lower right side of format

"GS 332
IDD
121/22 kts"

Page 101, FIGURE 2-11

Change dimension

5.75 in. to "5.5 in."

Page 102, FIGURE 2-12

Add to lower right side of format

"16 nmi/in.
G2D"

Page 102, FIGURE 2-12

Add to lower right side of format

"GS 332
IDD
121/22 kts"

Page 97

Replace

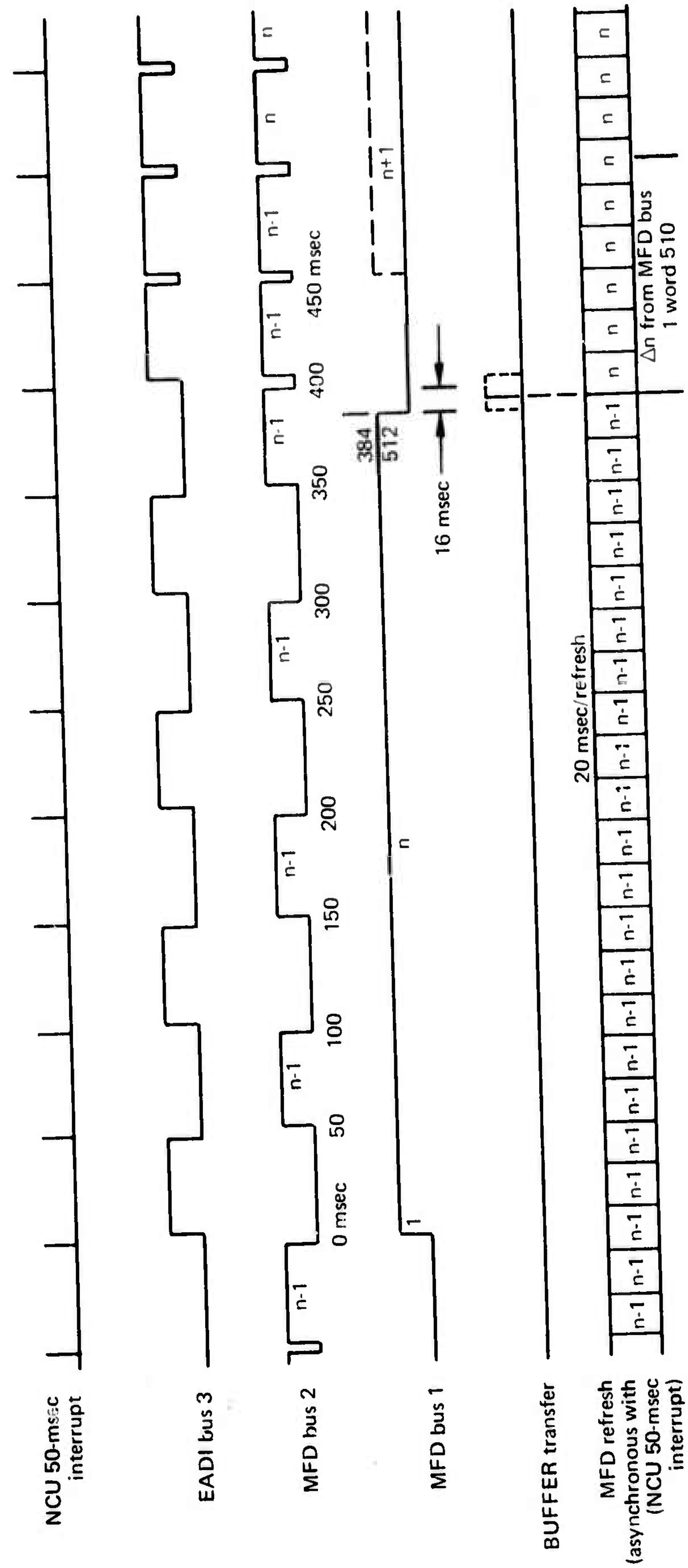


FIGURE 2-7.—MFD BUS 1, BUS 2, AND PCU TIMING RELATIONSHIP

Page 124, TABLE 3-4, Pointer to 2nd waypoint

Delete

"°/180 . . . B0"

Page 137, paragraph 2, third sentence

Change to

. . . on the screen scaled at "67 elements/in. horizontally and 86.6 elements/in. vertically."

Page 139, paragraph 4, first sentence

Change

. . . failure by annunciation of the NCDU . . . to ". . . failure by annunciation on the NCDU" . . .

Page 139, paragraph 4

Add

. . . for troubleshooting. "An alternate modification to the display system software that would cause the EADI display symbology generated from digital data to blank out if no parity error-free data were received over the EADI bus for a defined period of time was not mechanized."

Page 139, section 4.2.2.5

Add

The timing of the EADI bus data transmission is identical to that defined in section 2.2.4 and shown in figures 2-6 " and 2-7."

Page 141, section 4.4.2, paragraph 1, first sentence

Change

Table 2-5 to "table 4-5."

Page 141, section 4.4.2, paragraph 1, last sentence

Change to

"Initially, $\Delta\theta$ was zero ($\Delta\theta$ = PITCHB) but as a result of early flight test experience, $\Delta\theta$ was set to 5°."

Page 141, section 4.4.2, paragraph 2, last sentence

Delete and change to

"With the 5° bias airplane, pitch attitude θ is displayed by 5°."

Page 141, section 4.4.2, paragraph 3, last sentence

Change to

"The screen center position will be selectable through an erase/validity switch on the SCU."

Page 141, section 4.4.3, first sentence

Change to

. . . sharp boundary delineated by a "single," solid . . .

Page 142, paragraph 3

Change

A double, solid stroke-written line, vector code 1101000 . . . to
"A single, solid stroke-written line, vector code 1100000" . . .

Page 142, section 4.4.4, paragraph 1, first sentence

Change to

. . . "long at 5° increments between ±30°, as specified in table 4-5. The 5° increments" . . .

Page 142, section 4.4.4, paragraph 2, second sentence

Change to

. . . "generate the 5° pitch line;" . . .

Page 142, section 4.4.4, paragraph 4, second sentence

Change to

. . . "shall be scaled at 0.167 in./deg."

Page 143, section 4.4.5, paragraph 2, first sentence

Change to

. . . "long, dashed (*delete* 'double') stroke-written line, modulated as vector code 1100001, with" . . .

Page 144, section 4.4.7, paragraph 3

Change to

$$\text{"FPA} = \left(\frac{\text{HDOT}}{\text{VGS}}\right) \left(\frac{57.3}{180}\right) \quad \text{(deg)}$$

$$\text{DA} = f_1\,(\text{TK - HDG}) \quad \text{(deg)}$$

where f_1 is a 1-sec lag filter."

Page 144, section 4.4.7

Insert new paragraph

where f_1 is a 1-sec lag filter.

"The gamma wedges shall flash at approximately 4 times/sec when the flare initiate discrete is received from the ICP computer during coupled autoland approaches."

The NCU shall then transmit . . .

Page 145, paragraph 1

Change to

"where f_3 is a 1-sec lag filter."

Page 146, paragraph 1, third line

Change to

" . . .Under any other conditions, IASREF is limited to a minimum value of 115 kt by the NCDU software. When GUID4D is not set and the T-NAV switch on the MFD mode control unit is switched to OFF, PC is not computed, and the DM is set to invalid by the NCU."

Page 146, paragraph 3

Delete

"The acceleration . . .airspeed."

Page 146, section 4.4.10, paragraph 1, second sentence

Change to

. . . to a maximum of "1.0 in. above (+20 kt) and 1.5 in. below" . . .

Page 146, section 4.4.10, paragraph 3, first definition of DELV

Delete

"DELV = IAS - HLDIAS when IASSEL flag is set"

Page 146, section 4.4.10, paragraph 3, second definition of DELV

Change to

. . . as defined in section 4.4.9 "not in a 4D guidance mode" and IASSEL is not set.

Page 146, section 4.4.10, paragraph 3, last definition of DELV

Change to

"DELV = VGS - SDC when in 4D guidance mode and not latched below IASREF on an IASREF speed leg."

Page 147, third and fourth lines

Delete

"and

$|\Delta V| > 1.54$ kt"

Page 147, paragraph 1, first sentence

Change to

"The NCU will scale ΔV at 231 kt/bit and will generate a word as shown in figure 4-3, with label 01000100, to define the length of the speed error symbol."

Delete second sentence

"The coordinates will be defined as follows:

ΔV positive . . .

Y bottom = ΔV

where Y coordinates . . . raster elements."

Change last sentence to

"The symbol length is defined in raster elements. When GUID4D is not set and not on an IASREF speed leg, the DM will be set to invalid."

Page 147, paragraph 2

Change to

The PCU will generate . . . DM is valid "using the symbol length received" from the NCU . . .

Page 147, section 4.4.11, title and paragraphs 1 and 2

Replace

"4.4.11 ILS Symbology

Localizer and glide slope deviation shall be indicated by the displacement of one of the two ILS symbols, specified in table 4-5, from the boresight dot of the reference airplane symbol. The cross symbol shall be used on all manual approaches and the ILS gate symbol shall be used for autolands only.

No data are required from the NCU to generate or position these symbols. The PCU shall use the localizer and glide slope signals, which are input directly to the PCU as dc analog signals (see table 4-1), to position these symbols."

Insert

"4.4.11.1 Cross Symbol

The cross symbol shall be composed of six raster-generated rectangles as specified in table 4-5. The symbol shall be shaded black (0001) and have priority levels (10001) through (10110) assigned to it.

The localizer deviation signal shall be mechanized to move the ILS cross left and right relative to the reference airplane symbol at 0.4333 element/μ amp. The maximum lateral movement shall be limited to ±1.433 in. (±96 elements) from the zero position. Note that this corresponds to a 222-μamp (2.95 dot) localizer deviation. The maximum input will be approximately ±225 μamp.

The glide slope deviation signal shall be mechanized to move the ILS cross up and down relative to the reference airplane symbol at 0.266 element/μamp. The maximum vertical movement shall be limited to ±0.625 in. (±54 elements) from the zero position. Note that this corresponds to a 203-μamp (2.70 dot) glide slope deviation. The maximum input will be approximately ±225 μamp.

4.4.11.2 ILS Box

The ILS box symbol shall be used in lieu of the ILS cross symbol whenever both a LAND ENGAGE and an AUTO ENGAGE discrete are received from the flight control computers. The symbol shall be composed of four raster-generated rectangles as specified in table 4-5. The symbol shall be shaded white (1111) and have priority levels (01101) through (10000) assigned to it."

Page 147, section 4.4.11, paragraph 3

Change and insert as second paragraph, section 4.4.11.2

"The localizer . . . airplane symbol at 2.7 elements/μamp. The maximum lateral movement shall be limited to ±1.94 in. (±130 elements) from the zero position. Note that this corresponds to a 48-μamp (approximately 2/3 dot) localizer deviation. The maximum input signal will be ±225 μamp."

Page 148, paragraph 1

Change and insert as third paragraph, section 4.4.11.2

". . . airplane symbol at 0.505 element/μamp. The maximum vertical movement shall be limited to ±0.875 in. (±76 elements) from the zero position, which corresponds to a 150-μamp (2 dot) glide slope deviation. The maximum input will be ±225 μamp."

Page 148, paragraph 2

Delete

"Radio . . appropriate)."

Page 148, paragraph 4, first sentence (fourth paragraph, section 4.4.11.2)

Change

. . . the ILS symbol . . . to "the ILS box symbol" . . .

Page 149, third and fourth lines

Change to

"K_P = pitch command scale factor = 2610

K_R = roll command scale factor = 468"

Page 149, paragraph 1

Change to

"The NCU shall scale the pitch command at 14.5 bits/deg θ and the roll command at 2.6 bits/deg ϕ, and shall limit the respective movements of ±1.0 in. (±87 bits) vertically and ±0.97 in. (±65 bits) horizontally. The NCU shall then transmit these roll and pitch commands on labels 01000101 and 01000110 as an X and a Y coordinate, respectively."

Page 149, section 4.4.13, paragraph 3, first sentence

Change

. . . the circle and dashed gamma wedges symbol will be generated alone . . . to ". . .the circle or dashed gamma wedges symbol will be generated alone dependent upon which VNAVF option is selected on the NCDU."

Page 150, section 4.4.13.1, paragraph 1, last sentence

Change to

. . ."identifier display in the lower right corner of the EADI."

Page 150, section 4.4.13.1, paragraph 3

Change to

$$\text{"}XS' = 4388.76 \left[ANGLE + DA - TKE - \tan^{-1} \left(\frac{XTK}{DTOGO + DIST} \right) \right]$$

$$YS' = 4388.76 \left[\tan^{-1} \left(\frac{HERR}{DTOGO+DIST} \right) + PITCH + PITCHB^* \right] \text{"}$$

Page 150, section 4.4.13.1, paragraph 3

Add

. . . next waypoint "and all angles are defined in degrees/180." (See figures . . .

Page 151, paragraph 2

Change

24.8 (both times) to "4388.76"

Page 151, paragraph 4

Change to

"XSL = ±400 bits
YSL = ±285 bits"

Page 151, paragraph 4

Add

For the upper airplane position "(as used in the ADEDS configuration)," the YSL . . .

Page 151, subparagraph, paragraph 4

Change to

"YSL $= \begin{matrix} +120 \text{ bits} \\ -450 \text{ bits"} \end{matrix}$

Page 152, paragraph 1, third sentence

Delete

"The type 2 word . . . the symbol."

Page 152, paragraph 1, last sentence

Add

. . . to the horizon " and will be equal to $-(\phi)$, where ϕ = roll angle."

Page 152, paragraph 3

Change

24.8 (both times) to "2388.76"

Page 152, paragraph 4

Change to

"Airplane at screen center: XCL = ±400, YCL = ±285

Airplane at offset position: XCL = ±400, YCL = $\begin{matrix} +120 \\ -500 \end{matrix}$"

Page 153, paragraph 1

Change

Y_1 = YC + 26* to "YC + 42*"
Y_3 = YC – 26* to "YC – 42*"
*26 bits to "*42 bits"

Page 153, paragraph 2, first sentence

Change

. . . vector code 1100001 . . . to . . . " vector code 1100000" . . .

Page 153, paragraph 3, first sentence

Change to

"A three- to five-character alphanumeric label identifying the displayed waypoint shall be displayed in the lower right corner of the EADI, as shown in table 4-5."

Page 153, paragraph 3, last sentence

Change to

"have WF = 0, ST = 0, and . . ."

Page 153, paragraph 4

Delete

"Additional type 4 . . . (sec. 4.4.13)."

Page 153, footnote

Change to

"*42 bits = 0.360 in.," which . . .

Page 154, paragraph 3, first sentence

Change to

. . ."these data at 0.167 in./deg and shall subtract pitch and pitch bias" . . .

Page 154, last paragraph

Change to

$$\begin{aligned} \text{“}XC' &= KR' (RCMD) + 4388.76\ (DA) \\ YC' &= KP' (PCMD) - 4388.76\ (PITCH + PITCHB - FPA)\text{”} \end{aligned}$$

Page 155, paragraph 1

Change

KR′ figure to "2102.4"
Change KP′ figure to "8760"

Page 155, section 4.4.14, paragraph 3, last sentence

Change to

"The display shall read in 2-ft increments from 0 to 100 ft, in 10-ft increments from 100 to 1500 ft, and in 100-ft increments from 1500 to 2500 ft."

Page 157, the Y5 equation

Change to

"where S_f = 4388.76 bits per semicircle."

Page 157, next to last paragraph, first sentence

Change to

. . . "using vector code 1100010, with I_V set" . . .

Page 158, third item

Change to

"Width of runway (300 ft assumed)"

Page 158, section 4.5.1, first sentence

Change to

"This mode is initiated by selecting TEST mode on the EADI mode control unit (see fig. 46)." Selection . . .

Page 159, paragraph 2, first sentence

Change to

. . . "EADI test pattern defined in" figure . . .

Page 159, section 4.7, Switch 4

Change to

"OFF Reference airplane symbol position"

Page 160, last line

Delete

"Switch 11 . . . position"

Page 162, TABLE 4-2, line 11

Change to

"I&R control word with IC = 00, RC = 0, RS = 0, OC = 1, TC = 1, WF = 1"

Page 163, TABLE 4-3, second section, PITCH REF

Add to

. . . reference line. "Readout follows: Auto FPA from NCU."

Page 165, TABLE 4-5, dimensions

Change

All 1.02 figures to "0.97"
All 0.44 figures to "0.38"
All 0.06 figures to "0.05"

Page 166, TABLE 4-5–Continued, Pitch Attitude Scale

Replace

Page 167, TABLE 4-5–Continued, Roll Pointer and Scale

Change

Figure 0.15 to "0.26"

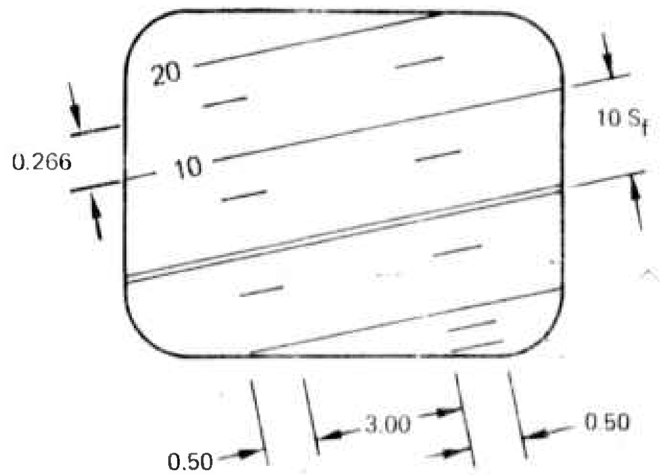
Page 170, TABLE 4-5–Continued, V-Nav Identifier

Change

CAR to "CARNN"
move CARNN to lower right corner of indicator face

Page 166
Replace

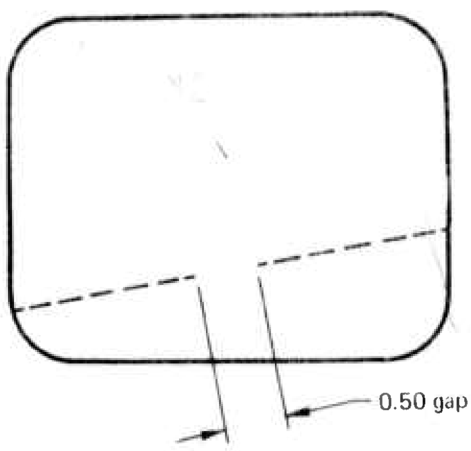
TABLE 4-5.–CONTINUED



Note: S_f = scale factor

Pitch Attitude Scale

Dimensions in inches



Pitch Reference Line

Page 175, TABLE 4-6—Continued, last item

Add

"WR" in label column

Page 176, TABLE 4-6—Concluded, Label column

Add

"KP" in Label column on Pitch flight director command scale factor line
"KR" in Label column on Roll flight director command scale factor line

Page 176, TABLE 4-7, Data content column

Change to

"Position: X = −288 bits"

Page 176, TABLE 4-7, Data content column, following N + 7

Add

"N + 8 Symbol word—type 4 D WF 1"

Change

N + 8 to "N + 9"

Page 176, TABLE 4-7, footnote, first line

Change to

"N = first word of table data"

Page 183, FIGURE 4-6, Pitch Ref

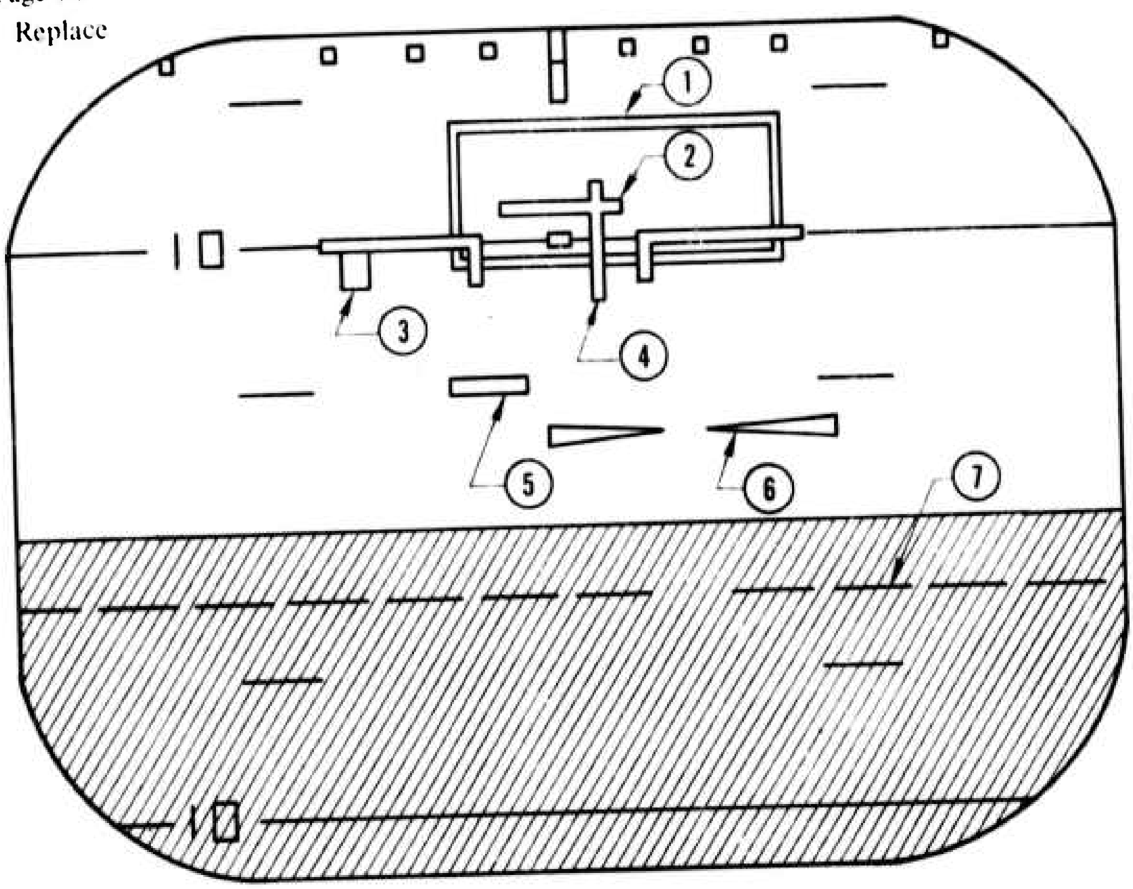
Change

22.7 to " −12.7"

Page 185, FIGURE 4-8

Replace

Page 185
Replace



(1) Center of beam above and to right of airplane

(2) Plus pitch command (calls for pitch up)

(3) Plus speed error (calls for speed increase)

(4) Plus roll command (calls for roll right)

(5) Plus flightpath acceleration (forward acceleration)

(6) Plus flightpath (above horizon) and plus drift angle (drift to right)

(7) Minus pitch (or flightpath angle) reference

FIGURE 4-8.—POLARITY DEFINITION—EADI SYMBOLOGY

Page 192, FIGURE 4-16

Replace

Page 199, section 5.3.2, paragraph 2, item 2

Change

TAE to "TKE"

Page 201, section 5.4.2, item 8

Change to

"Track angle error (TKE)"

Page 202, section 5.4.3, item 1

Change to

"Airplane track angle error (TKE)"

Page 204, TABLE 5-2, item 6

Change

TAE to "TKE"

Page 224, paragraph 1, last sentence

Add

. . . zeroed out. "Entry of a new origin also reinitializes navigation airplane position to the present INS values of latitude and longitude."

Page 231, third subparagraph, next to last sentence

Change to

. . . increasing or when "XTK" is greater than 15,000 ft. The . . .

Page 231, Note

Delete

"Note: . . . displays."

Page 192
Replace

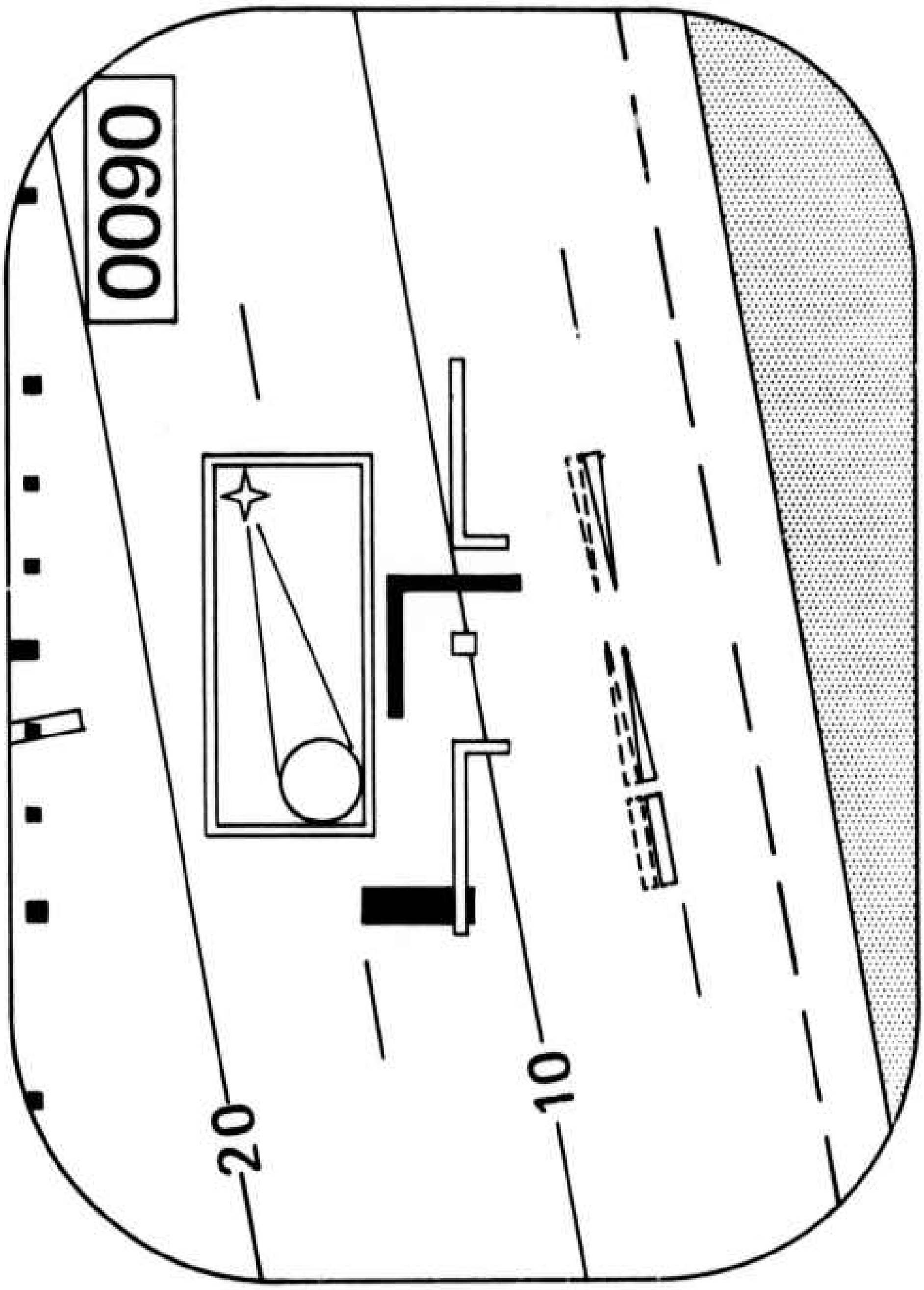


FIGURE 4-16.–EADI SELF-TEST DISPLAY FORMAT

Page 234, paragraph 1, last subparagraph

Change to

"● OFFSET, TK SEL, ALT ENG, FPA ENG, IAS ENG"

Page 234, footnote

Delete

"*These modes . . . panel."

Page 238, lines 2 and 3

Change to

"4	NAVAID	#2"
"5	NEXT	#1"

Page 238, first subparagraph

Change to

"Data that will override the autotune station selection can be entered on lines 3 and 5. The letter M will appear in position 24 following the three-letter code of the manually tuned station. Reversion to the autotune of navaid 1 will occur when keys 3, REJ are pressed in the NAV DATA 3 mode. Similarly, keys 4, REJ cause reversion to the autotune of navaid 2."

Page 238, last subparagraph, first sentence

Change to

. . . a flag "RETUN2" is set and the cue RETUNE "NAVAID #2" will appear . . .

Page 238, last subparagraph, last sentence

Change to

. . . next waypoint is "passed" and the same . . .

Page 238, section 6.5.5

Change to

"There are three SEL modes: hold modes, EADI options, and EPR limit selection. Each display format is activated by successive presses of the SEL key."

Page 238, section 6.5.5.1

Change to

"The first and fourth press" of the . . .

Page 239, first paragraph

Change to

"The SEL 1 modes WPT HOLD and OFFSET, when activated, cause no automatic change to the path guidance output to the flight controls, autothrottle, and EADI display. However, additional symbology will appear on the MFD.

- WPT HOLD
  - GUID–Lateral path guidance output unchanged.
  - MFD–Holding pattern symbology (see sec. 2.4.1.7.6). Mode and scaling annunciation (see sec. 2.4.1.10).
  - EADI–VNAV and flight director options driven by original path guidance.

- OFFSET
  - GUID–Lateral path guidance output unchanged.
  - MFD–Offset path displayed, original path shows as provisional. Time box stays on original path. Mode and scaling annunciation (see sec. 2.4.1.10).
  - EADI–VNAV 1 and flight director options driven by original path guidance."

Page 240, first subparagraph

Change to

- EADI–VNAV . . . the flight plan "path." (*Delete* "and LINKUP displayed below waypoint . . . set.")

Page 240, ALT ENG subparagraph, last item

Change to

. . . flight plan path. (*Delete* "SEL/ALT displayed . . . designator.")

Page 240, IAS ENG, last item

Change to

"EADI–Acceleration command and speed error continue to be driven by 4D path guidance."

Page 240, FPA SEL, last item, last sentence

Delete

"SEL/FPA will . . . designator."

Page 241, fourth subparagraph

Change to

"When the HOLD waypoint becomes the TO waypoint, the annunciation on line 8 of the NAV DATA 1 and NAV DATA 2 pages will become HOLD RANGR."

Page 243, preceding section 6.5.6

Add

"6.5.5.3 SEL 3—EPR Status

The third press of the SEL key will bring up the SEL 3 format (see fig. 6-12a), and the cue message on line 8: CHECK AIRBLEED STATUS. SEL 3 EPR status display options will be activated as follows:

- Press key 1. Airbleed status will toggle between ON and OFF each time 1 is pressed. The ABSTAT flag will be set correspondingly to 1 or 0 for the EPR limit calculations (see sec. 8.5). SEL 3 line 8 message will become SELECT # FOR ACTIVE.

- Press key 2, 3, or 4 to select the active EPR limit. SELECTED appears on the line corresponding to the number key and the flag EPRFLG used in the EPR limit algorithms (sec. 8.5) will become 0 for a line 2 press, 1 for a line 3 press, and 1 for a line 4 press."

Page 243, section 6.5.6.2, paragraph 1

Change

. . . page (see fig. "6-14)." This page . . .

Page 243, last paragraph, second sentence

Change

. . . status page for a minimum of 10 "sec." (*Delete* "and the cue . . . this message.")

Page 247, section 6.7.2

Delete

Items 1, 2, 3, 4, and 7

Page 248, section 6.8

Change to

"6.8 NCDU DEBUG PAGES AND COMMANDS

There are three NCDU debug pages on which any NCU memory location may be displayed and changes stored back into memory. The update rate is once per second. There are five display formats: octal, decimal, angles, alpha, and dump. All modes except dump display one location per line. Dump displays two locations per line. The contents of the displayed line may be changed in all modes except dump mode.

In NCDU debug commands, x represents an octal address, y represents an octal value, a represents an alpha character, and represents a decimal digit. The procedures for debug commands are as follows:

- Push zero to initiate debug on to change pages.
- Push REJ to clear a debug page.
- To enter a command, push a line number (1 through 8). The word LINE and the number will appear on line 8. Then, key one of the following comments:

  - <u>A (octal) format</u>
    - Display: Key Ax
      - If x = 0, line is cleared .
    - Change: Key CY
  - <u>B (alpha) format</u>
    - Display: Key Kx for 8-bit ASC
      Key KxK for 7-bit ASC
    - Change:
  - <u>C (angle) format</u>
    - Display: Key Gx for deg/180
      Key GxG for deg/360
      Key GxB for 0-360 deg/360
    - Change: Key C $\begin{Bmatrix} E \\ W \end{Bmatrix}$ $\underbrace{ddd}_{\text{degrees}}$ $\underbrace{dd.d}_{\text{minutes}}$
    - Will store 1-180 deg/180 for G Command
      1-180 deg/360 for GG Command
      0-360 deg/360 for GB Command

  - <u>E (decimal) format</u>
    - Display: Key ExBdd
      if Bdd missing, assumes B23 (integer)
    - Change: Key C $\begin{Bmatrix} \\ M \end{Bmatrix}$ $\underbrace{dddd.d}_{\text{any legal 9 character ASCBIN number}}$

- D (dump) format

Display only: Key Dx
Displays two octal locations/line from entered line, number to bottom of page

- Override octal store

Change only: Key CAy
Octal value y will be stored into the displayed location. The format of the display will not be changed.

6.9 NCDU SOFTWARE LABELS

The machine language labels for the variables defined in section 6.6 are summarized in table 6-9. These labels are used by the NAV, GUID, MFD, and EADI programs."

Page 249, TABLE 6-1

Add to end of list

"CHECK AIRBLEED STATUS PRESS # FOR ACTIVE"

Page 256, TABLE 6-7—Concluded, Mode (page) used column

Add

Draw arrow from SEL #1 to RADIAL line

Page 256, TABLE 6-7—Concluded

Add to end of Table

Displayed Name	Mode (page) Used	Parameter	Units
MCT	SEL #3	Mag continuous thrust EPR limit	—
CLIMB		Mag climb thrust EPR limit	—
CRUISE		Mag cruise thrust EPR limit	—
EPR 1		Engine 1 EPR	—
EPR 2		Engine 2 EPR	—

Page 259, TABLE 6-9—Concluded, item 7, Label column

Change

HLDTK to "HLDTRK"

Page 259, TABLE 6-9—Concluded, item 10

Delete

"GSSEL . . ."

Page 259, TABLE 6-9—Concluded, item 11

Delete

"HLDGS . . ."

Page 279, FIGURE 6-10

Replace

Following page 281

Insert Figure 6-12a—SEL 3 (SELECT 3) MODE

Page 295, section 7.1, paragraph 2, last sentence

Delete

"The fast loop . . . time/sec."

Page 295, section 7.1.1, paragraph 1

Change to

"INS updated by two DMEs (IDD) where the first D refers to DME 1 and the second D refers to DME 2

INS updated by one DME and one VOR (IDV, or IVD)
INS updated by one DME (IDX or IXD)
INS alone (IXXX)
Air data and magnetic heading updated by two DMEs (ADD)
Air data and magnetic heading updated by one DME and one VOR (ADV or AVD)
Air data and magnetic heading alone (AXX)
Air data and magnetic heading updated by one DME (ADX or AXD)
Radio navigation alone (XDD, XDV, XDX, etc.)"

Page 295, paragraph 2, first sentence

Add

. . . of preference. "Because only the DMEs are autotuned (sec. 7.1.2.3), the VOR modes above are not primary modes." Automatic mode . . .

Page 279
Replace

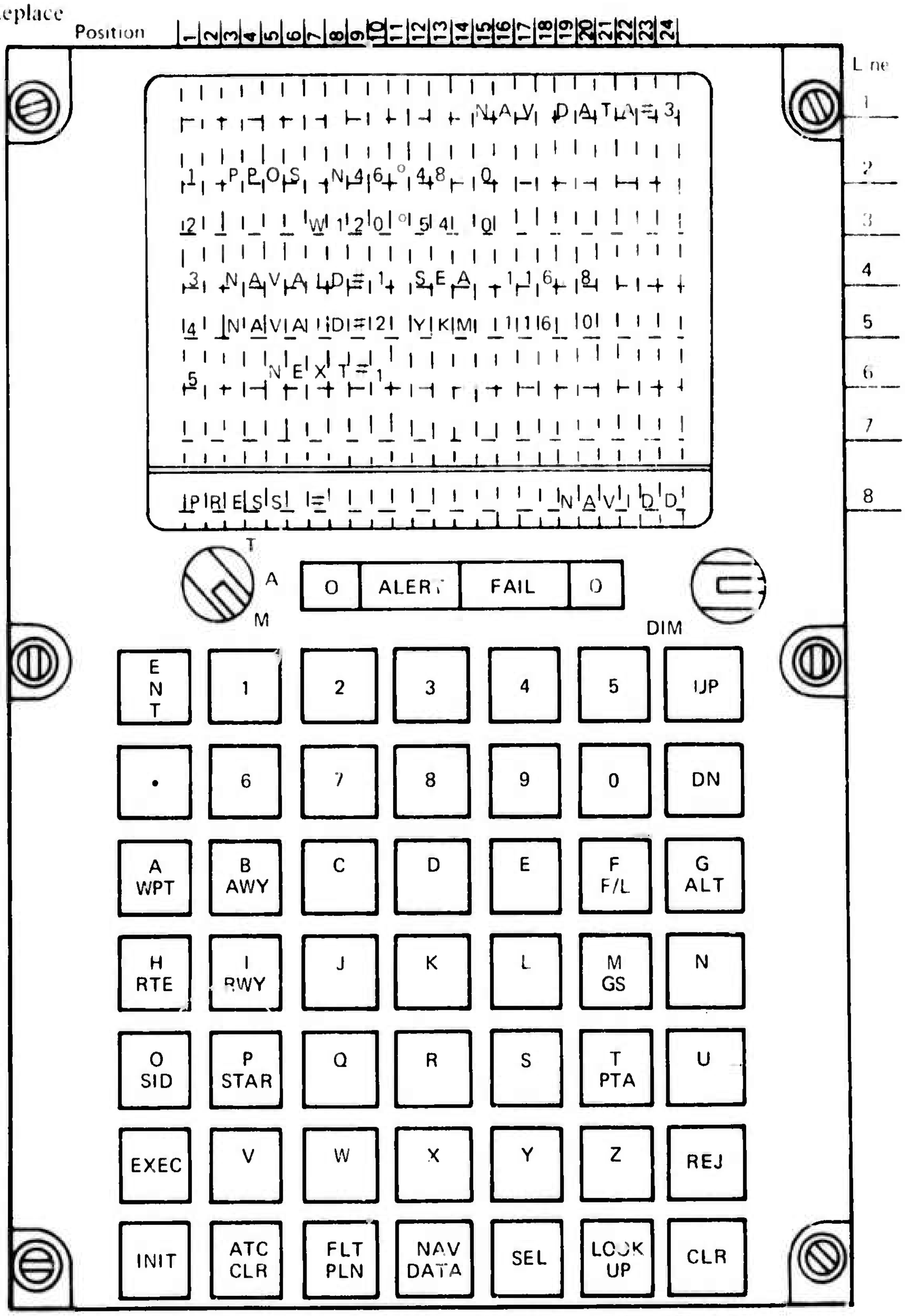


FIGURE 6-10.—NAV DATA 3 (NAVIGATION DATA 3) MODE

Page 281a

Add

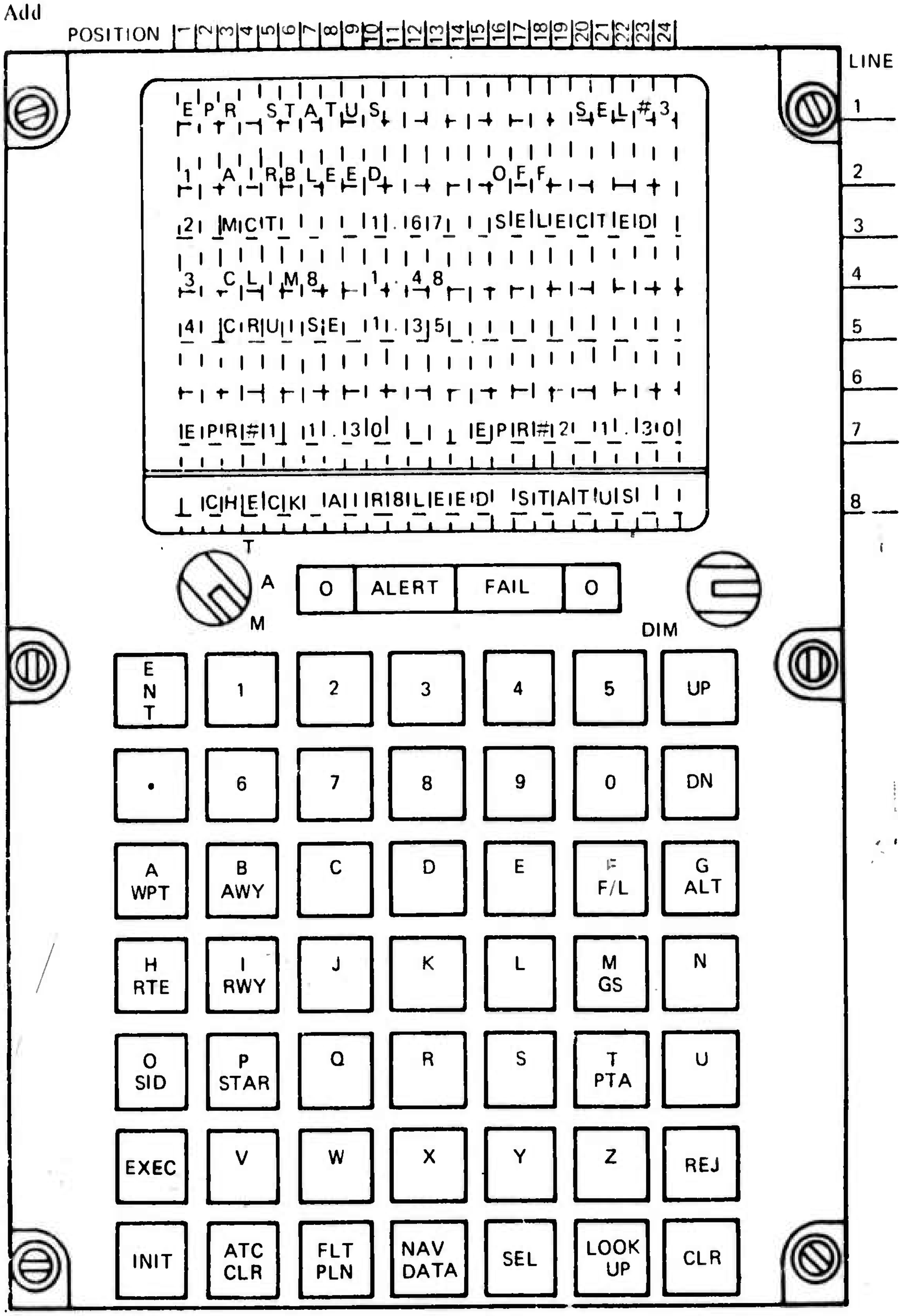


FIGURE 6-12a.–SEL 3 (SELECT 3) MODE

Page 296, section 1.2.1, first sentence

Change to

three flags "F0, F2, and F3." These . . .

Page 296, section 7.1.2.2, paragraph 2

Change to

. . . AUTO position. "VOR 2" tuning is . . .

Page 296, section 7.1.2.3, paragraph 1

Change

All navaid 1, TUNE NAVAID #1, and RETUN1 should be changed to "navaid 2," "TUNE NAVAID #2," and "RETUN2."

Page 296, section 7.1.2.3, paragraph 2, first and second sentence

Change to

"The navaid 1 autotuning selects the best VORTAC station available for triangulation with navaid 2 data. When airplane altitude is below 18,000 ft, a search is made of all VORTAC stations within a range of 40 nmi and a station bearing estimation is made."

Page 297, first sentence

Change to

"first station whose bearing relative to the navaid 2 satisfies the expression defined below will be autotuned as navaid 1.

$$150^\circ > (\text{bearing navaid 1 - bearing navaid 2}) > 30^\circ \text{ "}$$

Page 297, section 7.1.3.1, paragraph 1

Change to

"The NCU receives velocity north and velocity east from the INS 5 times/sec over the ARINC 561 digital bus (see table 7-3)." (*Delete* "These accelerations . . . 20 times/sec.")

"$\hat{V}_N$ = INS north velocity

$\hat{V}_E$ = INS east velocity"

Page 297, section 7.1.3.2, items 1 and 2

Change to

$$\text{"}\hat{V}_N = V_{TAS} \cos(\psi)$$

$$\hat{V}_E = V_{TAS} \sin(\psi)\text{"}$$

Page 298, section 7.1.3.2, first paragraph

Change to

"MAGVAR is calculated in the INS and transmitted to the NCU as shown in table 7-3. In the event of INS failure, the last transmitted value of MAGVAR received from the INS is used to convert the analog magnetic heading input to true heading for use in the reversionary air data/magnetic heading navigation modes."

Page 298, section 7.1.4

Change to

"The following computations are performed in the slow loop."

Page 298, section 7.1.4.1

Change

All DME and VOR to "VORTAC" (eight changes)

Pages 300, 301, and 302

Replace with the following:

"7.1.4.3 Selection of Weights w_1 Through w_8

For the DME/DME mode:

$$w_1 = w_3 = w_5 = w_7 = 0.125$$

$$w_2 = w_4 = w_6 = w_8 = 0.0$$

For the VOR 2/DME 1 mode (1DV):

$$w_1 = w_5 = 0.125$$

$$w_3 = w_7 = w_4 = w_8 = 0$$

$$w_2 = w_6 = (0.125)\left(\frac{1}{R_{M1}}\right)$$

$$R_{max} = 20 \text{ nmi}$$

For the VOR/DME 2 mode (IVD):

$$w_3 = w_7 = 0.125$$

$$w_1 = w_5 = w_2 = w_6 = 0$$

$$w_4 = w_8 = (0.125)\left(\frac{1}{R_{M2}}\right)$$

For air data modes:

$$w_1 = w_3 = w_5 = w_7 = 0.5$$

7.1.4.4 Computation of Filter First and Second Order Feedback Terms

$$K_1 = 2w\,dt = s/T dt$$

$$K_2 = w^2 dt = 1/T^2 dt$$

$$T = 20 \text{ sec air data mode}$$

$$T = 50 \text{ sec INS mode}$$

$$\begin{pmatrix} N_{F1} \\ E_{F1} \end{pmatrix} = K'_1 \begin{pmatrix} \Delta P_N \\ \Delta P_E \end{pmatrix}$$

$$\begin{pmatrix} N_{F2} \\ E_{F2} \end{pmatrix} = K_2 \begin{pmatrix} \Delta P_N \\ \Delta P_E \end{pmatrix}$$

First and Second Order Gains

$$K'_1 = 1/K_1 dt$$

$$K'_2 = 360\, K_2 dt$$

7.1.4.5 Computation of Meridional Radius of Curvature and Radius of Curvature Normal to Meridian

Normal radius of curvature:

$$R'_N = h_{A/C} + a\,(1 + f \sin^2 \phi) \cos \phi$$

Meridional radius of curvature:

$$R'_M = h_{A/C} + A(1 - 2f + 3f\sin^2\phi)$$

7.1.4.6 Wind Calculations

Wind is calculated in the slow executive loop.

$$\text{Wind direction} = 180^\circ + \tan^{-1}\left[\frac{V_E - V_{TAS}\sin(HDG)}{V_N - V_{TAS}\cos(HDG)}\right]$$

$$\text{Windspeed} = \sqrt{\left|V_N - V_{TAS}\cos(HDG)\right|^2 + \left|V_E - V_{TAS}\sin(HDG)\right|^2}$$

If radar altitude is less than 5 feet, windspeed is set to zero and wind direction is left unchanged. Also note from table 7-7 that V_{TAS} is set to the value of calibrated airspeed when $V_{TAS} < 150$ kt.

7.1.5 Fast-Loop Computations

The following computations are performed 20 times/sec in the fast loop.

7.1.5.1 Analog-to-Digital Conversions

A description of the A/D conversions is included in table 7-7, which shows the input data from all analog interfaces, and also the digital input data from the ICP, which also requires conversions from ICP machine units to units compatible with the C-4000.

7.1.5.2 Navigation Mode Flags (see Table 7-1)

When the INS data are valid, the INS valid discrete (bit 4, see table 7-3) will be set. If it is desired to ignore the INS data, then the flag, NOINS, may be set to non-zero via the NCDU debug page. If the discrete is set and the flag, NOINS, is zero, then the INS mode flag is set and the inertial velocities are stored (see sec. 7.1.3.1).

If the INS data are not to be used, then the altitude valid discrete (bit 7) is tested. If valid, the air data mode flag is set and the velocities are calculated as indicated in section 7.1.3.2.

If neither the INS nor the air data modes are valid, then the system dead reckons using the last available velocities.

7.1.5.3 Latitude and Longitude Initialization

There are three ways by which latitude (ϕ) and longitude (λ) can be initialized in the NCU. At initial power-on of the NCU, latitude and longitude are automatically initialized on a one-time-only basis by latitude (ϕ_I) and longitude (λ_I) received from the INS ARINC 561 input bus. (See table 7-6.)

When groundspeed is less than 4 kt, latitude and longitude initialization from the INS can be overridden by manual entry through the NCDU NAV DATA 3 mode.

Whenever a new origin is entered through the NCDU INIT mode, latitude and longitude are reinitialized to INS position.

7.1.5.4 Velocity Updates

Error velocity:

$$\Delta V_N = \Delta V_N + K'_2 \Delta P_N$$

$$\Delta V_E = \Delta V_E + K'_2 \Delta P_E$$

System velocity:

$$V_N = \hat{V}_N + \Delta V_N$$

$$V_E = \hat{V}_E + \Delta V_E$$

7.1.5.5 Latitude/Longitude Updates

The following updates occur only if groundspeed is greater than 4 kt.

Latitude and longitude updates:

$$\Delta\phi_R = \Delta\phi_R + (V_N dt + K'_1 \Delta P_N) R'_M$$

$$\Delta\lambda_R = \Delta\lambda_R + (V_E dt + K'_1 \Delta P_E)/R'_N$$

System latitude/longitude:

$$\phi = \phi + \Delta\phi_R$$

$$\lambda = \lambda + \Delta\lambda_R$$

A conversion factor of 6076.12 ft/min of latitude is used.

7.1.5.6 Inertial Latitude/Longitude Updates

This calculation of uncorrected inertial position is required for instrumentation purposes.

$$\phi_I = \phi_I + \frac{V_N dt}{R'_M}$$

$$\lambda_I = \lambda_I + \frac{V_E dt}{R'_N}$$

7.1.5.7 Track and Heading Calculations

$$TK = \tan^{-1}\left(\frac{V_E}{V_N}\right)$$

HDG = INS true heading from the INS ARINC 561 bus input

DFTANG = TK – HDG

If groundspeed is less than 64 knots:

DFTANG = 0

TK = HDG

7.1.5.8 Digital/Synchro Outputs

The following output functions are processed.

- sin (DFTANG) → location 100_8
- cos (DFTANG → location 101_8
- sin (TKE) → location 104_8
- cos (TKE) → location 105_8

(TKE is calculated in guidance (see sec. 5.3.2).)

If bit 10 of the input discrete is zero:

- sin (TK) → location 102_8
- cos (TK) → location 103_8

If bit 10 is a one:

- sin $(TK - \Delta\psi_M)$ → location 102_8
- cos $(TK - \Delta\psi_M)$ → location 103_8

7.1.5.9 Groundspeed

$$GS = V_N \cos(TK) + V_E \sin(TK) \text{ kt}$$

$$VGS = GS * 1.6878 \text{ ft/sec}$$

Two groundspeed flags are processed.

$$\begin{aligned} NAVFLG &= 0 \text{ if } GS \leqslant 4 \text{ kt} \\ &\neq 0 \text{ if } GS > 4 \text{ kt} \\ NAV65K &= 0 \text{ if } GS \leqslant 64 \text{ kt} \\ &\neq 0 \text{ if } GS > 64 \text{ kt} \end{aligned}$$

7.1.5.10 INS Accelerations

Along- and across-track accelerations are received on the INS ARINC 561 bus and rescaled to produce along-track acceleration (VGSDOT) and across-track acceleration (ACNORM). ACNORM is further processed by a 1-sec lag filter as follows:

$$-ACNORM = ACNORM + ((INS \text{ cross-track acceleration}) - ACNORM) \ \Delta t$$

7.1.5.11 Baro-Inertial Loop

Baro altitude, H_{BARO}, is calculated from the synchro values of altitude fine and altitude coarse.

Barometric altitude is mixed with inertially derived vertical acceleration to yield vertical velocity and baro-inertial altitude as shown in figure 7-3 where

$$\begin{aligned} KA &= 0.000125 \\ KV &= 0.0075 \\ KD &= 0.15 \end{aligned}$$

Corrected altitude as used in the guidance equations, outer-loop flight control mode equations, and the NCDU display quantities is obtained by compensating baro-inertial altitude for changes in the barometric pressure setting (see figure 7-4). Barometric pressure setting changes are introduced into the navigation calculations via entry through NCDU initialize page 1 (see sec. 6.5.1).

7.1.6 Symbols

Symbol definitions are listed in table 7-4.

7.2 INPUT/OUTPUT DATA

Defined in table 7-5 are the signals, channel selects, and associated memory locations in the NCU system.

7.3 INS

ADEDS requires an ARINC 562 type INS to provide data to the NCU. A modified Litton LTN-51 is used to satisfy the ADEDS system requirements.

7.3.1 Hardware Modifications

The LTN-51 is modified to provide an acceleration pulse weight of 1/64 ft/sec^2 in the navigate mode instead of the standard 1/8 ft sec^2 per pulse. The resolution provided by this change is compatible with the EADI display functions of flightpath angle and flightpath acceleration. In addition, an accelerometer identical to the horizontal accelerometers is installed in the vertical position.

7.3.2 Input/Output Modifications

The following changes are required to the INS inputs for the ADEDS configuration:

- The ARINC 561 intersystem A input bus is connected to the NCU ARINC 561 test data output bus to receive runway heading data on label 301."

Page 303, first sentence

Change to

"The INS air data system 28-V" . . .

Page 304

Add

"7.3.4 Magnetic Variation

Magnetic variation (MAGVAR) is computed in the INS computer for the following equation:

$$\text{MAGVAR} = \left(20.6^\circ + \frac{\phi}{40^\circ} \cdot \frac{\Delta 0}{2}\right) \cdot \sin\left(\frac{\Delta\lambda + \frac{\Delta\phi}{2}}{0.2\lambda - 18}\right) \cdot \frac{\Pi}{2} - 2.73^\circ$$

where

ϕ = Present position latitude
λ = Present position longitude
$\Delta\phi$ = ϕ - 40°
$\Delta\lambda$ = ψ + 82.5°"

Page 305, TABLE 7-1

Add

Under "Flag state" heading, insert an additional column in first position—INS. "Flag state" subcolumns will then be: INS, Air data[a], Radio mode[b], Update[c].

	INS
Inertial	On
Air data	Off
Radio inertial	On
Radio air data	Off
Radio	Off
DR	Off

Page 306, TABLE 7-2

Replace

Mode	Flag state		
	F0 (DME 1)[a]	F3 (VOR 2)[b]	F2 (DME 2)[c]
DME/DME	Off	—	Off
VOR 2/DME 1	Off	Off	On
VOR 2/DME 2	On	Off	Off
DME 1[d]	Off	On	On
DME 2[d]	On	On	Off
No radio update	On	On	On

[a]F0 is set ON if:

- DME 1 is invalid or not received
- 0 > DME 1 range > 200 nmi
- Measured—estimated range > 5 nmi
- Groundspeed < 64 knots
- Altitude > computed horizontal range
- Bank angle > 15°
- Computed horizontal range > 2 nmi

[b]F3 is set ON if:

- VOR 2 is invalid or not received
- F2 is ON
- Range > 20 nmi
- Measured—estimated bearing > 2°
- Groundspeed < 64 knots

- Altitude > computed horizontal range
- (Measured–estimated bearing) Range > 5 nmi

CF2 is set ON if:

- DME 2 is invalid or not received
- 0 > DME 2 range > 200 nmi
- Measured–estimated range > 5 nmi
- Groundspeed < 64 knots
- Altitude > range
- Bank angle > 15°
- Computed horizontal range > 2 nmi

Note: In the single DME modes, position and velocities are only updated as follows:

- Latitude is updated if:
  345 < Bearing < 15 degrees
  165 < Bearing < 195 degrees
- Longitude is updated if:
  75 < Bearing < 105 degrees
  255 < Bearing < 285 degrees

Page 307, TABLE 7-3
Replace

TABLE 7-3.–DISCRETE WORD FORMATS

Bit position	Input location 46	Output location 60
1	VOR/LOC valid	Tune 1 invalid
2	PCU valid	Tune 2 invalid
3	MFD 1 valid	WPT alert
4	INS valid	NCU valid
5	DME 2 valid	RWY heading discrete
6	DME 1 valid	NCDU NPD
7	Altitude valid	To/from flag (low level)
8	EADI valid	Not used
9	ETD (end of NCDU transmission)	Vertical low level flag valid
10	True heading/magnetic heading	XTK low level flag valid
11	Spare	Spare
12	Spare	Spare
13	Land mode armed	Autothrottle run/clamp
14	Land mode engaged	Autothrottle disengage lights
15	Auto engaged (MSP)	Not used
16	Palm switch (MAP engage)	Not used
17	Autothrottle disengage	Not used
18	Autothrottle aft limit	Not used
19	Not used	Not used
20	Not used	Not used
21	Not used	Not used
22	Not used	Not used
23	Not used	Not used
24	Not used	Not used

Page 308, TABLE 7-4

Change first seven items

Symbol	Definition
V_N	System north velocity
V_E	System east velocity
$\hat{V}_N$	INS north velocity
$\hat{V}_E$	INS east velocity
ΔV_N	North velocity error
ΔV_E	East velocity error
V_{TAS}	True airspeed
. . .	. . .
. . .	. . .
(continue with information from published table 7-4)	

Page 309, TABLE 7-4.– Concluded

Change and add

Symbol	Definition
ΔP_N	North position correction
ΔP_E	East position correction
d^t or Δt	0.05 sec
TK	Track
HDG	Heading
DFTANG	Drift angle
TKE	Track angle error
GS	Groundspeed in knots
VGS	Groundspeed in feet/second
VGSDOT	Along-track acceleration
ACNORM	Cross-track acceleration
H_{Baro}	Baro altitude
ALT	Baro-inertial altitude
ALTCOR	Baro-inertial altitude corrected for baro setting
HDOT	Altitude acceleration

Page 310, TABLE 7-5, ARINC 561/575 Receiver Inputs

Change

Spare to "Mode Select Panel (MSP)" and 200-207 to "200-204"

Page 310, TABLE 7-5, SPBP Receiver Inputs

Change

Spare to "ICP System"

Page 310, TABLE 7-5, SPBP Transmitter Outputs

Change

Spare to "Output bus, ICP and MSP"

Page 310, TABLE 7-5, Radio Navigation Receiver Inputs

Replace

Radio Navigation Receiver Inputs:

Pulse pair 2	568	1	40	SCS 1
Pulse pair 1	568	1	41	SCS 2
2 x 5 receiver 2		1	42	SCS 3
2 x 5 receiver 1		1	43	SCS 4
Nav tune 2		1	64	SCS 5
Nav tune 1		1	65	SCS 6

Page 311, TABLE 7-5.—Concluded, Analog/Digital Inputs, fifth and sixth items

Change

Roll to "EPR 1/Roll"
Pitch to "EPR 2/Pitch"

Page 312, TABLE 7-6, Rate (updates/sec)

Change

Under Rate (updates/sec) change the figure 1 to "4" in all cases (four times)

Insert page following page 312 (312a)

Insert table 7-7

Insert page following page 314 (314a)

Insert figures 7-3 and 7-4

Insert

TABLE 7-7. FAST-LOOP ANALOG-TO-DIGITAL AND ICP INPUT CONVERSIONS

	ADEDS mode		AGCS mode		Units
	Data source	Frequency of conversion	Data source	Frequency of conversion	
Localizer	DC	20/sec	DC	20/sec	Deg/180
Glide slope	DC	20/sec	DC	20/sec	Deg/180
Vertical acceleration[a]	DC	20/sec	DC	20/sec	Ft/sec^2
Altitude fine	Synchro	20/sec	Synchro	20/sec	Deg/180
Roll	Synchro	10/sec	ICP	20/sec	Deg/180
Pitch	Synchro	10/sec	ICP	20/sec	Deg/180
EPR 1	—		Synchro	10/sec	EPR units
EPR 2	—		Synchro	10/sec	EPR units
FD pitch command	—		ICP	20/sec	Deg/180
FD roll command	—		ICP	20/sec	Deg/180
Radar altitude	—		ICP	20/sec	Feet
True airspeed[b]	Synchro	3-1/3/sec	Synchro	3-1/3/sec	Knots
	Synchro	3-1/3/sec	Synchro	3-1/3/sec	—
Magnetic heading	Synchro	3-1/3/sec	Synchro	3-1/3/sec	Deg/180
Altitude coarse	Synchro	3-1/3/sec	Synchro	3-1/3/sec	Knots
Calibrated airspeed	Synchro	3-1/3/sec	Synchro	3-1/3/sec	Knots
VOR	Synchro	3-1/3/sec	Synchro	3-1/3/sec	Deg/180

[a]If radar altitude is less than 5 ft. vertical acceleration is set to zero.

[b]Below 150 kt. TAS is set to the current value of CAS.

Page 314a

Insert

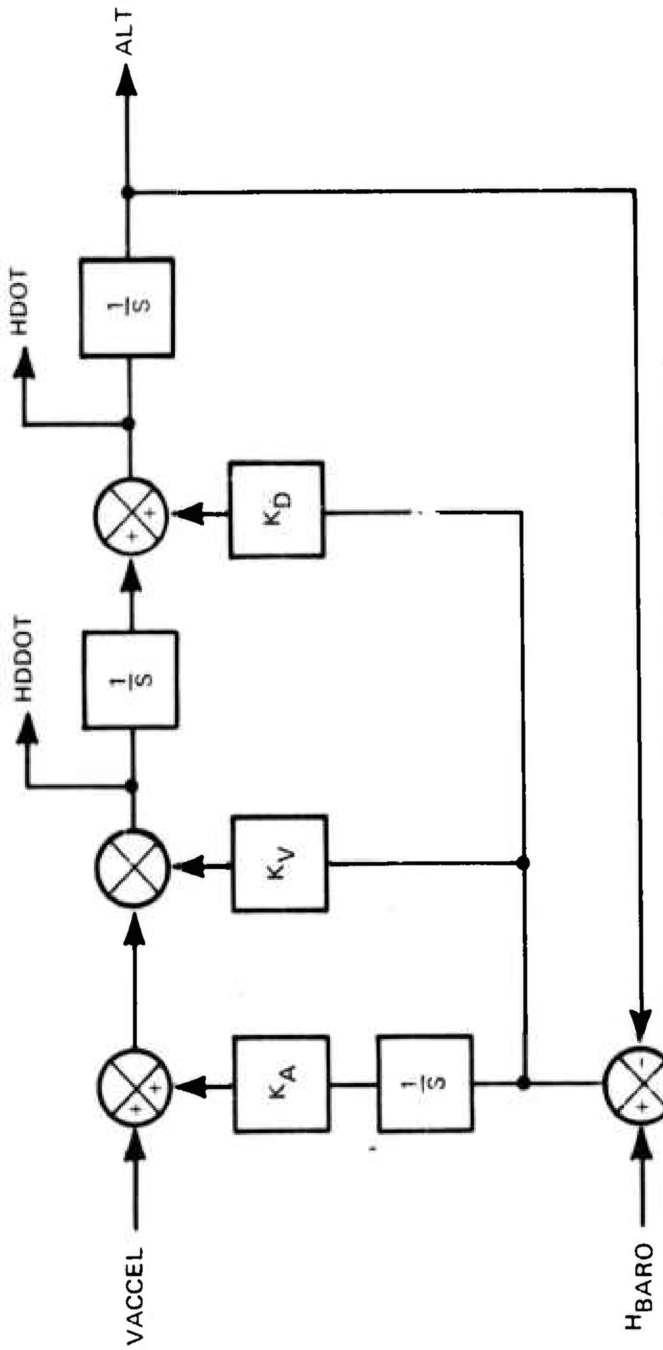


FIGURE 7-3.—BARO-INERTIAL LOOP DIAGRAM

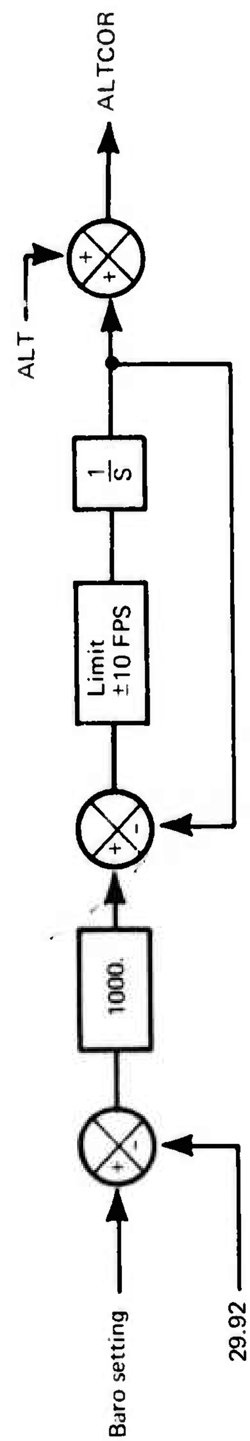


FIGURE 7-4.—ALTITUDE CORRECTED FOR BAROMETRIC SETTING

Insert page 314b

Add

8.0 ADVANCED GUIDANCE AND CONTROL SYSTEM

8.1 GENERAL

Throughout this document many references are made to the Advanced Guidance and Control System (AGCS) mode select panel and the outer loop, noncritical flight modes: track angle select/hold, flightpath angle select/hold, altitude select/hold, indicated airspeed select/hold, and the path modes horizontal path, vertical path, and time path. This section describes the above in brief detail. See table 8-1 for AGCS label definitions.

8.2 AGCS MODE SELECT PANEL/NCU INTERFACE

The AGCS Mode Select Panel (MSP) interfaces with the NCU via an SPBP receiver and an ARINC 575 transmitter. The MSP provides the interface between the pilot and the AGCS required to select operating modes and to set reference parameters for automatic flight control functions. The NCU detects mode button pushes and knob increments incoming on the ARINC 575 bus and performs the mode logic computation to establish the mode and parameter setting selected by the pilot. The NCU also sends the lamp status corresponding to the mode(s) selected to the MSP via the SPBP bus.

8.3 LATERAL AND VERTICAL NONCRITICAL FLIGHT MODE STEERING SIGNALS

The NCU performs the synchronization and error signal computations of each of the modes in the lateral and vertical axis, then selects and limits the error signal of the selected mode and scales the number in incremental computer (ICP) machine units to be sent to the ICP via the SPBP bus as horizontal path command (HPC) and vertical path command (VPC).

8.4 AUTOTHROTTLE CONTROL LAW

The NCU performs the computations necessary to drive the throttle as needed to fly four-dimensional path profiles or to fly the indicated airspeed select/hold mode. The 4D mode requires V_{MO}, M_{MO} limiting, and both modes require EPR thrust limiting (section 8.5). The autothrottle control law yields a delta throttle position command (APC), which is transmitted as a D to A signal to the autothrottle servo.

8.5 EPR THRUST LIMIT CALCULATIONS

The autothrottle is thrust command limited as determined by the following EPR limit calculations. The gain of the throttle command is reduced as it approaches the appropriate EPR limit. EPR limits are computed for the following operating conditions.

Insert page 314c

1) Maximum continuous thrust
2) Maximum climb thrust
3) Maximum cruise thrust

Selection of the appropriate limit and airbleed status (ON or OFF) is done through the NCDU SELECT Page 3 (section 6.5.5.3) The limits are computed as functions of total temperature, pressure altitude, and static pressure. These quantities are computed as follows:

$$T_{SR} = \left[\frac{V_T}{49.02\ M}\right]^2 \qquad M \geq 0.2$$

$$T_{TC} = 5/9\ T_{SR}\ (1 + 0.2\ M^2) - 273$$

$$P_S = 29.92\ (1.0 - 5.258\ x + 11.9\ x^2 - 12.16\ x^3)$$

$$\text{where } x = \frac{h}{145{,}449.6}$$

and where

V_T = true airspeed in fps
M = Mach number
T_{SR} = static temperature in °R
T_{TC} = total temperature in °C
P_S = static pressure in inches H_g
h = pressure altitude

Nomenclature used in computing the EPA algorithms is:

MCLPRL	Maximum climb pressure EPR limit
MCLTL	Maximum climb temperature EPR limit
MCLEPR	Maximum climb EPR based on MCLPL and MCLTL
MCOPRL	Maximum continuous pressure EPR limit
MCOTL	Maximum continuous temperature EPR limit
MCOEPR	Maximum continuous EPR based on MCOPRL and MCOTL
MCRPRL	Maximum cruise pressure EPR limit
MCRTL	Maximum cruise temperature EPR limit
MCREPR	Maximum cruise EPR based on MCRPRL and MCRTL

8.5.1 Maximum Climb Thrust EPR Limit Algorithm

Airbleed on

$$MCLTL = \begin{cases} 1.94 - 0.00628\ T_{TC} \text{ for } h \leq 30{,}000 \text{ ft} \\ 1.94 - 0.00628\ T_{TC} - \dfrac{h - 30{,}000}{5{,}000}\ (0.025 + 00039\ T_{TC}) \text{ for } h > 30{,}000 \end{cases}$$

$$MCLPRL = 3.514 - 0.0535\ P_S$$

MCLEPR = lesser of MCLPRL and MCLTL

Insert page 314d

Airbleed off

$MCLTL = 1.97 - 0.0068\ T_{TC}$

$MCLPRL = 3.589 - 0.0549\ P_S$

$MCLEPR$ = lesser of MCLPRL and MCLTL

8.5.2 Maximum Continuous Thrust EPR Limit Algorithm

Airbleed on

MCOEPR
- for SL < h < 1,500 ft and h > 20,000 ft, use maximum climb curves for all, airbleed on
- for 1500 ≤ h ≤ 20,000 ft use the following

$$MCOTL = \begin{cases} 2.03 - 0.00545\ T_{TC} & \text{for } T_{TC} < 17.5^\circ C \\ 2.08 - 0.008375\ T_{TC} & \text{for } T_{TC} \geq 17.5^\circ C \end{cases}$$

$MCOPRL = 3.56 - 0.0547\ P_S$

MCOEPR = lesser of MCOTL and MCOPRL

Airbleed off

MCOEPR
- for SL < h < 1,500 ft and h > 20,000 ft, use maximum climb curves, all h airbleed off
- for 15,000 ft ≤ h ≤ 20,000 ft, use the following:

$$MCOTL = \begin{cases} 2.053 - 0.00538\ T_{TC} & \text{for } T_{TC} < 17.5^\circ C \\ 2.11 - 100853\ T_{TC} & \text{for } T_{TC} \geq 17.5^\circ C \end{cases}$$

MCOPRL use maximum climb curves, all h airbleed off

MCOEPR = lesser of MCOTL and MCOPRL

8.5.3 Maximum Cruise Thrust EPR Limit Algorithm

Airbleed on

for h < 10,000 ft use maximum climb curves, airbleed on

$$MCREPR = \begin{cases} 1.8568 - 0.00591\ T_{TC} & \text{for } T_{TC} < -20^\circ C \\ 1.8125 - 0.008125\ T_{TC} & \text{for } -20^\circ C \leq T_{TC} \leq 20^\circ C \\ 1.764 - 0.00571\ T_{TC} & \text{for } 20^\circ C < T_{TC} \end{cases}$$

Airbleed off

$$MCRTL = \begin{cases} 1.89 - 0.006\ T_{TC} & \text{for } T_{TC} < -20^\circ C \\ 1.855 - 0.00775\ T_{TC} & \text{for } -20^\circ C \leq T_{TC} \leq 20^\circ C \\ 1.843 - 0.00714\ T_{TC} & \text{for } 20^\circ C < T_{TC} \end{cases}$$

MCRPRL use maximum climb curves, airbleed off

MCREPR = lesser of MCRTL and MCRPRL

Insert page 314e

TABLE 8-1.—AGCS LABEL DEFINITION

Label	Definition
TKSEL	Track select/hold mode discrete
FPASEL	FPA select/hold mode discrete
ALTSEL	Altitude select/hold mode discrete
IASSEL	IAS select/hold mode discrete
PSTTKA	Track select mode preselect state
PSTFPA	FPA select mode preselect state
PSTALT	Altitude select mode preselect state
PSTIAS	IAS select mode preselect state
TKASUM	Track select mode knob Σ cell
FPASUM	FPA select mode knob Σ cell
ALTSUM	Altitude select mode knob Σ cell
IASSUM	IAS select mode knob Σ cell
HORARM	Horizontal path mode armed state
HORPTH	Horizontal path mode engaged state
VERARM	Vertical path mode armed state
VERPTH	Vertical path mode engaged state
TIMPTH	Time path mode engaged state
ATENG	Autothrottle engaged state
CLAMP	Autothrottle run/clamp signal
AUTO	Noncritical mode engaged state
ATDC	Autothrottle disengaged discrete
AFTLIM	Throttle aft limit discrete
PIASSE	IASSEL state last iteration
IASOFF	IASSEL ON to OFF discrete
PTIMPT	TIMPTH state last iteration
TIMOFF	TIMPTH ON to OFF discrete
RTKNOB	Track select mode knob increment discrete
RFKNOB	FPA select mode knob increment discrete
RAKNOB	Altitude select mode knob increment discrete
RCKNOB	IAS select mode knob increment discrete
DIKSEL	Track select button depressed, momentary
DFPSEL	FPA select button depressed, momentary
DALSEL	Altitude select button depressed, momentary
DIASEL	IAS select button depressed, momentary
D2D	Horizontal path button depressed, momentary
D3D	Vertical path button depressed, momentary
D4D	Time path button depressed, momentary
TKRF	Track select synchronization reference value
FPARF	FPA select synchronization reference value
ALTRF	Altitude select synchronization reference value
IASRF	IAS select synchronization reference value
ALFRF	α-flare synchronization reference value

Insert page 314f

TABLE 8-1.–Concluded

Label	Definition
ALFWYN	Synthesized α for noncritical flight modes
KALFA	α-gain as f (ALFSYN)
SQUAT	Radar altitude $\leq$ 0 ft discrete
FLR30	Radar altitude $\leq$ 30 ft discrete
LANDA	Land mode armed discrete
LAND	Land mode engaged discrete
SAVHER	/HER/last iteration (VERPTH logic)
VERSIN	Autothrottle versine compensation signal
DELCAS	Airspeed error signal
DELEPR	Selected EPR limit minus EPR
APCPRM	Autothrottle rate command
EPR 1	Engine 1 EPR
EPR 2	Engine 2 EPR
APC	Autothrottle delta throttle command
HPC	Horizontal path command
VPC	Vertical path command

APPENDIX B

OPERATION EVALUATION TEST DATA

This appendix provides a summary of all crosstrack error (XTKE), altitude error (HER), and time error (PTE) data for the ADEDS operational evaluation flights. The data are presented with respect to the end waypoint of each flightpath leg, and the related guidance option being used is identified. An X indicates that flight test data were not valid for the specified flight conditions.

CROSSTRACK ERROR SUMMARY
SID/STAR–TAN14L

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	JMS	BR14L	X	X	X	X	6-11
PPC	JMS		X	X	X	X	6-11
VDO	IBD		X	X	X	X	6-17
PPS	IBD		X	X	X	X	6-17
VDO	JHA		X	X	X	X	6-18
VDO	JMS	AGL30	764	-328	191	334	6-11
PPC	JMS		236	8	103	57	6-11
VDO	IBD		704	-60	440	226	6-17
PPS	IBD		456	156	326	86	6-17
VDO	JHA		168	-168	66	76	6-18
VDO	JMS	TANGO	5440	-720	1234	2280	6-11
PPC	JMS		344	-2900	-1021	1121	6-11
VDO	IBD		2260	-312	1259	963	6-17
PPS	IBD		368	-252	45	174	6-17
VDO	JHA		2216	-4000	-861	1777	6-18
VDO	JMS	LO14L	-172	-204	-188	8	6-11
PPC	JMS		504	388	445	34	6-11
VDO	IBD		-1661	-284	-215	28	6-17
PPS	IBD		536	0	290	251	6-17
VDO	JHA		-120	-244	-166	25	6-18
VDO	JMS	MWH	884	-304	396	415	6-11
PPC	JMS		108	-44	51	38	6-11
VDO	IBD		640	-300	1	284	6-17
PPS	IBD		176	-116	56	87	6-17
VDO	JHA		136	-216	-72	102	6-18
VDO	JMS	AGL15	-180	-392	-294	71	6-11
PPC	JMS		564	220	457	99	6-11
VDO	IBD		356	-260	-33	183	6-17
PPS	IBD		774	456	625	79	6-17
VDO	JHA		-140	-392	-304	67	6-18
VDO	JMS	WARDN	5208	-244	2063	1399	6-11
PPC	JMS		2220	-900	564	853	6-11
VDO	IBD		2260	2260	2260	34	6-17
PPS	IBD		-224	-3328	-1532	1076	6-17
VDO	JHA		2856	-1924	-159	1566	6-18

ALTITUDE ERROR SUMMARY
SID/STAR–TAN14L

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	JMS	BR14L	X	X	X	X	6-11
PPC	JMS		X	X	X	X	6-11
VDO	IBD		X	X	X	X	6-17
PPS	IBD		X	X	X	X	6-17
VDO	JHA		X	X	X	X	6-18
VDO	JMS	AGL30	40	-48	-23	24	6-11
PPC	JMS		180	104	141	23	6-11
VDO	IBD		156	64	94	20	6-17
PPS	IBD		200	60	147	48	6-17
VDO	JHA		64	-40	-5	32	6-18
VDO	JMS	TANGO	276	-248	-87	136	6-11
PPC	JMS		440	128	252	70	6-11
VDO	IBD		248	-4	132	97	6-17
PPS	IBD		284	16	106	85	6-17
VDO	JHA		244	-4	91	57	6-18
VDO	JMS	LO14L	-64	-168	-87	32	6-11
PPC	JMS		-40	-116	-49	17	6-11
VDO	IBD		-52	-276	-89	63	6-17
PPS	IBD		0	-56	-31	27	6-17
VDO	JHA		-8	-56	-20	8	6-18
VDO	JMS	MWH	-44	-240	-188	49	6-11
PPC	JMS		128	-16	38	37	6-11
VDO	IBD		60	-72	-21	34	6-17
PPS	IBD		188	72	99	22	6-17
VDO	JHA		64	-2716	-113	151	6-18
VDO	JMS	AGL15	36	-1052	-73	114	6-11
PPC	JMS		164	-116	62	77	6-11
VDO	IBD		160	-216	-30	95	6-17
PPS	IBD		108	-52	88	29	6-17
VDO	JHA		52	-56	22	23	6-18
VDO	JMS	WARDN	352	-208	88	132	6-11
PPC	JMS		440	1[illegible]0	200	47	6-11
VDO	IBD		60	36	43	8	6-17
PPS	IBD		284	-12	108	87	6-17
VDO	JHA		468	-12	135	132	6-18

TIME ERROR SUMMARY
SID/STAR–TAN14L

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	JMS	BR14L	X	X	X	X	6-11
PPC	JMS		0	-95	0.19	4.2	6-11
VDO	IBD		X	X	X	X	6-17
PPS	IBD		X	X	X	X	6-17
VDO	JHA		X	X	X	X	6-18
VDO	JMS	AGL30	-12	-14	-13	0.56	6-11
PPC	JMS		-7	-11	-8.5	1 2	6-11
VDO	IBD		X	X	X	X	6-17
PPS	IBD		-37	-40	-39	1.06	6-17
VDO	JHA		-3	-4	-3.7	0.4	6-18
VDO	JMS	TANGO	20	-24	-3	15	6-11
PPC	JMS		15	-2	6	5.4	6-11
VDO	IBD		X	X	X	X	6-17
PPS	IBD		0	-9	-3.5	32	6-17
VDO	JHA		-3	-8	-6.3	1.6	6-18
VDO	JMS	LO14L	-13	-24	-18	3	6-11
PPC	JMS		-15	-93	-36.6	20	6-11
VDO	IBD		X	X	X	X	6-17
PPS	IBD		0	-36	-19.7	17.1	6-17
VDO	JHA		5	-1	1.16	1.38	6-18
VDO	JMS	MWH	-2	-12	-8	3.0	6-11
PPC	JMS		0	-7	-3.4	2	6-11
VDO	IBD		X	X	X	X	6-17
PPS	IBD		-32	-37	-34.5	1.36	6-17
VDO	JHA		4	-3	0.31	2.3	6-18
VDO	JMS	AGL15	-13	-14	-14	0.2	6-11
PPC	JMS		-11	-15	-13	1.3	6-11
VDO	IBD		X	X	X	X	6-17
PPS	IBD		-32	-39	-35.9	2.1	6-17
VDO	JHA		-1	-4	2.4	0.85	6-18
VDO	JMS	WARDN	19	-2	7	5.0	6-11
PPC	JMS		15	0	9	5	6-11
VDO	IBD		X	X	X	X	6-17
PPS	IBD		-9	-17	-12.9	2.6	6-17
VDO	JHA		7	-4	3	3.75	6-18

CROSSTRACK ERROR SUMMARY
SID/STAR–SIP32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		WINCR	-88	-1000	-604	270	5-6
FD	RLM		1552	108	393	371	5-6
Auto			440	328	373	24.6	6-1
V+W	RLM		3564	-48	1740	1072	6-1
V+W	RLM						6-5
PPC	RLM						6-5
FD	JHA		1436	-608	127	445	6-6
Auto			-272	-1028	-634	257	6-9
Auto			-508	-900	-669	103	6-11
Auto							6-14
V+W	JMS		760	84	263	140	6-15
PPS	IBO						6-17
PPS	JHA		-176	-1524	-941	396	6-18
VDO	JHA		324	-3072	-434	989	6-18
Auto		SIPHN	300	-132	39	124	5-6
FD	RLM		416	76	203	83	5-6
Auto			480	-384	193	116	6-1
V+W	RLM		-76	-1508	-636	394	6-1
V+W	RLM		168	-272	-70	118	6-5
PPC	RLM		80	-528	-147	200	6-5
FD	JHA		2836	136	920	897	6-6
Auto			-12	-320	-163	112	6-9
Auto			136	-520	-124	201	6-11
Auto			-396	-460	-435	13	6-14
V+W	JMS		6332	548	4465	1767	6-15
PPS	IBD		-280	-328	-303	11	6-17
PPS	JHA		-52	-1072	-465	264	6-18
VDO	JHA		-92	-7680	-3124	2833	6-18
Auto		CHAPL	596	188	393	131	5-6
FD	RLM		656	176	403	156	5-6
Auto			556	208	380	117	6-1
V+W	RLM		408	-120	262	124	6-1
V+W	RLM		196	-68	154	55	6-5
PPC	RLM		496	56	287	157	6-5
FD	JWA		564	0	330	184	6-6
Auto			216	-48	81	75	6-9
Auto			488	112	339	103	6-11
Auto			-20	-416	-136	79	6-14
V+W	JMS		528	116	205	75	6-15
PPS	IBD		136	-280	53	75	6-17
PPS	JHA		-92	-260	-190	50	6-18
VDO	JHA		756	-300	435	327	6-18

CROSSTRACK ERROR SUMMARY
SID/STAR–SIP32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	MWH	208	-308	23	97	5-6
Auto			248	-768	51	170	6-1
V+W	RLM		2956	-648	1143	1234	6-1
V+W	RLM		1792	-600	583	631	6-5
PPC	RLM		3744	-132	584	1076	6-5
FD	JHA		308	-640	-14	178	6-6
Auto			4712	-360	20	881	6-9
Auto			68	-528	-48	118	6-11
Auto			-92	-580	-259	154	6-14
V+W	JMS		2012	-2360	230	1200	6-15
PPS	IBD		388	-268	80	183	6-17
PPS	JHA		488	-220	238	167	6-18
VDO	JHA		1512	-1904	763	935	6-18
FD	RLM	PELIN	-20	-140	-70	41	5-6
Auto			-656	-788	-748	32	6-1
V+W	RLM		-340	-528	-476	47	6-1
V+W	RLM		-128	-588	-401	140	6-5
PPC	RLM		68	-120	5.8	40	6-5
FD	JHA		236	-32	158	85	6-6
Auto			4712	4712	4712	14	6-9
Auto			-396	-568	-507	48	6-11
Auto			-236	-548	-407	94	6-14
V+W	JMS		124	-412	-180	176	6-15
PPS	IBD		144	-220	-54	94	6-17
PPS	JHA		316	72	230	69	6-18
VDO	JHA		608	88	283	153	6-18
FD	RLM	TD32R	-12	-440	163	138	5-6
Auto			-656	-1048	-868	109	6-1
V+W	RLM		-412	-1488	1240	370	6-1
V+W	RLM		0	-648	-353	212	6-5
PPC	RLM						6-5
FD	JHA		192	-460	-68	158	6-6
Auto			4712	4712	4712	0	6-9
Auto							6-11
Auto			-432	-568	-529	38	6-14
V+W	JMS		152	-360	11	155	6-18
PPS	IBD		144	-40	62	52	6-17
PPS	JHA		116	-52	15	44	6-18
VDO	JHA		644	-648	20	477	6-18

ALTITUDE ERROR SUMMARY
SID/STAR–SIP32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		WINCR	28	-68	-16	28	5-6
FD	RLM		8	-112	-65	34	5-6
Auto			4	-68	-8.5	17.7	6-1
V+W	RLM		72	8	30	20	6-1
V+W	RLM						6-5
PPC	RLM						6-5
FD	JHA		-56	-176	-123	34	6-6
Auto			0	-264	-174	49	6-9
Auto							6-14
V+W	JMS		-32	-92	-42	13	6-15
PPS	IBD						6-17
PPS	JHA		-88	-292	-191	58	6-18
VDO	JHA		104	-32	2.2	39	6-18
Auto		SIPHN	28	-4	1.4	3.4	5-6
FD	RLM		148	-44	32	48	5-6
Auto			4	-68	0.6	7.6	6-1
V+W	RLM		228	-192	63	74	6-1
V+W	RLM		116	-32	43	31	6-5
PPC	RLM		120	32	66	16	6-5
FD	JHA		80	-96	-17	57	6-6
Auto			212	-84	8.3	55	6-9
Auto			0	-4	-1.2	1.9	6-14
V+W	JMS		132	-92	36	58	6-15
PPS	IBD		64	52	59	4	6-17
PPS	JHA		496	-108	78	136	6-18
VDO	JHA		152	-120	18	82	6-18
Auto		CHAPL	16	0	4.6	3.5	5-6
FD	RLM		160	-80	57	75	5-6
Auto			16	-12	4.9	4	6-1
V+W	RLM		4	-36	-15	10	6-1
V+W	RLM		92	20	50	2.3	6-5
PPC	RLM		108	72	98	7.7	6-5
FD	JHA		4	-104	-32	26	6-6
Auto			12	0	3.8	3.1	6-9
Auto			20	-4	3.5	6.7	6-14
V+W	JMS		76	-52	11	39	6-15
PPS	IBD		188	64	141	28	6-17
PPS	JHA		100	-104	26	54	6-18
VDO	JHA		36	-108	-25	43	6-18

ALTITUDE ERROR SUMMARY
SID/STAR–SIP32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		MWH					5-6
FD	RLM		64	-396	-59	127	5-6
Auto			36	-92	1.4	15.6	6-1
V+W	RLM		212	-172	-2	91	6-1
V+W	RLM		112	-136	5.3	66	6-5
PPC	RLM		104	-76	-0.63	50	6-5
FD	JHA		16,156	-396	-66	440	6-6
Auto							6-9
Auto			60	-8	8.6	16	6-14
V+W	JMS		264	-244	3.4	101	6-15
PPS	IBD		120	-276	-45	104	6-17
PPS	JHA		144	-124	-6.3	63	6-18
VDO	JHA		56	-286	-67	64	6-18
Auto		PELIN					5-6
FD	RLM		56	-16	15	29	5-6
Auto			32	-48	19.2	11.4	6-1
V+W	RLM		100	32	66	22	6-1
V+W	RLM		4	-120	-65	40	6-5
PPC	RLM		52	-8	22	18	6-5
FD	JHA		8	-20	-5.8	7.0	6-6
Auto							6-9
Auto			84	36	79	4.9	6-14
V+W	JMS		72	4	30	18	6-15
PPS	IBD		28	-16	12	14	6-17
PPS	JHA		40	0	28	8.5	6-18
VDO	JHA		52	-36	29	22	6-18
Auto		TD32R					5-6
FD	RLM		-4	-140	-77	41	5-6
Auto			20	-96	-45.1	31.1	6-1
V+W	RLM		52	-104	-8.5	36	6-1
V+W	RLM		124	-136	-18	72	6-5
PPC	JMS						6-5
FD	JHA		36	-20	7.8	12	6-6
Auto							6-9
Auto			12	-48	-6.7	14	6-14
V+W	JMS		184	-24	53	50	6-15
PPS	IBD		104	-56	31	43	6-17
PPS	JHA		176	-108	19	69	6-18
VDO	JHA		40	-40	11	19	6-18

TIME ERROR SUMMARY
SID/STAR–SIP32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		WINCR	1	1	1	0	5-6
FD	RLM		10	7	8.4	0.94	5-6
Auto			3	2	2.67	0.467	6-1
V+W	RLM		-18	-19	-18	0.48	6-1
FD	JHA		0	0	0	0	6-6
Auto			7	0	2.4	2	6-9
Auto			-20	-31	-26	3.1	6-11
V+W	JMS		0	-1.0	-0.35	0.48	6-15
PPS	JHA		-31	-37	-34	1.9	6-18
VDO	JHA		6	-1	3.2	1.9	6-18
Auto		SIPHN	1	1	1	0	5-6
FD	RLM		7	0	1.9	1.6	5-6
Auto			3	0	0.96	0.99	6-1
V+W	RLM		-1	-18	-10	4.9	6-1
V+W	RLM		1	0	0.23	0.42	6-5
PPC	RLM		0	0	0	0	6-5
FD	JHA		1	0	0.14	0.35	6-6
Auto			10	1	7	2.7	6-9
Auto			18	20	-8.3	11	6-11
Auto			1	0	0.89	0.31	6-14
V+W	JMS		1	-4	-1.9	2	6-15
PPS	IBD		0	0	0	0	6-17
PPS	JHA		-14	-31	-2.4	4.7	6-18
VDO	JHA		1	-650	-8.8	19	6-18
Auto		CHAPL	1	1	1	0	5-6
FD	RLM		1	0	0.24	0.43	5-6
V+W	RLM		3	-1	1.4	1.2	6-1
V+W	RLM		1	0	0.01	0.12	6-5
PPC	RLM		0	-1	-0.09	0.29	6-5
FD	JHA		0	0	0	0	6-6
Auto			1	0	0.88	0.33	6-9
Auto			28	18	23	2.9	6-11
Auto			1	0	0.61	0.49	6-14
V+W	JMS		7	1	3.8	1.7	6-15
PPS	IBD		0	-1	-0.33	0.47	6-17
PPS	JHA		2	-14	-6.2	4.6	6-18
VDO	JHA		11	1	6.3	2.9	6-18

TIME ERROR SUMMARY
SID/STAR–SIP32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	MWH	2	0	0.58	0.56	5-6
Auto			2	0	0.53	0.502	6-1
V+W	RLM		5	0	2.6	1.5	6-1
V+W	RLM		5	0	1.6	1.4	6-5
FD	JHA		2	-3	0.06	1.5	6-6
Auto			1	0	0.02	0.14	6-9
Auto			14	-42	-21	17	6-11
Auto			0	0	0	0	6-14
V+W	JMS		9	-9	-1.5	5.8	6-15
PPS	IBD		7	-1	1.6	1.5	6-17
PPS	JHA		11	-3	2.4	3.5	6-18
VDO	JHA		11	-23	-8.4	11	6-18
FD	RLM	PELIN	1	0	0.51	0.50	5-6
Auto			4	1	2.45	0.69	6-1
V+W	RLM		2	0	0.49	0.51	6-1
V+W	RLM		0	-2	-1.5	0.54	6-5
PPC	RLM		13	12	13	0.49	6-5
FD	JHA		0	-1	-0.79	0.40	6-6
Auto			0	-1	-0.77	0.42	6-9
Auto			-40	-41	-40	0.39	6-11
Auto			5	0	2	1.3	6-14
V+W	JMS		144	-1	4.1	20	6-15
PPS	IBD		150	7	10	18	6-17
PPS	JHA		7	4	4.8	0.88	6-18
VDO	JHA		119	1	6.2	18	6-18
FD	RLM	TD32R	14	0	5.9	4	5-6
Auto			31	-47	10.56	6.29	6-1
V+W	RLM		18	1	13	6.1	6-1
V+W	RLM		8	-2	2.7	2.7	6-5
FD	JHA		16	0	7.2	4.4	6-6
Auto			5	-1	0.71	1.6	6-9
Auto			10	4	9	1.1	6-14
V+W	JMS		35	0	13	8	6-15
PPS	IBD		27	0	18	7.8	6-17
PPS	JHA		8	0	6.4	3.2	6-18
VDO	JHA		9	0	4.3	2.5	6-18

CROSSTRACK ERROR SUMMARY
SID/STAR–TUM32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		BR32R	0	0	0	0	6-14
VDC	JMS		X	X	X	X	6-15
PPS	IBD		X	X	X	X	6-17
VDO	JHA		0	0	0	0	6-18
PPC	IBD		X	X	X	X	6-21
Auto		LO32R	1252	1024	1186	64	6-14
VDO	JMS		1504	1460	1487	4.7	6-15
PPS	IBD		-3040	-3092	-3051	2.2	6-17
VDO	JHA		-860	-912	-878	9.7	6-18
PPC	IBD		-116	28	70	24	6-21
Auto		TH14L	1024	536	840	133	6-14
VDO	JMS		1692	1460	1582	64	6-15
PPS	IBD		-2672	-3092	-2904	113	6-17
VDO	JHA		-608	-912	-767	72	6-18
PPC	IBD		276	104	205	44	6-21
Auto		OLSON	544	-920	-574	331	6-14
VDO	JMS		-172	-728	-454	171	6-15
PPS	IBD		268	-2672	-480	918	6-17
VDO	JHA		4440	-5100	-277	3319	6-18
PPC	IBD		296	-200	-68	122	6-21
Auto		TUMBD	103	-548	-251	146	6-14
VDO	JMS		-1516	-3856	-3228	639	6-15
PPS	IBD		8	-212	-90	69	6-17
VDO	JHA		1272	-4124	-819	1464	6-18
PPC	IBD		316	-452	137	160	6-21

ALTITUDE ERROR SUMMARY
SID/STAR–TUM32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		BR32R	0	0	0	0	6-14
VDO	JMS		X	X	X	X	6-15
PPS	IBD		X	X	X	X	6-17
VDO	JHA		0	0	0	0	6-18
PPC	IBD		X	X	X	X	6-21
Auto		LO32R	-44	-328	-92	76	6-14
VDO	JMS		-52	-52	-1.1	11	6-15
PPS	IBD		-56	-68	-58	2.5	6-17
VDO	JHA		-248	-256	-253	2.7	6-18
PPC	IBD		-68	-21,828	-263	1786	6-21
Auto		TH14L	-332	-960	-638	188	6-14
VDO	JMS		12	-52	-1.1	11	6-15
PPS	IBD		-68	-464	-291	138	6-17
VDO	JHA		-204	-256	-236	13	6-18
PPC	IBD		-268	-400	-356	42	6-21
Auto		OLSON	-181	-1,412	-1058	313	6-14
VDO	JMS		16	4	11	4.1	6-15
PPS	IBD		132	-852	-269	310	6-17
VDO	JHA		180	-176	42	91	6-18
PPC	IBD		96	-240	-19	86	6-21
Auto		TUMBD	224	-356	-1.1	80	6-14
VDO	JMS		28,272	36	427	3051	6-15
PPS	IBD		816	80	528	200	6-17
VDO	JHA		156	-92	26	48	6-18
PPC	IBD		528	36	110	93	6-21

TIME ERROR SUMMARY
SID/STAR–TUM32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		8R32R	0	0	0	0	6-14
VDO	JMS		X	X	X	X	6-15
PPS	I8D		X	X	X	X	6-17
VDO	JHA		0	0	0	0	6-18
PPC	I8D		X	X	X	X	6-21
Auto		LO32R	X	X	X	X	6-14
VDO	JMS		-38	-76	-57	11	6-15
PPS	IBD		-54	-113	-82	17	6-17
VDO	JHA		5	1	1.9	1.4	6-18
PPC	I8D		-23	-44	-33	7	6-21
Auto		TH14L	-1153	-1235	-1193	24	6-14
VDO	JMS		-36	-38	-37	0.75	6-15
PPS	I8D		-54	-55	-55	0.47	6-17
VDO	JHA		2	1.3	1.3	0.46	6-18
PPC	IBD		-23	-25	-25	0.59	6-21
Auto		OLSON	-1064	-1150	-1108	25	6-14
VDO	JMS		-18	-18	-18	0	6-15
PPS	I8D		-55	-55	-55	0	6-17
VDO	JHA		24	4	15	6.4	6-18
PPC	IBD		-5	-24	-15	6.3	6-21
Auto		TUM8D	-862	-1066	-959	58	6-14
VDO	JMS		-6	-11	-8.7	1.4	6-15
PPS	I8D		-55	-55	-55	0	6-17
VDO	JHA		9	0	2.2	2.8	6-18
PPC	I8D		0	-7	-1.5	2.1	6-21

CROSSTRACK ERROR SUMMARY
SID/STAR—MAE14L

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
V+W	RLM	BR14L	X	X	X	X	6-5
PPC	RLM		X	X	X	X	6-5
PPS	JHA		X	X	X	X	6-18
V+W	RLM	MAEVY	540	-696	-89	414	6-5
PPC	RLM		440	-1860	-227	701	6-5
PPS	JHA		1604	-608	-57	543	6-18
V+W	RLM	LO14L	260	168	207	23	6-5
PPC	RLM		276	236	262	7.8	6-5
PPS	JHA		2292	0	1219	1127	6-18
V+W	RLM	POTHS	356	-720	101	240	6-5
PPC	RLM		276	-1904	-65	526	6-5
PPS	JHA		576	-220	225	132	6-18
V+W	RLM	BR32R	260	56	155	53	6-5
PPC	RLM		260	68	164	52	6-5
PPS	JHA		2300	1592	2083	201	6-18
V+W	RLM	COLUA	X	X	X	X	6-5
PPC	RLM		328	-32	158	87	6-5
PPS	JHA		212	-3424	-100	473	6-18

ALTITUDE ERROR SUMMARY
SID/STAR–MAE14L

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
V+W	RLM	BR14L	X	X	X	X	6-5
PPC	RLM		X	X	X	X	6-5
PPS	JHA		X	X	X	X	6-18
V+W	RLM	MAEVY	48	-236	-71	86	6-5
PPC	RLM		116	-176	22	88	6-5
PPS	JHA		188	-144	72	75	6-18
V+W	RLM	LO14L	-72	-192	-89	31	6-5
PPC	RLM		-64	-276	-116	66	6-5
PPS	JHA		0	-84	-23	23	6-18
V+W	RLM	POTHS	80	-48	14	28	6-5
PPC	RLM		264	-44	56	56	6-5
PPS	JHA		200	-84	78	79	6-18
V+W	RLM	BR32R	-128	-192	-171	20	6-5
PPC	RLM		-144	-284	-230	44	6-5
PPS	JHA		-36	-136	-85	36	6-18
V+W	RLM	COLUA	X	X	X	X	6-5
PPC	RLM		216	48	84	34	6-5
PPS	JHA		92	-64	19	48	6-18

TIME ERROR SUMMARY
SID/STAR–MAE14L

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
V+W	RLM	BR14L	X	X	X	X	6-5
PPC	RLM		X	X	X	X	6-5
PPS	JHA		X	X	X	X	6-18
V+W	RLM	MAEVY	-31	-40	-36	2.8	6-5
PPC	RLM		-1	-15	-6.2	4.8	6-5
PPS	JHA		-3	-9	-5.8	2	6-18
V+W	RLM	LO14L	-37	80	-56	13	6-5
PPC	RLM		-16	-198	-51	40	6-5
PPS	JHA		0	-47	-8.8	11	6-18
V+W	RLM	POTHS	-13	-30	-21	4.9	6-5
PPC	RLM		1	0	0.15	0.35	6-5
PPS	JHA		0	-2	-0.92	0.46	6-18
V+W	RLM	BR32R	-36	-38	-38	0.31	6-5
PPC	RLM		-14	-17	-15	0.76	6-5
PPS	JHA		-7	-8	-7.6	0.49	6-18
V+W	RLM	COLUA	X	X	X	X	6-5
PPC	RLM		1	0	0.01	0.07	6-5
PPS	JHA		0	-4	-0.08	0.41	6-18

CROSSTRACK ERROR SUMMARY
SID/STAR–POW32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	BR32R	X	X	X	X	5-6
V+W	RLM		X	X	X	X	6-1
Auto			X	X	X	X	6-1
FD	IBD		X	X	X	X	6-3
VDO	JMS		X	X	X	X	6-6
PPS	JMS		X	X	X	X	6-6
PPC	JMS		X	X	X	X	6-6
FD	JHA		0	0	0	0	6-6
V+W	JHA		X	X	X	X	6-6
FD	RLM	LO32R	X	X	X	X	5-6
V+W	RLM		2040	0	26	231	6-1
Auto			X	X	X	X	6-1
FD	IBD		2588	1900	2304	212	6-3
VDO	JMS		X	X	X	X	6-6
PPS	JMS		X	X	X	X	6-6
PPC	JMS		X	X	X	X	6-6
FD	JHA		-1080	-1128	-1073	12	6-6
V+W	JHA		1760	0	344	693	6-6
FD	RLM	BR14L	-52	-300	-178	72	5-6
V+W	RLM		2168	2020	2097	47	6-1
Auto			X	X	X	X	6-1
FD	IBD		1920	1732	1851	51	6-3
VDO	JMS		-60	-132	-96	21	6-6
PPS	JMS		1452	1252	1403	45	6-6
PPC	JMS		3196	2708	2999	137	6-6
FD	JHA		-728	-1120	-956	97	6-6
V+W	JHA		1952	1740	1832	60	6-6
FD	RLM	POWER	316	-96	150	85	5-6
V+W	RLM		1976	-116	666	606	6-1
Auto			104	-1948	-352	545	6-1
FD	IBD		2308	1260	1752	357	6-3
VDO	JMS		7028	-116	3911	2684	6-6
PPS	JMS		1260	104	670	303	6-6
PPC	JMS		2696	-444	401	882	6-6
FD	JHA		4828	-752	2923	1839	6-6
V+W	JHA		4548	1916	3125	765	6-6

CROSSTRACK ERROR SUMMARY
SID/STAR–POW32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	WINCR	336	-92	150	85	5-6
V+W	RLM		1432	-868	-175	493	6-1
Auto			158	0	111	41.6	6-1
FD	IBD		1332	-228	147	325	6-3
VDO	JMS		2368	-2540	378	1832	6-6
PPS	JMS		372	128	330	32	6-6
PPC	JMS		2292	0	812	806	6-6
FD	JHA		3036	-1088	66	694	6-6
V+W	JHA		5036	-272	1374	2000	6-6
FD	RLM	QUINY	232	-304	119	140	5-6
V+W	RLM		824	196	659	175	6-1
Auto			208	-180	-17.8	104	6-1
FD	IBD		X	X	X	X	6-3
VDO	JMS		X	X	X	X	6-6
PPS	JMS		292	52	172	60	6-6
PPC	JMS		2272	728	1676	342	6-6
FD	JHA		X	X	X	X	6-6
V+W	JHA		X	X	X	X	6-6

ALTITUDE ERROR SUMMARY
SID/STAR–POW32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	BR32R	X	X	X	X	5-6
V+W	RLM		X	X	X	X	6-1
Auto			X	X	X	X	6-1
FD	IBD		X	X	X	X	6-3
VDO	JMS		X	X	X	X	6-6
PPS	JMS		X	X	X	X	6-6
PPC	JMS		X	X	X	X	6-6
FD	JHA		0	0	0	0	6-6
V+W	JHA		X	X	X	X	6-6
FD	RLM	LO32R	X	X	X	X	5-6
V+W	RLM		0	-72	-0.74	8.2	6-1
Auto			X	X	X	X	6-1
FD	IBD		-40	-720	-276	213	6-3
VDO	JMS		X	X	X	X	6-6
PPS	JMS		X	X	X	X	6-6
PPC	JMS		X	X	X	X	6-6
FD	JHA		-44	-92	-52	7.6	6-6
V+W	JHA		0	-56	-10	21	6-6
FD	RLM	BR14L	-32	-60	-42	9.2	5-6
V+W	RLM		256	-68	129	107	6-1
Auto			X	X	X	X	6-1
FD	IBD		-460	-720	-586	84	6-3
VDO	JMS		336	-32	184	131	6-6
PPS	JMS		232	-4	176	75	6-6
PPC	JMS		-800	-816	-806	4.7	6-6
FD	JHA		24	-92	-22	37	6-6
V+W	JHA		228	-52	132	96	6-6
FD	RLM	POWER	152	-96	1.8	81	5-6
V+W	RLM		188	16	90	36	6-1
Auto			256	-16	20.5	56.5	6-1
FD	IBD		-192	-460	-265	64	6-3
VDO	JMS		308	-200	69	139	6-6
PPS	JMS		188	36	101	42	6-6
PPC	JMS		-348	-828	-577	150	6-6
FD	JHA		48	-296	-133	118	6-6
V+W	JHA		192	-196	11	87	6-6

ALTITUDE ERROR SUMMARY
SID/STAR–POW32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	WINCR	164	-116	17	61	5-6
V+W	RLM		88	-48	28	32	6-1
Auto			72	-752	-46.7	156	6-1
FD	I8D		24	-288	-137	101	6-3
VDO	JMS		24	-52	-13	16	6-6
PPS	JMS		168	72	159	15	6-6
PPC	JMS		184	-336	17	171	6-6
FD	JHA		156	-284	-13	130	6-6
V+W	JHA		116	-248	-44	109	6-6
FD	RLM	QUINY	-24	-196	-112	33	5-6
V+W	RLM		160	-96	-6.1	56	6-1
Auto			152	-800	-86.5	226	6-1
FD	I8D		X	X	X	X	6-3
VDO	JMS		X	X	X	X	6-6
PPS	JMS		636	92	391	201	6-6
PPC	JMS		980	96	438	292	6-6
FD	JHA		X	X	X	X	6-6
V+W	JHA		X	X	X	X	6-6

TIME ERROR SUMMARY
SID/STAR–POW32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	BR32R	X	X	X	X	5-6
V+W	RLM		X	X	X	X	6-1
Auto			X	X	X	X	6-1
FD	IBD		X	X	X	X	6-3
VDO	JMS		X	X	X	X	6-6
PPS	JMS		X	X	X	X	6-6
PPC	JMS		X	X	X	X	6-6
FD	JHA		0	0	0	0	6-6
FD	RLM	LO32R	X	X	X	X	5-6
V+W	RLM		17	0	0.22	1.9	6-1
Auto			X	X	X	X	6-1
FD	IBD		E	E	E	E	6-3
VDO	JMS		X	X	X	X	6-6
PPS	JMS		X	X	X	X	6-6
PPC	JMS		X	X	X	X	6-6
FD	JHA		-3.0	-5.0	-4.1	0.65	6-6
FD	RLM	BR14L	-7	-8	-7.8	0.40	5-6
V+W	RLM		17	14	15	0.88	6-1
Auto			X	X	X	X	6-1
FD	IBD		-42	-51	-46	2.8	6-3
VDO	JMS		-11	-20	-17	2.6	6-6
PPS	JMS		-44	-47	-46	0.97	6-6
PPC	JMS		-31	-85	-83	1	6-6
FD	JHA		-2	-4	-2.9	0.53	6-6
FD	RLM	POWER	-1	-8	-4.6	1.9	5-6
V+W	RLM		14	3	9.5	2.7	6-1
Auto			X	X	X	X	6-1
FD	IBD		-31	-42	-36	3.1	6-3
VDO	JMS		-19	-32	-24	3.6	6-6
PPS	JMS		-41	-47	-45	2	6-6
PPC	JMS		-69	-82	-77	4.2	6-6
FD	JHA		-1	-4	-1.5	0.87	6-6
FD	RLM	WINCR	2	-1	0.71	0.86	5-6
V+W	RLM		3	0	0.66	0.75	6-1
Auto			6	-4	0.425	2.15	6-1
FD	IBD		-1	-30	-14	9.2	6-3
VDO	JMS		-20	-26	-22	1.4	6-6
PPS	JMS		X	X	X	X	6-6
PPC	JMS		0	-69	-54	11.5	6-6
FD	JHA		0	-4	-1.03	1.6	6-6

TIME ERROR SUMMARY
SID/STAR--POW32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	QUINY	0	0	0	0	5-6
V+W	RLM		0	-5	-2.7	2.1	6-1
Auto			-4	-14	-9.16	3.03	6-1
FD	IBD		X	X	X	X	6-3
VDO	JMS		X	X	X	X	6-6
PPS	JMS		-26	-36	-29	3.4	6-6
PPC	JMS		-49	-61	-53	4	6-6
FD	JHA		X	X	X	X	6-6

CROSSTRACK ERROR SUMMARY
SID/STAR–GLE16

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	BRP16	208	196	207	4	6-2
PPS	RLM		0	0	0	0	6-2
Auto			X	X	X	X	6-7
Auto			408	388	397	4	6-7
Auto			544	524	533	3.4	6-8
FD	JMS		X	X	X	X	6-10
V+W	JMS		X	X	X	X	6-10
Auto			X	X	X	X	6-16
PPC	JHA		X	X	X	X	6-17
Auto			X	X	X	X	6-19
VDO	RLM	HATID	488	-2,860	-1,121	1,236	6-2
PPS	RLM		64	-2,084	-788	740	6-2
Auto			-108	-3,348	-1,139	1,119	6-7
Auto			1,192	-2,092	426	686	6-7
Auto			-108	-7,072	-3,045	2,494	6-8
FD	JMS		352	-10,520	-4,719	3,899	6-10
V+W	JMS		948	-2,660	-1,069	1,226	6-10
Auto			-168	-200	-188	8.5	6-16
PPC	JHA		716	-2,780	-1,118	1,037	6-17
Auto			-108	-1,524	-498	381	6-19
VDO	RLM	LOP16	256	208	231	12.7	6-2
PPS	RLM		-72	-132	-107	14	6-2
Auto			0	-24	-16	4.3	6-7
Auto			516	416	440	20	6-7
Auto			564	416	483	33	6-8
FD	JMS		3,964	940	3,856	535	6-10
V+W	JMS		-728	-808	-778	23	6-10
Auto			-1,944	-1,956	-1,951	5.3	6-16
PPC	JHA		X	X	X	X	6-17
Auto			-748	-808	-799	18	6-19

CROSSTRACK ERROR SUMMARY
SID/STAR–GLE16
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	ARLIN	1,092	-508	222	368	6-2
PPS	RLM		4,444	0	839	1,137	6-2
Auto			-92	-408	-191	86	6-7
Auto			240	-420	-133	103	6-7
Auto			28	-300	79	88	6-8
FD	JMS		776	64	436	240	6-10
V+W	JMS		928	-520	-112	279	6-10
Auto			248	-200	33	149	6-16
PPC	JHA		12	-252	-124	73	6-17
Auto			-116	-480	-234	76	6-19
VDO	RLM	GLENE	-240	-2,392	-693	1,236	6-2
PPS	RLM		68	-1,892	-588	470	6-2
Auto			8	-3,148	-935	813	6-7
Auto			528	-18,876	-10,590	6,467	6-7
Auto			456	-6,904	-3,980	1,990	6-8
FD	JMS		3,972	-10,408	-4,192	4,395	6-10
V+W	JMS		248	-4,972	-2,413	1,892	6-10
Auto			-704	-2,952	-1,790	655	6-16
PPC	JHA		3,604	716	2,320	850	6-17
Auto			-384	-2,600	-2,132	646	6-19

ALTITUDE ERROR SUMMARY
SID/STAR–GLE16

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	BRP16	-88	-216	-122	39	6-2
PPS	RLM		0	0	0	0	6-2
Auto			X	X	X	X	6-7
Auto			-4	-228	-67	47	6-7
Auto			-36	-136	-51	24	6-8
FD	JMS		X	X	X	X	6-10
V+W	JMS		X	X	X	X	6-10
Auto			X	X	X	X	6-16
PPC	JHA		X	X	X	X	6-17
Auto			X	X	X	X	6-19
VDO	RLM	HATID	372	4	147	109	6-2
PPS	RLM		336	208	265	38	6-2
Auto			4	-72	-7.1	16	6-7
Auto			-528	-1,304	-1,149	183	6-7
Auto			0	-152	-22	28	6-8
FD	JMS		-2,300	-2,712	-2,454	118	6-10
V+W	JMS		-44	-356	-139	92	6-10
Auto			-60	-64	-64	1	6-16
PPC	JHA		104	-64	38	46	6-17
Auto			8	-8	-0.55	3.9	6-19
VDO	RLM	LOP16	-132	-220	-185	26	6-2
PPS	RLM		-36	-204	-82	43	6-2
Auto			8	-1,052	-86	252	6-7
Auto			-232	-300	-278	19	6-7
Auto			-124	-156	-133	8.5	6-8
FD	JMS		-80	-311,936	-10,517	55,972	6-10
V+W	JMS		-24	-352	-95	89	6-10
Auto			168	-44	63	67	6-16
PPC	JHA		X	X	X	X	6-17
Auto			-204	-320	-254	34	6-19
VDO	RLM	ARLIN	112	-164	7.8	64	6-2
PPS	RLM		88	-540	-323	182	6-2
Auto			132	-76	-14	49	6-7
Auto			4	-528	-60	118	6-7
Auto			4	-108	-20	29	6-8
FD	JMS		-172	-2,568	-1,408	790	6-10
V+W	JMS		68	-180	-48	58	6-10
Auto			212	-8	52	81	6-16
PPC	JHA		120	-112	33	72	6-17
Auto			4	-84	-17	24	6-19

ALTITUDE ERROR SUMMARY
SID/STAR–GLE16
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	GLENE	308	76	226	54	6-2
PPS	RLM		472	-100	128	169	6-2
Auto			0	-1,052	-122	154	6-7
Auto			-188	964	-710	253	6-7
Auto			-92	-512	-202	132	6-8
FD	JMS		-52	-132,352	-1,202	6,041	6-10
V+W	JMS		-204	-700	-379	141	6-10
Auto			4	-16	-3.7	4	6-16
PPC	JHA		52	-308	-65	104	6-17
Auto			-12	-64	-33	18	6-19

TIME ERROR SUMMARY
SID/STAR–GLE16

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	BRP16	24	20	22	1.2	6-2
PPS	RLM		0	0	0	0	6-2
Auto			X	X	X	X	6-7
Auto			-16	-47	-27	8.9	6-7
Auto			-18	-47	-29	8.4	6-8
FD	JMS		X	X	X	X	6-10
V+W	JMS		X	X	X	X	6-10
Auto			X	X	X	X	6-16
PPC	JHA		X	X	X	X	6-17
Auto			X	X	X	X	6-19
VDO	RLM	HATID	47	42	44	1.4	6-2
PPS	RLM		-315	-315	-315	1	6-2
Auto			0	-3	-0.85	1.1	6-7
Auto			-96	108	-102	3.6	6-7
Auto			-23	-41	-32	5.2	6-8
FD	JMS		-28	-39	-33	2.7	6-10
V+W	JMS		-15	-28	-21	3.8	6-10
Auto			-1370	-1370	-1370	1.5	6-16
PPC	JHA		4	-6	-3.5	2.7	6-17
Auto			-1	-6	-3.5	1.6	6-19
VDO	RLM	LOP16	24	20	22	1.3	6-2
PPS	RLM		-314	-336	-315	2	6-2
Auto			3	2	2.4	0.49	6-7
Auto			-16	-16	-16	0	6-7
Auto			-17	-18	-18	0.11	6-8
FD	JMS		-15	-16	-16	0.18	6-10
V+W	JMS		-17	-40	-28	6.8	6-10
Auto			-1370	-1370	-1370	1.8	6-16
PPC	JHA		X	X	X	X	6-17
Auto			-7	-7	-7	0	6-19
VDO	RLM	ARLIN	52	0	43	19	6-2
PPS	RLM		-315	-315	-315	1	6-2
Auto			1	0	0.77	0.42	6-7
Auto			-81	-96	-89	3.4	6-7
Auto			-3	-23	-11	5.7	6-8
FD	JMS		-11	-28	-16	4.9	6-10
V+W	JMS		0	-15	-6.7	4.3	6-10
Auto			-1370	-1370	-1370	8.6	6-16
PPC	JHA		1	-6	-0.96	2.2	6-17
Auto			1	-57	-19	27	6-19

TIME ERROR SUMMARY
SID/STAR–GLE16
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	GLENE	50	43	47	1.9	6-2
PPS	RLM		-315	-315	-315	1.2	6-2
Auto			2	-3	-0.28	1.3	6-7
Auto			-15	-107	-60	32	6-7
Auto			-17	-41	-29	7.4	6-8
FD	JMS		-10	-39	-21	8.5	6-10
V+W	JMS		-14	-28	-19	4.9	6-10
Auto			-1370	-1370	-1370	4.6	6-16
PPC	JHA		5	2	4.4	0.81	6-17
Auto			-3	-8	-6.7	0.73	6-19

CROSSTRACK ERROR SUMMARY
SID/STAR–SUM13R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	IBD	BR13R	X	X	X	X	6-9
PPS	JMS		X	X	X	X	6-11
PPC	JHA		X	X	X	X	6-18
FD	IBD	AGL30	56	-888	-179	245	6-9
PPS	JMS		-152	-360	-197	44	6-11
PPC	JHA		-52	-452	-161	99	6-18
FD	IBD	LO13R	0	-1636	-383	683	6-9
PPS	JMS		8	-112	-27	35	6-11
PPC	JHA		48	-20	2	9	6-18
FD	IBD	PANTR	156	-1108	-559	392	6-9
PPS	JMS		94,608	-740	-236	4793	6-11
PPC	JHA		-180	-828	-530	212	6-18
FD	IBD	AGL15	-868	-1584	-1418	194	6-9
PPS	JMS		8	-212	-96	72	6-11
PPC	JHA		28	-540	-234	199	6-18
FD	IBD	SUMNR	556	-508	-21	295	6-9
PPS	JMS		912	-8624	-3.1	661	6-11
PPC	JHA		532	-200	18	166	6-18

ALTITUDE ERROR SUMMARY
SID/STAR–SUM13R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	IBD	BR13R	X	X	X	X	6-9
PPS	JMS		X	X	X	X	6-11
PPC	JHA		X	X	X	X	6-18
FD	IBD	AGL30	44	-20	7.4	15	6-9
PPS	JMS		280	96	165	52	6-11
PPC	JHA		48	-204	-80	71	6-18
FD	IBD	LO13R	0	-28	-6.2	11	6-9
PPS	JMS		0	-1052	-18	93	6-11
PPC	JHA		36	-52	11	18	6-18
FD	IBD	PANTR	44	-188	-96	74	6-9
PPS	JMS		276	-72	21	103	6-11
PPC	JHA		12	192	-102	57	6-18
FD	IBD	AGL15	100	-20	52	33	6-9
PPS	JMS		1340	-1564	66	374	6-11
PPC	JHA		-52	-324	-211	89	6-18
FD	IBD	SUMNR	924	320	679	144	6-9
PPS	JMS		1118	-52	640	219	6-11
PPC	JHA		580	16	225	104	6-18

TIME ERROR SUMMARY
SID/STAR–SUM13R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD PPS PPC	IBD JMS JHA	BR13R	X X X	X X X	X X X	X X X	6-9 6-11 6-18
FD PPS PPC	IBD JMS JHA	AGL30	-13 -19 -11	-20 -20 -13	-17 -20 -12	1.9 0.49 0.55	6-9 6-11 6-18
FD PPS PPC	IBD JMS JHA	LO13R	0 0 0	-6 -52 -6	-0.94 -15 -1.9	1.8 17 2.4	6-9 6-11 6-18
FD PPS PPC	IBD JMS JHA	PANTR	-13 -12 -7	-21 -19 -12	-18 -16 -10	2.1 2.1 1.7	6-9 6-11 6-18
FD PPS PPC	IBD JMS JHA	AGL15	-6 -4 -4	-13 -27 -10,890	-9 -19 -40	2 3.4 589	6-9 6-11 6-18
FD PPS PPC	IBD JMS JHA	SUMNR	2 1 0	-8 -12 -7	-2.8 -5.6 -2.3	2.5 3.4 2.3	6-9 6-11 6-18

CROSSTRACK ERROR SUMMARY
SID/STAR–DOU32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	BR32R	356	0	3.7	36	6-5
PPS	RLM		X	X	X	X	6-5
FD	JMS		0	-220	-0.28	7.9	6-5
FD	JHA		X	X	X	X	6-6
Auto			X	X	X	X	6-6
Auto			X	X	X	X	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		X	X	X	X	6-17
V+W	JHA		X	X	X	X	6-21
VDO	RLM	LO32R	368	316	345	12	6-5
PPS	RLM		0	0	0	0	6-5
FD	JMS		-192	-220	-211	7	6-5
FD	JHA		X	X	X	X	6-6
Auto			X	X	X	X	6-6
Auto			X	X	X	X	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		220	136	193	19	6-17
V+W	JHA		-1488	-1,524	-1503	9.8	6-21
VDO	RLM	AGL15	340	-72	96	101	6-5
PPS	RLM		1116	368	824	218	6-5
FD	JMS		68	-232	-70	97	6-5
FD	JHA		240	-160	-0.10	118	6-6
Auto			1376	496	1099	208	6-6
Auto			X	X	X	X	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		228	68	120	31	6-17
V+W	JHA		-52	-1,524	-872	487	6-21
VDO	RLM	AGL30	428	-72	250	142	6-5
PPS	RLM		476	44	308	143	6-5
FD	JMS		296	68	205	56	6-5
FD	JHA		276	-80	107	114	6-6
Auto			496	-12	222	146	6-6
Auto			X	X	X	X	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		216	-12	135	50	6-17
V+W	JHA		984	-40	672	294	6-21

CROSSTRACK ERROR SUMMARY
SID/STAR–DOU32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	EPH	656	16	253	229	6-5
PPS	RLM		196	-456	-121	188	6-5
FD	JMS		328	-4	133	84	6-5
FD	JHA		352	-112	48	95	6-6
Auto			X	X	X	X	6-6
Auto			6152	-11,608	766	2382	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		228	-136	55	74	6-17
V+W	JHA		476	-340	-92	193	6-21
VDO	RLM	DOUGS	3324	-1,704	1244	1274	6-5
PPS	RLM		2788	-316	524	781	6-5
FD	JMS		X	X	X	X	6-5
FD	JHA		5156	-40	1050	1415	6-6
Auto			X	X	X	X	6-6
Auto			-668	-1,312	-899	183	6-9
V+W	JMS		760	196	542	168	6-11
PPS	JHA		1304	-1,560	192	435	6-17
V+W	JHA		7996	-68	3446	2803	6-21

ALTITUDE ERROR SUMMARY
SID/STAR–DOU32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	BR32R	0	-76	-0.79	7.7	6-5
PPS	RLM		X	X	X	X	6-5
FD	JMS		0	-80	-0.10	2.9	6-5
FD	JHA		X	X	X	X	6-6
Auto			X	X	X	X	6-6
Auto			X	X	X	X	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		X	X	X	X	6-17
V+W	JHA		X	X	X	X	6-21
VDO	RLM	LO32R	-76	-244	-98	43	6-5
PPS	RLM		0	0	0	0	6-5
FD	JMS		-72	-1052	-126	207	6-5
FD	JHA		X	X	X	X	6-6
Auto			X	X	X	X	6-6
Auto			X	X	X	X	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		4	-48	-4.4	8.6	6-17
V+W	JHA		-88	-232	-106	34	6-21
VDO	RLM	AGL15	-140	-240	-174	27	6-5
PPS	RLM		480	-40	288	147	6-5
FD	JMS		88	-76	63	36	6-5
FD	JHA		504	-44	304	179	6-6
Auto			372	-36	177	129	6-6
Auto			X	X	X	X	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		32	-48	3.9	22	6-17
V+W	JHA		-24	-284	-194	73	6-21
VDO	RLM	AGL30	40	-200	-66	65	6-5
PPS	RLM		336	228	272	36	6-5
FD	JMS		60	8	32	17	6-5
FD	JHA		336	264	244	18	6-6
Auto			24	8	15	4.6	6-6
Auto			X	X	X	X	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		216	-32	45	87	6-17
V+W	JHA		72	-24	37	28	6-21

ALTITUDE ERROR SUMMARY
SID/STAR–DOU32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	EPH	116	-100	15	67	6-5
PPS	RLM		312	-80	10	83	6-5
FD	JMS		32	-172	-73	66	6-5
FD	JHA		300	-88	28	95	6-6
Auto			X	X	X	X	6-6
Auto			-1472	-4592	-165	370	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		396	-296	127	208	6-17
V+W	JHA		40	-384	-162	113	6-21
VDO	RLM	DOUGS	304	-40	8.1	60	6-5
PPS	RLM		308	-336	18	130	6-5
FD	JMS		X	X	X	X	6-5
FD	JHA		104	-332	-73	123	6-6
Auto			X	X	X	X	6-6
Auto			8	-1704	-23	40	6-9
V+W	JMS		48	-152	-65	57	6-11
PPS	JHA		188	-1156	-285	377	6-17
V+W	JHA		0	-108	-26	17	6-21

TIME ERROR SUMMARY
SID/STAR–DOU32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	BR32R	112	0	1.2	11	6-5
PPS	RLM		X	X	X	X	6-5
FD	JMS		0	-19	-0.02	0.68	6-5
FD	JHA		X	X	X	X	6-6
Auto			X	X	X	X	6-6
Auto			X	X	X	X	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		X	X	X	X	6-17
V+W	JHA		X	X	X	X	6-21
VDO	RLM	LO32R	2667	-2702	-31	388	6-5
PPS	RLM		0	0	0	0	6-5
FD	JMS		18	-28	-19	4.7	6-5
FD	JHA		X	X	X	X	6-6
Auto			X	X	X	X	6-6
Auto			X	X	X	X	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		-25	-150	-61	31	6-17
V+W	JHA		X	X	X	X	6-21
VDO	RLM	AGL15	-8	-14	-11	1.8	6-5
PPS	RLM		-36	-48	-44	2.8	6-5
FD	JMS		-10	-13	-12	1.1	6-5
FD	JHA		-56	-67	-64	3.1	6-6
Auto			-92	-100	-98	2.4	6-6
Auto			X	X	X	X	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		-24	-25	-25	0.5	6-17
VDO	RLM	AGL30	-20	-8	-4.6	1.8	6-5
PPS	RLM		-47	-48	-48	0.23	6-5
FD	JMS		-8	-10	-8.7	0.74	6-5
FD	JHA		-60	-67	-64	2.2	6-6
Auto			-91	-100	-96	2.9	6-6
Auto			X	X	X	X	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		-24	-24	-24	0	6-17

TIME ERROR SUMMARY
SID/STAR–DOU32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	EPH	11	-2	6	3.6	6-5
PPS	RLM		-36	-47	-41	3.9	6-5
FD	JMS		4	-8	-0.88	3.6	6-5
FD	JHA		-38	-60	-50	7	6-6
Auto			X	X	X	X	6-6
Auto			0	-17	-6.4	4.9	6-9
V+W	JMS		X	X	X	X	6-11
PPS	JHA		-17	-25	-23	2.7	6-17
VDO	RLM	DOUGS	6	0	0.77	1.2	6-5
PPS	RLM		-30	-43	-35	3.9	6-5
FD	JMS		X	X	X	X	6-5
FD	JHA		11	-38	-2.9	14	6-6
Auto			X	X	X	X	6-6
Auto			0	-1	-0.06	0.23	6-9
V+W	JMS		-12	-22	-16	3.6	6-11
PPS	JHA		3	-17	-3.6	58	6-17

CROSSTRACK ERROR SUMMARY
SID/STAR–GRA32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Time flight No.
FD	RLM	BR32R	0	0	0	0	5-6
V+W	RLM		X	X	X	X	6-1
PPC	RLM		236	0	0.97	15.1	6-1
FD	IBD		0	0	0	0	6-3
FD	JMS		X	X	X	X	6-6
V+W	JMS		0	0	0	0	6-15
VDO	JMS		X	X	X	X	6-15
PPC	IBD		X	X	X	X	6-21
V+W	JHA		X	X	X	X	6-21
PPC	JHA		X	X	X	X	6-21
FD	RLM	LO32R	476	448	461	7.5	5-6
V+W	RLM		X	X	X	X	6-1
PPC	RLM		276	228	253	14	6-1
FD	IBD		-4532	-5920	-5743	320	6-3
FD	JMS		0	-320	-0.19	7.7	6-6
V+W	JMS		696	636	668	17	6-15
VDO	JMS		276	0	218	97	6-15
PPC	IBD		X	X	X	X	6-21
V+W	JHA		16	8	11	3.8	6-21
PPC	JHA		X	X	X	X	6-21
FD	RLM	CRACK	536	-32	204	223	5-6
V+W	RLM		1104	108	786	330	6-1
PPC	RLM		268	48	122	75.6	6-1
FD	IBD		36	-4504	-992	1346	6-3
FD	JMS		60	-352	-105	159	6-6
V+W	JMS		844	524	693	106	6-15
VDO	JMS		2460	276	961	656	6-15
PPC	IBD		1104	-1516	404	822	6-21
V+W	JHA		896	-12	400	327	6-21
PPC	JHA		356	176	246	51	6-21
FD	RLM	LEVEE	112	-260	-153	84	5-6
V+W	RLM		132	-1792	-958	601	6-1
PPC	RLM		80	-268	158	70.8	6-1
FD	IBD		380	-1644	-169	480	6-3
FD	JMS		72	-168	-78	52	6-6
V+W	JMS		560	-2152	-877	620	6-15
VDO	JMS		168	-188	-55	107	6-15
PPC	IBD		7344	-3240	-609	2846	6-21
V+W	JHA		208	-5388	-2109	1555	6-21
PPC	JHA		188	-1124	-519	418	6-21

CROSSTRACK ERROR SUMMARY
SID/STAR–GRA32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	GRANY	228	-52	35	55	5-6
V+W	RLM		924	-1388	119	621	6-1
PPC	RLM		248	-192	54.6	111	6-1
FD	IBD		524	-1964	-228	675	6-3
FD	JMS		X	X	X	X	6-6
V+W	JMS		796	-2284	-187	1029	6-15
VDO	JMS		1132	604	753	146	6-15
PPC	IBD		X	X	X	X	6-21
V+W	JHA		368	-5432	-2625	1697	6-21
PPC	JHA		1312	268	1123	226	6-21
FD	RLM	BATUM	504	-208	81	228	5-6
V+W	RLM		1892	-1068	577	986	6-1
PPC	RLM		256	-292	-35.4	174.3	6-1
FD	IBD		804	36	300	215	6-3
FD	JMS		X	X	X	X	6-6
V+W	JMS		3652	428	2300	962	6-15
VDO	JMS		X	X	X	X	6-15
PPC	IBD		X	X	X	X	6-21
V+W	JHA		2856	-400	1408	1092	6-21
PPC	JHA		1012	148	548	266	6-21

ALTITUDE ERROR SUMMARY
SID/STAR–GRA32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	BR32R	0	0	0	0	5-6
V+W	RLM		X	X	X	X	6-1
PPC	RLM		0	-64	-0.3	4.1	6-1
FD	IBD		0	0	0	0	6-3
FD	JMS		X	X	X	X	6-6
V+W	JMS		0	0	0	0	6-15
VDO	JMS		0	0	0	0	6-15
PPC	IBD		X	X	X	X	6-21
V+W	JHA		X	X	X	X	6-21
PPC	JHA		X	X	X	X	6-21
FD	RLM	LO32R	-104	-108	-108	1.2	5-6
V+W	RLM		X	X	X	X	6-1
PPC	RLM		-64	-68	-67	1.59	6-1
FD	IBD		-68	-800	-425	311	6-3
FD	JMS		0	-60	-0.03	1.4	6-6
V+W	JMS		-24	-32	-31	2.6	6-15
VDO	JMS		0	-104	-33	19	6-15
PPC	IBD		X	X	X	X	6-21
V+W	JHA		-72	-112	-92	11	6-21
PPC	JHA		X	X	X	X	6-21
FD	RLM	CRACK	36	-492	-188	183	5-6
V+W	RLM		116	40	61	11	6-1
PPC	RLM		284	-64	157	70	6-1
FD	IBD		252	-732	39	253	6-3
FD	JMS		340	-24	178	84	6-6
V+W	JMS		80	-24	36	22	6-15
VDO	JMS		68	-104	26	49	6-15
PPC	IBD		2220	1256	1585	272	6-21
V+W	JHA		40	-136	-23	42	6-21
PPC	JHA		104	56	68	13	6-21
FD	RLM	LEVEE	164	16	83	44	5-6
V+W	RLM		160	-168	6.4	97	6-1
PPC	RLM		492	272	386	58	6-1
FD	IBD		252	-120	26	100	6-3
FD	JMS		88	-76	-16	42	6-6
V+W	JMS		20	-40	-21	14	6-15
VDO	JMS		24	-24	-12	11	6-15
PPC	IBD		2216	-176	163	489	6-21
V+W	JHA		852	-16	160	265	6-21
PPC	JHA		268	12	85	60	6-21

ALTITUDE ERROR SUMMARY
SID/STAR–GRA32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	GRANY	304	-36	141	74	5-6
V+W	RLM		112	-160	17	5B	6-1
PPC	RLM		2232	412	1431	644	6-1
FD	IBD		-24	-312	-224	65	6-3
FD	JMS		X	X	X	X	6-6
V+W	JMS		44	-52	4.1	23	6-15
VDO	JMS		64	32	3B	7.2	6-15
PPC	IBD		X	X	X	X	6-21
V+W	JHA		1476	20	57B	471	6-21
PPC	JHA		116	-500	-100	184	6-21
FD	RLM	BATUM	324	-92	52	124	5-6
V+W	RLM		200	-60	34	73	6-1
PPC	RLM		1B60	1[illegible]20	1435	187	6-1
FD	IBD		136	-64	59	63	6-3
FD	JMS		X	X	X	X	6-6
V+W	JMS		172	-100	5.4	73	6-15
VDO	JMS		X	X	X	X	6-15
PPC	IBD		X	X	X	X	6-21
V+W	JHA		220	-348	9.4	78	6-21
PPC	JHA		224	-164	-9.2	122	6-21

TIME ERROR SUMMARY
SID/STAR–GRA32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	BR32R	0	0	0	0	5-6
V+W	RLM		X	X	X	X	6-1
PPC	RLM		21	0	0.086	1.344	6-1
FD	IBD		0	0	0	0	6-3
FD	JMS		X	X	X	X	6-6
V+W	JMS		0	0	0	0	6-15
VDO	JMS		X	X	X	X	6-15
PPC	IBD		X	X	X	X	6-21
V+W	JHA		X	X	X	X	6-21
PPC	JHA		X	X	X	X	6-21
FD	RLM	LO32R	11	5	7.1	1.8	5-6
V+W	RLM		X	X	X	X	6-1
PPC	RLM		21	10	14.27	14.6	6-1
FD	IBD		X	X	X	X	6-3
FD	JMS		0	-38	-0.02	0.92	6-6
V+W	JMS		-22	-53	-37	9.1	6-15
VDO	JMS		0	-457	-126	106	6-15
PPC	IBD		X	X	X	X	6-21
V+W	JHA		3	3	3	0	6-21
PPC	JHA		X	X	X	X	6-21
FD	RLM	CRANK	7	4	5.2	0.99	5-6
V+W	RLM		0	-9	-4.5	2.5	6-1
PPC	RLM		28	10	19.55	20.18	6-1
FD	IBD		-13	-42	-26	8.8	6-3
FD	JMS		-39	-47	-44	2.7	6-6
V+W	JMS		-10	-22	-17	3.7	6-15
VDO	JMS		-37	-52	-44	4.8	6-15
PPC	IBD		-16	-18	-17	0.81	6-21
V+W	JHA		3	0	1.7	1.1	6-21
PPC	JHA		0	-1	-0.98	0.13	6-21
FD	RLM	LEVEE	X	8	X	X	5-6
V+W	RLM		1	-6	-1.1	2.2	6-1
PPC	RLM		31	19	27.51	27.7	6-1
FD	IBD		-6	-13	-8.2	1.8	6-3
FD	JMS		-31	-39	-32	2.2	6-6
V+W	JMS		-8	-12	-9.4	0.94	6-15
VDO	JMS		-24	-25	-24	0.46	6-15
PPC	IBD		26	-21,779	-21	500	6-21
V+W	JHA		1	-172	-4.7	7.1	6-21
PPC	JHA		1	-10	-2.7	3.5	6-21

TIME ERROR SUMMARY
SID/STAR–GRA32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	GRANY	18	-2	8.9	6.8	5-6
V+W	RLM		-6	-10	-8.5	1.4	6-1
PPC	RLM		19	-2	8.23	10.46	6-1
FD	IBD		2	-8	-5.3	3.1	6-3
FD	JMS		X	X	X	X	6-6
V+W	JMS		-13	-22	-18	2.5	6-15
VDO	JMS		-34	-36	-35	0.58	6-15
PPC	IBD		X	X	X	X	6-21
V+W	JHA		-13	-5459	-24	168	6-21
PPC	JHA		1	-13	-10	2	6-21
FD	RLM	BATUM	-1	-3	-2.4	0.54	5-6
V+W	RLM		-1	-6	-3.3	1.6	6-1
PPC	RLM		-1	-5	-3.03	3.11	6-1
FD	IBD		3	-3	1	1.9	6-3
FD	JMS		X	X	X	X	6-6
V+W	JMS		-17	-22	-21	1.5	6-15
VDO	JMS		X	X	X	X	6-15
PPC	IBD		X	X	X	X	6-21
V+W	JHA		-2	-13	-6.4	3.4	6-21
PPC	JHA		1	-6	-3.4	1.8	6-21

CROSSTRACK ERROR SUMMARY
SID/STAR–LOF16

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	BRP16	0	0	0	0	6-2
PPC	RLM		X	X	X	X	6-2
FD	JRG		X	X	X	X	6-12
VDO	RLM	KITSP	1272	-2700	-759	1101	6-2
PPC	RLM		756	36	321	206	6-2
FD	JRG		28	-528	-179	136	6-12
VDO	RLM	LOP16	280	236	249	3.7	6-2
PPC	RLM		1076	976	1004	18	6-2
FD	JRG		-2424	-2504	-2462	25	6-12
VDO	RLM	LOFAL	864	-3068	-1123	1196	6-2
PPC	RLM		X	X	X	X	6-2
FD	JRG		8	-300	-141	91	6-12
VDO	RLM	FREEY	556	-820	271	265	6-2
PPC	RLM		1164	-532	797	426	6-2
FD	JRG		308	-2532	-966	1159	6-12

ALTITUDE ERROR SUMMARY
SID/STAR—LOF16

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO PPC FD	RLM RLM JRG	BRP16	0 X X	0 X X	0 X X	0 X X	6-2 6-2 6-12
VDO PPC FD	RLM RLM JRG	KITSP	224 84 2992	0 -4 -112	68 37 966	50 23 1011	6-2 6-2 6-12
VDO PPC FD	RLM RLM JRG	LOP16	-28 8 -28	-132 -148 -60	-56 -14 -31	24 26 6.5	6-2 6-2 6-12
VDO PPC FD	RLM RLM JRG	LOFAL	352 X 3160	32 X 676	84 X 2313	65 X 790	6-2 6-2 6-12
VDO PPC FD	RLM RLM JRG	FREEY	228 260 88	-132 -60 -96	93 104 -16	64 64 57	6-2 6-2 6-12

TIME ERROR SUMMARY
SID/STAR–LOF16

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	BRP16	0	0	0	0	6-2
PPC	RLM		X	X	X	X	6-2
FD	JRG		X	X	X	X	6-12
VDO	RLM	KITSP	17	7	14	3.6	6-2
PPC	RLM		6	3	5.1	0.95	6-2
FD	JRG		14	-54	8.9	11	6-12
VDO	RLM	LOP16	5	0	1.5	1.2	6-2
PPC	RLM		-19	-43	-31	6.9	6-2
FD	JRG		-57	-161	-97	30	6-12
VDO	RLM	LOFAL	16	3	9.2	3.8	6-2
PPL	RLM		X	X	X	X	6-2
FD	JRG		15	11	14	0.94	6-12
VDO	RLM	FREEY	8	-1	2.3	2.7	6-2
PPC	RLM		-10	-21	-16	3.6	6-2
FD	JRG		-54	-57	-56	0.92	6-12

CROSSTRACK ERROR SUMMARY
SID/STAR–BUR13R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		BR13R	X	X	27	540	5-6
Auto			X	X	X	X	6-1
VDO	RLM		X	X	X	X	6-2
Auto			X	X	X	X	6-3
FD	IBD		X	X	X	X	6-4
Auto			X	X	X	X	6-5
Auto			X	X	X	X	6-6
Auto			X	X	X	X	6-7
Auto			0	-1,804	-4.4	89	6-7
Auto			X	X	X	X	6-8
Auto			X	X	X	X	6-10
Auto			X	X	X	X	6-12
PPS	JMS		X	X	X	X	6-13
Auto			644	0	3.2	45	6-14
PPC	JMS		X	X	X	X	6-15
Auto			X	X	X	X	6-16
Auto			X	X	X	X	6-17
Auto			X	X	X	X	6-19
Auto			X	X	X	X	6-19
Auto			X	X	X	X	6-20
PPS	IBD		X	X	X	X	6-21
PPS	JHA		X	X	X	X	6-23
Auto		TUKWA	1,052	-192	392	494	5-6
Auto			-200	-1,156	-938	263	6-1
VDO	RLM		1,172	428	640	212	6-2
Auto			724	-1,676	-889	849	6-3
FD	IBD		28	-1,276	-736	506	6-4
Auto			-24	-33	-29	2.7	6-5
Auto			-380	-1,076	-907	195	6-6
Auto			291,248	-1,308	482	17,010	6-7
Auto			1,424	-1,704	-619	1,003	6-7
Auto			-340	-1,228	-842	298	6-8
Auto			180	36	111	44	6-10
Auto			76	-432	-191	200	6-12
PPS	JMS		536	128	309	113	6-13
Auto			936	584	695	83	6-14
PPC	JMS		268	-12	150	99	6-15
Auto			8	-452	-187	176	6-16
Auto			X	X	X	X	6-17
Auto			608	-16	243	209	6-19
Auto			16	-440	-179	174	6-19
Auto			-80	-1,356	-910	447	6-20
PPS	IBD		128	-1,008	-419	385	6-21
PPS	JHA		220	-52	69	69	6-23

CROSSTRACK ERROR SUMMARY
SID/STAR–BUR13R
(Continued)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		FAUNY	11,604	-1,156	-494	624	5-6
Auto			-24	-144	-80	32	6-1
VDO	RLM		924	-1,736	-279	718	6-2
Auto			-840	-2,284	-1,783	433	6-3
FD	IBD		56	-868	-394	239	6-4
Auto			-62	-66	-65	1.1	6-5
Auto			-2,980	-4,624	-4,042	482	6-6
Auto			76	-928	-140	298	6-7
Auto			-104	-808	-406	211	6-7
Auto			-294	-980	-588	211	6-8
Auto			48	-548	-102	182	6-10
Auto			-4	-1,148	-746	449	6-12
PPS	JMS		-124	-880	-554	207	6-13
Auto			-32	-680	-226	191	6-14
PPC	JMS		-156	-588	-341	130	6-15
Auto			-216	-1,000	-488	207	6-16
Auto			-740	-2,064	-1,551	418	6-17
Auto			636	-88	278	250	6-19
Auto			256	-320	74	157	6-19
Auto			-936	-4,364	-2,522	1,055	6-20
PPS	IBD		328	-780	-403	259	6-21
PPS	JHA		128	-472	-70	164	6-23
Auto		LO13R	1,004	764	866	70	5-6
Auto			0	1,068	-372	498	6-1
VDO	RLM		460	80	105	192	6-2
Auto			0	-1,684	-457	741	6-3
FD	IBD		0	-1,248	-290	521	6-4
Auto			0	-70	-25	23	6-5
Auto			-968	-1,028	-1,002	18	6-6
Auto			28,768	-1,328	-138	1,924	6-7
Auto			-1,704	-1,804	-1,770	26	6-7
Auto			0	-412	-142	182	6-8
Auto			X	X	X	X	6-10
Auto			0	-440	-117	185	6-12
PPS	JMS		X	X	X	X	6-13
Auto			728	636	671	22	6-14
PPC	JMS		280	0	70	107	6-15
Auto			-440	-528	-488	24	6-16
Auto			X	X	X	X	6-17
Auto			608	0	322	273	6-19
Auto			-220	-460	-423	25	6-19
Auto			0	-1,368	-565	664	6-20
PPS	IBD		X	X	X	X	6-21
PPS	JHA		220	0	87	80	6-23

CROSSTRACK ERROR SUMMARY
SID/STAR—BUR13R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		BURIN	-152	-2,332	-1,032	686	5-6
Auto			8	-2,312	-1,018	755	6-1
VDO	RLM		1,212	-4,046	-1,380	2,025	6-2
Auto			764	-1,992	-731	735	6-3
FD	IBD		168	-1,912	-576	581	6-4
Auto			-32	-65	-51	9.9	6-5
Auto			-240	-3,516	-657	724	6-6
Auto			100	-1,196	-408	476	6-7
Auto			1,484	-2,024	-491	393	6-7
Auto			356	-3,208	-1,034	1,075	6-8
Auto			80	-2,192	-792	696	6-10
Auto			100	-1,864	-725	568	6-12
PPS	JMS		904	-1,796	-298	858	6-13
Auto			984	-1,912	-596	775	6-14
PPC	JMS		20	-1,884	-755	577	6-15
Auto			-92	-976	-367	211	6-16
Auto			-232	-2,164	-1,207	552	6-17
Auto			-72	-200	-148	27	6-19
Auto			-260	-320	-291	12	6-19
Auto			-260	-4,584	-2,802	1,608	6-20
PPS	IBD		-168	-688	-32	158	6-21
PPS	JHA		0	-560	-279	135	6-23
Auto		SOUND	-292	-1,028	-571	185	5-6
Auto			16	-812	-137	133	6-1
VDO	RLM		1,172	-1,952	350	785	6-2
Auto			108	-832	-201	219	6-3
FD	IBD		2,496	-252	155	489	6-4
Auto			-57	-63	-61	1.8	6-5
Auto			-2,980	-4,624	-4,042	482	6-6
Auto			148	-232	-16	88	6-7
Auto			128	-480	-70	147	6-7
Auto			28	-252	-66	52	6-8
Auto			188	-100	7.5	83	6-10
Auto			1,772	8	1,163	449	6-12
PPS	JMS		3,332	-132	1,599	1,071	6-13
Auto			116	-92	-16	52	6-14
PPC	JMS		416	-156	219	151	6-15
Auto			36	-208	-60	65	6-16
Auto			148	-728	-34	195	6-17
Auto			-340	-420	-381	13	6-19
Auto			16	-668	-427	228	6-19
Auto			60	-1,184	-479	375	6-20
PPS	IBD		1,024	-116	535	363	6-21
PPS	JHA		580	-88	154	160	6-23

ALTITUDE ERROR SUMMARY
SID/STAR–BUR13R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		BR13R	X	X	X	X	5-6
Auto			X	X	X	X	6-1
VDO	RLM		X	X	X	X	6-2
Auto			X	X	X	X	6-3
FD	IBD		X	X	X	X	6-4
Auto			X	X	X	X	6-5
Auto			X	X	X	X	6-6
Auto			X	X	X	X	6-7
Auto			0	-52	-0.13	2.6	6-7
Auto			X	X	X	X	6-8
Auto			X	X	X	X	6-10
Auto			X	X	X	X	6-12
PPS	JMS		X	X	X	X	6-13
Auto			0	-36	-0.18	2.5	6-14
PPC	JMS		X	X	X	X	6-15
Auto			X	X	X	X	6-16
Auto			X	X	X	X	6-17
Auto			X	X	X	X	6-19
Auto			X	X	X	X	6-19
Auto			X	X	X	X	6-20
PPS	IBD		X	X	X	X	6-21
PPS	JHA		X	X	X	X	6-23
Auto		TUKWA	X	-1,360	X	X	5-6
Auto			932	-660	304	179	6-1
VDO	RLM		188	-148	116	71	6-2
Auto			172	24	102	31	6-3
FD	IBD		528	-128	363	154	6-4
Auto			96	-128	-24	50	6-5
Auto			312	-32	223	72	6-6
Auto			36	-1,052	-375	457	6-7
Auto			216	-216	30	136	6-7
Auto			708	-64	158	156	6-8
Auto			88	-72	12	44	6-10
Auto			84	-44	18	37	6-12
PPS	JMS		324	60	222	77	6-13
Auto			280	-48	170	76	6-14
PPC	JMS		276	-124	153	108	6-15
Auto			8	-100	-14	24	6-16
Auto			X	X	X	X	6-17
Auto			192	-192	57	122	6-19
Auto			52	-220	-120	90	6-19
Auto			416	-32	311	86	6-20
PPS	IBD		188	68	114	21	6-21
PPS	JHA		108	-72	60	43	6-23

ALTITUDE ERROR SUMMARY
SID/STAR–BUR13R
(Continued)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		FAUNY	104	-44	8	29	5-6
Auto			1,060	-3,052	976	459	6-1
VDO	RLM		160	-56	68	75	6-2
Auto			88	-36	10	24	6-3
FD	IBD		40	-68	-16	20	6-4
Auto			88	-40	-3.1	27	6-5
Auto			84	-80	-5	34	6-6
Auto			9,996	-48	112	1,021	6-7
Auto			92	-32	7.7	27	6-7
Auto			88	-36	12	24	6-8
Auto			96	-32	14	26	6-10
Auto			4	-208	-111	60	6-12
PPS	JMS		200	100	59	33	6-13
Auto			80	-36	11	23	6-14
PPC	JMS		212	72	169	44	6-15
Auto			60	-48	-0.01	14	6-16
Auto			32	-176	-64	46	6-17
Auto			52	-40	-8	16	6-19
Auto			48	-40	-3.6	16	6-19
Auto			-100	-324	206	58	6-20
PPS	I8D		208	120	150	21	6-21
PPS	JHA		140	0	63	51	6-23
Auto		LO13R	-8	-116	-26	28	5-6
Auto			0	-28	-8.5	11.5	6-1
VDO	RLM		0	-156	-54	59	6-2
Auto			20	-44	-5.2	15	6-3
FD	IBD		0	-132	-30	55	6-4
Auto			0	-128	-48	40	6-5
Auto			-24	-36	-28	3.3	6-6
Auto			0	-1,052	-29	134	6-7
Auto			-48	-220	-73	4.3	6-7
Auto			0	-64	-3	8.5	6-8
Auto			X	X	X	X	6-10
Auto			0	-44	-8.2	13	6-12
PPS	JMS		X	X	X	X	6-13
Auto			-32	-36	-36	1.2	6-14
PPC	JMS		0	-128	-16	27	6-15
Auto			-56	-104	-63	7.3	6-16
Auto			X	X	X	X	6-17
Auto			0	-196	-44	46	6-19
Auto			-44	-188	-65	33	6-19
Auto			0	-36	-15	17	6-20
PPS	IBD		X	X	X	X	6-21
PPS	JHA		0	-76	-22	21	6-23

ALTITUDE ERROR SUMMARY
SID/STAR–BUR13R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		BURIN	44	X	X	X	5-6
Auto			1,524	-2,964	527	490	6-1
VDO	RLM		184	-128	6.4	71	6-2
Auto			180	-24	5.4	33	6-3
FD	I8D		564	-80	169	195	6-4
Auto			452	-4	177	165	6-5
Auto			340	-52	18	69	6-6
Auto			14,364	-1,052	83	1,081	6-7
Auto			256	-28	11	49	6-7
Auto			1,376	-780	246	613	6-8
Auto			40	-32	-12	14	6-10
Auto			48	-188	-116	64	6-12
PPS	JMS		288	32	98	48	6-13
Auto			316	68	44	97	6-14
PPC	JMS		296	-60	81	86	6-15
Auto			4	-16	-2.9	4	6-16
Auto			32	-34,996	-182	1,261	6-17
Auto			8	-4	0.14	3	6-19
Auto			0	-8	-4.9	2.2	6-19
Auto			348	-280	30	186	6-20
Auto			X	84	2,765	85,394	6-21
PPS	I8D		172	28	64	35	6-23
PPS	JHA						
Auto		SOUND	104	-4	20	27	5-6
Auto			1,020	-1,368	223	334	6-1
VDO	RLM		96	-296	-105	96	6-2
Auto			88	-52	-4.5	23	6-3
FD	IBD		44	-84	-43	30	6-4
Auto			88	-16	1.2	15	6-5
Auto			X	X	X	X	6-6
Auto			11,084	-4	327	1,798	6-7
Auto			88	-540	-96	180	6-7
Auto			92	-8	18	26	6-8
Auto			92	-8	6.6	17	6-10
Auto			4	-856	-578	275	6-12
PPS	JMS		196	24	59	33	6-13
Auto			76	-80	-1.6	20	6-14
PPC	JMS		212	-40	119	43	6-15
Auto			X	X	X	X	6-16
Auto			36	-160	-62	42	6-17
Auto			68	-4	11	22	6-19
Auto			72	-24	4.6	21	6-19
Auto			-76	-132	-109	18	6-20
PPS	I8D		208	-16	33	48	6-21
PPS	JHA		80	-176	61	87	6-23

TIME ERROR SUMMARY
SID/STAR–BUR13R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		BR13R	X	X	X	X	5-6
Auto			X	X	X	X	6-1
VDO	RLM		X	X	X	X	6-2
Auto			X	X	X	X	6-3
FD	IBD		X	X	X	X	6-4
Auto			X	X	X	X	6-5
Auto			X	X	X	X	6-6
Auto			X	X	X	X	6-7
Auto			0	-231	-0.56	11	6-7
Auto			X	X	X	X	6-8
Auto			X	X	X	X	6-10
Auto			X	X	X	X	6-12
PPS	JMS		X	X	X	X	6-13
PPC	JMS		X	X	X	X	6-15
Auto			X	X	X	X	6-16
Auto			X	X	X	X	6-17
Auto			X	X	X	X	6-19
Auto			X	X	X	X	6-19
Auto			X	X	X	X	6-20
PPS	IBD		X	X	X	X	6-21
PPS	JHA		X	X	X	X	6-23
Auto		TUKWA	X	X	X	X	5-6
Auto			-126	-143	-136	4.7	6-1
VDO	RLM		-16	-26	-20	3.2	6-2
Auto			-214	-229	-220	4.2	6-3
FD	IBD		-5	-21	-12	4.8	6-4
Auto			-24	-33	-29	2.7	6-5
Auto			-75	-77	-76	0.5	6-6
Auto			-8	-31	-21	5.9	6-7
Auto			-22	-28	-25	1.9	6-7
Auto			-19	-33	-26	4.4	6-8
Auto			0	0	0	0	6-10
Auto			-12	-24	-17	3.6	6-12
PPS	JMS		-15	22	-19	1.9	6-13
PPC	JMS		-15	20	-18	1.5	6-15
Auto			1	-8	-3	2.8	6-16
Auto			X	X	X	X	6-17
Auto			11	4	8.7	2.1	6-19
Auto			-18	-22	-21	1.1	6-19
Auto			0	-11	-5.3	3.2	6-20
PPS	IBD		-8	-21	-14	3.9	6-21
PPS	JHA		-6	-20	-12	4	6-23

TIME ERROR SUMMARY
SID/STAR–BUR13R
(Continued)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		FAUNY	X	X	X	X	5-6
Auto			-129	-145	-144	2.4	6-1
VDO	RLM		-49	-51	-49	0.5	6-2
Auto			-203	-235	-217	9.1	6-3
FD	IBD		-45	-49	-47	1.2	6-4
Auto			-63	-66	-65	1.1	6-5
Auto			-75	-90	-82	4.5	6-6
Auto			-37	-39	-38	0.44	6-7
Auto			-17	-23	-20	1.9	6-7
Auto			-58	-67	-62	2.6	6-8
Auto			0	0	0	0	6-10
Auto			-39	-48	-43	2.4	6-12
PPS	JMS		-38	-39	-38	0.48	6-13
PPC	JMS		-21	-30	-25	2.5	6-15
Auto			1	-7	-4.7	1.5	6-16
Auto			43	X	X	X	6-17
Auto			0	-210	-0.71	0.58	6-19
Auto			-12	-18	-15	1.8	6-19
Auto			-8	-15	-11	2	6-20
PPS	IBD		-13	-87,399	-239	4,412	6-21
PPS	JHA		-25	-29	-26	1.3	6-23
Auto		LO13R	X	X	X	X	5-6
Auto			0	-769	-117	186	6-1
VDO	RLM		0	-38	-12	13	6-2
Auto			0	-496	-95	159	6-3
FD	IBD		1	-5	-6	1.3	6-4
Auto			0	-70	-25	23	6-5
Auto			-76	-216	-129	40	6-6
Auto			0	-24	-4.1	8.1	6-7
Auto			-22	-223	-59	44	6-7
Auto			0	-42	-11	15	6-8
Auto			X	X	X	X	6-10
Auto			0	-23	-4.8	7.8	6-12
PPS	JMS		X	X	X	X	6-13
PPC	JMS		0	-65	-9	15	6-15
Auto			4	1	2.1	0.74	6-16
Auto			X	X	X	X	6-17
Auto			20	0	8.8	7.7	6-19
Auto			-18	-117	-43	24	6-19
Auto			6	0	1.1	1.7	6-20
PPS	IBD		X	X	X	X	6-21
PPS	JHA		0	-14	-4.7	4.6	6-23

TIME ERROR SUMMARY
SID/STAR–BUR13R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		BURIN	X	X	X	X	5-6
Auto			-126	-149	-137	8.5	6-1
VDO	RLM		-25	-50	-36	7.8	6-2
Auto			-48	-240	-232	9.8	6-3
FD	IBD		-20	-48	-39	9	6-4
Auto			-32	-65	-51	9.9	6-5
Auto			-74	-89	-83	3.8	6-6
Auto			-12	-37	-35	2.3	6-7
Auto			0	-36	-29	5.1	6-7
Auto			-32	-66	-52	11	6-8
Auto			0	0	0	0	6-10
Auto			-22	-48	-39	8.3	6-12
PPS	JMS		-21	-38	-31	5.8	6-13
PPC	JMS		-19	-33	-27	4.9	6-15
Auto			-7	-16	-11	2.1	6-16
Auto			-24	-29	-28	1.5	6-17
Auto			-1	-3	-2.6	0.63	6-19
Auto			-17	-18	-18	0.45	6-19
Auto			-10	-19	-17	3.6	6-20
PPS	I8D		-19	-29	-24	2.5	6-21
PPS	JHA		-19	-35	-30	4.4	6-23
Auto		SOUND	X	X	X	X	5-6
Auto			-127	-162	-153	5.4	6-1
VDO	RLM		-49	-53	-52	1.1	6-2
Auto			-195	-203	-200	2.4	6-3
FD	I8D		-44	-46	-45	0.62	6-4
Auto			-57	-63	-61	1.8	6-5
Auto			X	X	X	X	6-6
Auto			-6	-45	-42	3.6	6-7
Auto			-16	-17	-17	0.48	6-7
Auto			13	-59	-20	35	6-8
Auto			0	0	0	0	6-10
Auto			-57	-39	-38	0.78	6-12
PPS	JMS		-39	-47	-44	2.4	6-13
PPC	JMS		-19	-21	-19	0.58	6-15
Auto			X	X	X	X	6-16
Auto			X	X	X	X	6-17
Auto			0	0	0	0	6-19
Auto			-5	-12	-8.1	2.1	6-19
Auto			-1	-2	-1.6	0.49	6-20
PPS	I8D		-7	-13	-11	2.1	6-21
PPS	JHA		-25	-29	-27	1.2	6-23

CROSSTRACK ERROR SUMMARY
SID/STAR—WEN14L

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	JMS	EAT	3116	-2184	504	1711	6-11
PPC	JMS		696	-1000	-357	553	6-11
VDO	I8D		1084	248	577	234	6-17
VDO	JMS	TD14L	4748	0	1714	1740	6-11
PPC	JMS		2948	-112	1165	1235	6-11
VDO	IBD		5188	0	2464	2069	6-17
VDO	JMS	EPH	603 696	-2352	1796	11427	6-11
PPC	JMS		436	-708	52	259	6-11
VDO	I8D		2856	136	1210	843	6-17
VDO	JMS	CRACK	337 794	-1196	1997	22761	6-11
PPC	JMS		360	28	131	84	6-11
VDO	IBD		2092	-1248	-74	998	6-17

ALTITUDE ERROR SUMMARY
SID/STAR–WEN14L

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	JMS	EAT	660	116	431	170	6-11
PPC	JMS		760	64	407	237	6-11
VDO	IBD		484	180	377	91	6-17
VDO	JMS	TD14L	40	-288	-69	110	6-11
PPC	JMS		0	-404	-164	152	6-11
VDO	IBD		40	-2712	-86	115	6-17
VDO	JMS	EPH	656	-1052	40	197	6-11
PPC	JMS		756	-1052	118	148	6-11
VDO	IBD		480	-704	3.6	91	6-17
VDO	JMS	CRACK	68	-1052	-6.4	148	6-11
PPC	JMS		136	-1052	-21	141	6-11
VDO	IBD		88	-108	9.4	61	6-17

TIME ERROR SUMMARY
SID/STAR--WEN14L

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	JMS	EAT	6	1	4.7	1.6	6-11
PPC	JMS		6	4	4.7	0.59	6-11
VDO	IBD		2	1	1.9	0.23	6-17
VDO	JMS	TD14L	29	0	12	12	6-11
PPC	JMS		7	-59,686	19,460	27,970	6-11
VDO	IBD		37	0	20	13	6-17
VDO	JMS	EPH	19	-10	7.1	9.5	6-11
PPC	JMS		31	-5	17	11	6-11
VDO	IBD		1	-1	0.44	0.57	6-17
VDO	JMS	CRACK	28	-13	-5.5	2.3	6-11
PPC	JMS		-4	-11	-7.5	2.6	6-11
VDO	IBD		128	0	8.4	14	6-17

CROSSTRACK ERROR SUMMARY
SID/STAR–CON32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	CONNL	616	-172	323	222	5-6
V+W	RLM		1,456	1,168	1,359	84	6-1
PPC	RLM		72	-324	-76.5	109.4	6-1
FD	JMS		17,164	516	4,012	4,984	6-6
V+W	JMS		708	-1,552	-277	673	6-15
PPC	JMS		X	X	X	X	6-15
PPC	JHA		112	-48	37	46	6-18
PPC	I8D		X	X	X	X	6-21
V+W	JHA		160	-5,116	-1,557	1,587	6-21
FD	JHA		220	-444	-187	247	6-21
FD	RLM	WARDN	316	-952	-161	327	5-6
V+W	RLM		1,436	-868	330	569	6-1
PPC	RLM		936	-280	224	261	6-1
FD	JMS		17,176	2,364	8,703	4,649	6-6
V+W	JMS		148	-5,100	-1,932	1,812	6-15
PPC	JMS		388	-80	146	98	6-15
PPC	JHA		368	-8	215	91	6-18
PPC	I8D		X	X	X	X	6-21
V+W	JHA		308	-1,620	-224	570	6-21
FD	JHA		644	-368	266	280	6-21
FD	RLM	PELIN	896	-60	146	144	5-6
V+W	RLM		816	56	502	168	6-1
PPC	RLM		584	28	166.7	120.8	6-1
FD	JMS		2,344	-1,736	-55	556	6-6
V+W	JMS		876	88	434	204	6-15
PPC	JMS		244	196	225	11	6-15
PPC	JHA		288	28	155	65	6-18
PPC	I8D		176	8	68	46	6-21
V+W	JHA		524	88	365	77	6-21
FD	JHA		X	X	X	X	6-21
FD	RLM	MN32R	X	X	X	X	5-6
V+W	RLM		476	-120	39	109	6-1
PPC	RLM		88	-452	-103	145	6-1
FD	JMS		X	X	X	X	6-6
V+W	JMS		324	-220	-92	94	6-15
PPC	JMS		204	-136	89	69	6-15
PPC	JHA		456	-172	217	198	6-18
PPC	IBD		176	-40	16	48	6-21
V+W	JHA		316	-120	21	74	6-21
FD	JHA		X	X	X	X	6-21

CROSSTRACK ERROR SUMMARY
SID/STAR–CON32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	TD32R	X	X	X	X	5-6
V+W	RLM		0	-132	-57	61	6-1
PPC	RLM		0	-508	-471.5	59.5	6-1
FD	JMS		X	X	X	X	6-6
V+W	JMS		0	-212	-39	75	6-15
PPC	JMS		X	X	X	X	6-15
PPC	JHA		360	0	147	169	6-18
PPC	IBD		0	-40	-19	17	6-21
V+W	JHA		76	0	42	37	6-21
FD	JHA		X	X	X	X	6-21

ALTITUDE ERROR SUMMARY SID/STAR–CON32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	CONNL	152	-28	42	54	5-6
V+W	RLM		-204	-288	-253	24	6-1
PPC	RLM		544	380	441	43.6	6-1
FD	JMS		44	-588	-97	170	6-15
V+W	JMS		240	52	135	60	6-15
PPC	JMS		X	X	X	X	6-15
PPC	JHA		288	124	219	44	6-18
PPC	IBD		X	X	X	X	6-21
V+W	JHA		340	-176	6.7	131	6-21
FD	JHA		296	-80	63	128	6-21
FD	RLM	WARDN	456	-28	189	129	5-6
V+W	RLM		92	-228	7.3	76	6-1
PPC	RLM		380	32	143	73.1	6-1
FD	JMS		24	-544	-228	108	6-15
V+W	JMS		240	-40	23	57	6-15
PPC	JMS		204	12	69	39	6-15
PPC	JHA		288	-68	35	74	6-18
PPC	IBD		X	X	X	X	6-21
V+W	JHA		340	-24	81	86	6-21
FD	JHA		300	-192	-9.8	82	6-21
FD	RLM	PELIN	144	X	X	X	5-6
V+W	RLM		164	-128	54	71	6-1
PPC	RLM		132	-180	-43.4	79.1	6-1
FD	JMS		52	-88	-9.9	26	6-15
V+W	JMS		-16	100	-52	22	6-15
PPC	JMS		16	-4	5.1	6.5	6-15
PPC	JHA		60	-32	18	14	6-18
PPC	IBD		32	-60	-10	24	6-21
V+W	JHA		32	-64	-9.5	23	6-21
FD	JHA		X	X	X	X	6-21
FD	RLM	MM32R	144	-192	-25	126	5-6
V+W	RLM		64	-84	-5	43	6-1
PPC	RLM		-32	-164	-122.5	34.9	6-1
FD	JMS		X	X	X	X	6-15
V+W	JMS		-48	-124	-81	22	6-15
PPC	JMS		24	-52	-4.7	22	6-15
PPC	JHA		-32	-288	-156	74	6-18
PPC	IBD		72	-68	8.1	33	6-21
V+W	JHA		4	-84	-35	24	6-21
FD	JHA		X	X	X	X	6-21

ALTITUDE ERROR SUMMARY
SID/STAR—CON32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	TD32R	0	-136	-55	64	5-6
V+W	RLM		0	-84	-27	31	6-1
PPC	RLM		0	-132	-93.4	19.9	6-1
FD	JMS		X	X	X	X	6-15
V+W	JMS		0	-96	-9.9	23	6-15
PPC	JMS		X	X	X	X	6-15
PPC	JHA		4	-92	-17	27	6-18
PPC	IBD		0	-68	-39	28	6-21
V+W	JHA		0	-108	-49	44	6-21
FD	JHA		X	X	X	X	6-21

TIME ERROR SUMMARY
SID/STAR–CON32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	CONNL	1	0	0.21	0.41	5-6
V+W	RLM		-8	-9	-8.9	0.29	6-1
PPC	RLM		0	-1	-0.12	0.32	6-1
FD	JMS		-37	-60	-54	2.9	6-6
V+W	JMS		5	4	4.5	0.5	6-15
PPC	JMS		X	X	X	X	6-15
PPC	JHA		1	0	0.86	0.34	6-18
PPC	IBD		X	X	X	X	6-21
V+W	JHA		5	-8	-5.2	2.3	6-21
FD	RLM	WARDN	2	0	0.89	0.9	5-6
V+W	RLM		1	-8	-1	2.2	6-1
PPC	RLM		1	0	0.09	0.29	6-1
FD	JMS		-4	-37	-14	6.3	6-6
V+W	JMS		8	-2	3.8	3	6-15
PPC	JMS		2	-1	0.71	0.85	6-15
PPC	JHA		4	0	1.4	1.6	6-18
PPC	IBD		X	X	X	X	6-21
V+W	JHA		5	-2	1.4	2.2	6-21
FD	RLM	PELIN	4	0	1.2	1.2	5-6
V+W	RLM		3	-2	0.67	1.2	6-1
PPC	RLM		2	-1	0.65	1.07	6-1
FD	JMS		18	-5	8.1	7.6	6-6
V+W	JMS		2	-2	3.8	3	6-15
PPC	JMS		X	X	X	X	6-15
PPC	JHA		1	0	0.32	0.47	6-18
PPC	IBD		2	-3	-0.95	1.2	6-21
V+W	JHA		1	0	0.30	0.46	6-21
FD	RLM	MM32R	6	4	4.8	0.64	5-6
V+W	RLM		7	1	2.4	1.7	6-1
PPC	RLM		16	2	7.61	2.3	6-1
FD	JMS		X	X	X	X	6-6
V+W	JMS		0	-3	-1.8	0.81	6-15
PPC	JMS		-2	-6	-4.6	1.4	6-15
PPC	JHA		0	-8	-4	2.9	6-18
PPC	IBD		1	0	0.07	0.26	6-21
V+W	JHA		0	-6	-2.8	2.4	6-21

TIME ERROR SUMMARY
SID/STAR–CON32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	TD32R	8	0	2.9	3.3	5-6
V+W	RLM		9	0	3.8	4.1	6-1
PPC	RLM		19	0	17	2.3	6-1
FD	JMS		X	X	X	X	6-6
V+W	JMS		3	0	0.45	0.88	6-15
PPC	JMS						6-15
PPC	JHA		-7	X	X	X	6-18
PPC	IBD		2	0	0.6	0.5	6-21

CROSSTRACK ERROR SUMMARY
SID/STAR–MOU16

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	MOUVN	1,480	-548	317	639	6-2
FD	JRG		X	X	X	X	6-12
FD	JRG		X	X	X	X	6-12
PPS	JHA		176	-68	30	58	6-17
PPC	JHA		516	220	349	75	6-17
VDO	RLM	TDZ16	7,736	0	5,987	2,246	6-2
FD	JRG		816	0	204	216	6-12
FD	JRG		784	0	247	300	6-12
PPS	JHA		0	-320	-118	109	6-17
PPC	JHA		96	-1,236	-752	521	6-17
VDO	RLM	FLORE	1,708	736	1,100	317	6-2
FD	JRG		18,144	-2,772	1,345	4,937	6-12
FD	JRG		188	-980	-345	377	6-12
PPS	JHA		-40	-160	-112	28	6-17
PPC	JHA		540	-180	153	242	6-17
VDO	RLM	HATID	1,760	-112	533	639	6-2
FD	JRG		840	-160	224	358	6-12
FD	JRG		296	-240	-38	121	6-12
PPS	JHA		68	0	52	13	6-17
PPC	JHA		128	-12	29	31	6-17

ALTITUDE ERROR SUMMARY
SID/STAR–MOU16

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	MOUVN	8	-236	-104	64	6-2
FD	JRG		X	X	X	X	6-12
FD	JRG		X	X	X	X	6-12
PPS	JHA		0	-528	-232	186	6-17
PPC	JHA		72	-20	15	17	6-17
VDO	RLM	TDZ16	144	-172	-41	82	6-2
FD	JRG		0	-260	-91	86	6-12
FD	JRG		108	-204	-25	61	6-12
PPS	JHA		124	-48	17	49	6-17
PPC	JHA		0	-76	-38	27	6-17
VDO	RLM	FLORE	52	-252	-61	63	6-2
FD	JRG		268	-192	63	135	6-12
FD	JRG		52	-352	-83	114	6-12
PPS	JHA		104	72	87	12	6-17
PPC	JHA		72	-12	34	20	6-17
VDO	RLM	HATID	56	-268	-52	87	6-2
FD	JRG		196	-1108	437	336	6-12
FD	JRG		36	-1088	-531	374	6-12
PPS	JHA		-12	108	-64	26	6-17
PPC	JHA		-8	-116	-69	31	6-17

TIME ERROR SUMMARY
SID/STAR–MOU16

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
VDO	RLM	MOUVN	1	0	0.29	0.46	6-2
FD	JRG		X	X	X	X	6-12
FD	JRG		X	X	X	X	6-12
PPS	JHA		0	0	0	0	6-17
PPC	JHA		0	-1	-0.5	0.5	6-17
VDO	RLM	TDZ16	4	-23	-12	9	6-2
FD	JRG		70	0	40	30	6-12
FD	JRG		18	0	5.3	5.9	6-12
PPS	JHA		-91	-91	-91	0	6-17
PPC	JHA		5	-2	2	2.3	6-17
VDO	RLM	FLORE	2	0	0.69	0.7	6-2
FD	JRG		-7	-26	-19	5.6	6-12
FD	JRG		17	-14	-1.7	9.7	6-12
PPS	JHA		-9	-19	14	2.7	6-17
PPC	JHA		0	-1	-0.19	0.39	6-17
VDO	RLM	HATID	10	-1	[illegible].5	3.5	6-2
FD	JRG		42	-7	17	16	6-12
FD	JRG		24	17	21	2.3	6-12
PPS	JHA		-89	-91	-90	0.71	6-17
PPC	JHA		2	0	-0.45	0.52	6-17

CROSSTRACK ERROR SUMMARY
SID/STAR–COR32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	CORFU	-772	-2452	-1708	506	5-6
FD	18D		556	-152	89	215	6-3
FD	JMS		884	424	536	120	6-5
VDO	JMS		4360	-1196	562	1692	6-6
PPS	JMS		1092	-32	219	264	6-6
PPC	JMS		X	X	X	X	6-6
FD	JHA		536	16	197	178	6-6
V+W	JHA		1680	-440	612	592	6-6
PPC	18D		184	28	73	35	6-21
FD	RLM	OTHEO	292	-2584	-814	1092	5-6
FD	IBD		772	-236	310	387	6-3
FD	JMS		912	72	539	321	6-5
VDO	JMS		4748	432	3040	1309	6-6
PPS	JMS		1472	128	1049	377	6-6
PPC	JMS		X	X	X	X	6-6
FD	JHA		536	-844	-25	502	6-6
V+W	JHA		32	-840	-492	222	6-6
PPC	IBD		496	44	210	141	6-21
FD	RLM	PROPE	400	-232	36	169	5-6
FD	IBD		876	56	350	230	6-3
FD	JMS		320	-12	155	122	6-5
VDO	JMS		7004	272	1776	1670	6-6
PPS	JMS		724	128	366	180	6-6
PPC	JMS		2340	708	1596	576	6-6
FD	JHA		1764	-556	638	787	6-6
V+W	JHA		3012	32	1039	670	6-6
PPC	IBD		356	12	146	90	6-21
FD	RLM	PELIN	216	-80	47	69	5-6
FD	18D		488	8	171	122	6-3
FD	JMS		292	-52	63	76	6-5
VDO	JMS		15128	-1816	3609	5697	6-6
PPS	JMS		492	-100	286	154	6-6
PPC	JMS		936	-968	18	411	6-6
FD	JHA		1348	-88	1605	111	6-6
V+W	JHA		4144	28	2622	1167	6-6
PPC	IBD		360	-32	100	90	6-21

CROSSTRACK ERROR SUMMARY
SID/STAR–COR32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	TD32R	0	-728	-298	259	5-6
FD	IBD		48	-380	-212	155	6-3
FD	JMS		X	X	X	X	6-5
VDO	JMS		724	-200	209	305	6-6
PPS	JMS		-540	-1048	-935	157	6-6
PPC	JMS		0	-1836	-796	748	6-6
FD	JHA		X	X	X	X	6-6
V+W	JHA		X	X	X	X	6-6
PPC	IBD		0	-440	-143	155	6-21

ALTITUDE ERROR SUMMARY
SID/STAR–COR32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	CORFU	-4	-232	-127	80	5-6
FD	IBD		68	32	54	9.0	6-3
FD	JMS		152	80	109	16	6-5
VDO	JMS		176	-104	-18	61	6-6
PPS	JMS		92	-112	-44	52	6-6
PPC	JMS		X	X	X	X	6-6
FD	JHA		24	-64	-14	23	6-6
V+W	JHA		20	-52	-6.4	20	6-6
PPC	IBD		172	104	131	18	6-21
FD	RLM	OTHEO	-84	-184	-137	24	5-6
FD	IBD		48	-20	23	22	6-3
FD	JMS		124	76	98	13	6-5
VDO	JMS		152	-36	41	54	6-6
PPS	JMS		216	92	170	35	6-6
PPC	JMS		X	X	X	X	6-6
FD	JHA		-24	-120	-97	23	6-6
V+W	JHA		240	20	89	72	6-6
PPC	IBD		136	48	93	23	6-21
FD	RLM	PROPE	764	-188	61	273	5-6
FD	IBD		936	16	177	255	6-3
FD	JMS		940	56	212	234	6-5
VDO	JMS		808	-20	134	237	6-6
PPS	JMS		808	184	339	201	6-6
PPC	JMS		772	48	186	193	6-6
FD	JHS		808	-32	144	249	6-6
V+W	JHA		716	-64	141	196	6-6
PPC	IBD		828	48	201	218	6-21
FD	RLM	PELIN	760	-152	36	198	5-6
FD	IBD		936	-92	238	248	6-3
FD	JMS		936	-112	213	248	6-5
VDO	JMS		316	16	130	56	6-6
PPS	JMS		808	-104	59	189	6-6
PPC	JMS		828	-116	204	278	6-6
FD	JHA		684	-128	741	34	6-6
V+W	JHA		712	-80	86	188	6-6
PPC	IBD		828	-340	103	206	6-21

ALTITUDE ERROR SUMMARY
SID/STAR–COR32R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	TD32R	64	-128	-27	57	5-6
FD	IBD		240	-156	15	108	6-3
FD	JMS		X	X	X	X	6-5
VDO	JMS		80	-80	-1.3	37	6-6
PPS	JMS		X	X	X	X	6-6
PPC	JMS		0	-528	-216	211	6-6
FD	JHA		X	X	X	X	6-6
V+W	JHA		X	X	X	X	6-6
PPC	IBD		8	-96	-25	25	6-21

TIME ERROR SUMMARY
SID/STAR–COR32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	RLM	CORFU	-9	-12	-11	1	5-6
FD	IBD		1	0	0.41	0.49	6-3
FD	JMS		-5	-13	-8.6	2.6	6-5
VDO	JMS		1	-22	-11	6.2	6-6
PPS	JMS		-6	-23	-14	5.2	6-6
FD	JHA		0	0	0	0	6-6
V+W	JHA		0	-4	-1	1.2	6-6
PPC	IBD		1	0	0.01	0.08	6-21
FD	RLM	OTHEO	0	-9	-4.1	2.4	5-6
FD	IBD		1	0	0.61	0.49	6-3
FD	JMS		0	-5	-2	1.5	6-5
VDO	JMS		2	-3	-1.3	1.5	6-6
PPS	JMS		5	-6	-0.77	3.2	6 6
FD	JHA		2	0	0.47	0.66	6 6
V+W	JHA		B	0	4	2.1	6-6
PPC	IBD		1	0	0.20	0.40	6-21
FD	RLM	PROPE	0	0	0	0	5-6
FD	IBD		1	0	0.B	0.40	6-3
FD	JMS		3	0	1.1	0.68	6-5
VDO	JMS		14	2	9.7	4.1	6-6
PPS	JMS		15	8	13	2.1	6-6
FD	JHA		11	2	7.2	3.3	6-6
V+W	JHA		1B	8	13	3.1	6-6
PPC	IBD		1	0	1	0.05	6-21
FD	RLM	PELIN	40	0	1.5	1.5	5-6
FD	IBD		2	-1	0.19	0.94	6-3
FD	JMS		6	-2	2.3	2.7	6-5
VDO	JMS		-2	-17	-12	4.3	6-6
PPS	JMS		14	0	2.9	4	6-6
FD	JHA		11	0	2.8	2.8	6-6
V+W	JHA		19	-5	11	7.1	6-6
PPC	IBD		2	-2	0.73	0.4B	6-21
FD	RLM	TD32R	2	-6	-2.7	2.6	5-6
FD	IBD		0	-7	-3.7	2.6	6-3
FD	JMS		X	X	X	X	6-5
VDO	JMS		5	-3	-0.54	2.1	6-6
PPS	JMS		4	-1	1.3	1.6	6-6
FD	JHA		X	X	X	X	6-6
V+W	JHA		X	X	X	X	6-6
PPC	IBD		16	X	X	X	6-21

CROSSTRACK ERROR SUMMARY
SID/STAR–TIG13R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	JMS	TIGER	X	X	X	X	6-5
Auto			-8	-132	-81	33	6-6
Auto			88	-832	-71	85	6-7
Auto			88	-332	-129	93	6-7
Auto			16	-548	-165	138	6-8
PPC	JMS		X	X	X	X	6-13
Auto			-280	-940	-640	189	6-14
VDO	JMS		X	X	X	X	6-15
Auto			X	X	X	X	6-16
V+W	JHA		-52	-312	-202	70	6-18
Auto			39,880	-13,836	7,477	16,400	6-19
Auto			-24	-452	-178	138	6-19
FD	JMS	VASHN	288	-152	102	92	6-5
Auto			-16	-280	-175	73	6-6
Auto			68	-18,072	-94	725	6-7
Auto			48	-340	-72	97	6-7
Auto			36	-340	-81	97	6-8
PPC	JMS		564	0	319	178	6-13
Auto			0	-292	-94	51	6-14
VDO	JMS		956	248	591	263	6-15
Auto			0	-372	-116	73	6-16
V+W	JHA		428	-700	11	297	6-18
Auto			56	-496	-97	129	6-19
Auto			28	-380	-90	97	6-19
FD	JMS	MAGNA	X	X	X	X	6-5
Auto			176	-948	-179	351	6-6
Auto			41,736	-388	-72	1,319	6-7
Auto			508	-192	23	93	6-7
Auto			288	-212	3.2	78	6-8
PPC	JMS		8	-140	-62	34	6-13
Auto			356	-268	-80	106	6-14
VDO	JMS		-956	-956	-956	3.2	6-15
Auto			108	-200	-66	68	6-16
V+W	JHA		8,972	-788	1,705	2,622	6-18
Auto			60	-152	-49	51	6-19
Auto			128	20	76	26	6-19

CROSSTRACK ERROR SUMMARY
SID/STAR–TIG13R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	JMS	BASIN	136	36	101	20	6-5
Auto			X	X	X	X	6-6
Auto			68	-416	-58	127	6-7
Auto			X	X	X	X	6-7
Auto			108	8	67	21	6-8
PPC	JMS		0	-60	-24	15	6-13
Auto			X	X	X	X	6-14
VDO	JMS		X	X	X	X	6-15
Auto			196	0	99	56	6-16
V+W	JHA		608	-1,216	-440	497	6-18
Auto			176	-196	-82	120	6-19
Auto			80	-416	-224	136	6-19
FD	JMS	TD13R	X	X	X	X	6-5
Auto			X	X	X	X	6-6
Auto			0	-484	-414	105	6-7
Auto			X	X	X	X	6-7
Auto			36	-340	-129	150	6-8
PPC	JMS		676	-8	383	216	6-13
Auto			16	-844	211	318	6-14
VDO	JMS		-956	-956	-956	3.6	6-15
Auto			116	6	48	44	6-16
V+W	JHA		X	X	X	X	6-18
Auto			X	X	X	X	6-19
Auto			0	-404	-301	139	6-19

ALTITUDE ERROR SUMMARY
SID/STAR–TIG13R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	JMS	TIGER	X	X	X	X	6-5
Auto			8	-56	-2.1	6.8	6-6
Auto			100	-32	0.23	13	6-7
Auto			100	-44	-0.67	14	6-7
Auto			120	-28	3.4	15	6-8
PPC	JMS		X	X	X	X	6-13
Auto			96	-24	-0.97	10	6-14
VDO	JMS		X	X	X	X	6-15
Auto			X	X	X	X	6-16
V+W	JHA		28	-56	-37	18	6-18
Auto			3,404	0	1,413	1,251	6-19
Auto			84	-376	-166	151	6-19
FD	JMS	VASHN	112	-12	55	31	6-5
Auto			12	-1,128	-294	385	6-6
Auto			8	-32	2.6	3.7	6-7
Auto			8	-32	3	3.5	6-7
Auto			8	-24	2.1	3.4	6-8
PPC	JMS		56	-20	11	19	6-13
Auto			24	-24	1.5	5.7	6-14
VDO	JMS		-20	-76	-52	15	6-15
Auto			8	-28	0.60	1.8	6-16
V+W	JHA		60	-64	9.4	23	6-18
Auto			X	X	X	X	6-19
Auto			84	-8	2.1	8.5	6-19
FD	JMS	MAGNA	36	-64	-13	28	6-5
Auto			32	-16	6.1	8.3	6-6
Auto			11,376	-24	47	669	6-7
Auto			20	-24	1.9	5.9	6-7
Auto			20	-24	1.8	5.6	6-8
PPC	JMS		184	-64	74	57	6-13
Auto			20	-24	-1.5	5.1	6-14
VDO	JMS		-16	-56	-35	14	6-15
Auto			16	-4,372	-1.4	80	6-16
V+W	JHA		36	-464	-108	115	6-18
Auto			X	X	X	X	6-19
Auto			48	-72	-15	30	6-19

ALTITUDE ERROR SUMMARY
SID/STAR–TIG13R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	JMS	BASIN	-32	-64	-48	8.1	6-5
Auto			X	X	X	X	6-6
Auto			20	-1,052	-25	125	6-7
Auto			X	X	X	X	6-7
Auto			12	-36	0.72	11	6-8
PPC	JMS		52	-28	3.1	20	6-13
Auto			X	X	X	X	6-14
VDO	JMS		X	X	X	X	6-15
Auto			36	-16	18	11	6-16
V+W	JHA		32	-2,716	-121	141	6-18
Auto			X	X	X	X	6-19
Auto			72	-12	31	21	6-19
FD	JMS	TD13R	X	X	X	X	6-5
Auto			X	X	X	X	6-6
Auto			36	-1,052	-181	361	6-7
Auto			X	X	X	X	6-7
Auto			44	-40	6.9	18	6-8
PPC	JMS		44	-56	3.2	27	6-13
Auto			4	-76	-20	24	6-14
VDO	JMS		4	-32	-14	10	6-15
Auto			0	-64	-13	14	6-16
V+W	JHA		X	X	X	X	6-18
Auto			X	X	X	X	6-19
Auto			8	-52	-13	13	6-19

TIME ERROR SUMMARY
SID/STAR–TIG13R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	JMS	TIGER	X	X	X	X	6-5
Auto			-47	-64	-56	5.1	6-6
Auto			3	0	0.69	0.80	6-7
Auto			1	0	0.12	0.33	6-7
Auto			0	-7	-1.3	2	6-8
PPC	JMS		X	X	X	X	6-13
Auto			1	0	0.42	0.49	6-14
VDO	JMS		X	X	X	X	6-15
Auto			X	X	X	X	6-16
V+W	JHA		0	-1	-0.10	0.30	6-18
Auto			1	-49	-28	19	6-19
Auto			8	0	2.8	2.6	6-19
FD	JMS	VASHN	1	0	0.23	0.42	6-5
Auto			-6	-46	-31	12	6-6
Auto			2	0	0.01	0.04	6-7
Auto			1	0	0.01	0.03	6-7
Auto			1	0	0.09	0.29	6-8
PPC	JMS		4	0	1.8	0.95	6-13
Auto			2	0	0.13	0.34	6-14
VDO	JMS		4	-2	0.03	1.8	6-15
Auto			2	0	0.07	0.25	6-16
V+W	JHA		2	0	0.12	0.32	6-18
Auto			0.49	-49	-49	0	6-19
Auto			22	0	12	6.1	6-19
FD	JMS	MAGNA	2	-2	0.08	0.72	6-5
Auto			25	-6	17	7.7	6-6
Auto			1	-2	-0.26	0.65	6-7
Auto			1	-2	-0.16	0.59	6-7
Auto			4	-2	0.82	1.5	6-8
PPS	JMS		1	-5	-1.6	2	6-13
Auto			1	-1	0.19	0.56	6-14
VDO	JMS		1	-1	0.15	0.44	6-15
Auto			3	-1	0.46	0.98	6-16
V+W	JHA		24	-1	9.2	8.5	6-18
Auto			-49	-49	-49	0	6-19
Auto			0	-2	-0.29	0.49	6-19

TIME ERROR SUMMARY
SID/STAR–TIG13R
(Concluded)

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
FD	JMS	BASIN	3	1	1.2	0.44	6-5
Auto			X	X	X	X	6-6
Auto			2	-3	0.07	1.8	6-7
Auto			X	X	X	X	6-7
Auto			2	0	1.3	0.46	6-8
PPC	JMS		1	-3	-1.6	1.2	6-13
Auto			X	X	X	X	6-14
VDO	JMS		X	X	X	X	6-15
Auto			96	0	5.2	4	6-16
V+W	JHA		3	-6	-1.3	2.5	6-18
Auto			-49	-49	-49	0	6-19
Auto			1	-4	-2.9	1.5	6-19
FD	JMS	TD13R	X	X	X	X	6-5
Auto			X	X	X	X	6-6
Auto			0	-7	-4.8	2.3	6-7
Auto			X	X	X	X	6-7
Auto			0	0	0	0	6-8
PPC	JMS		6	-5	-2.2	2.4	6-13
Auto			5	2	2.4	0.70	6-14
VDO	JMS		3	-2	-0.57	1.5	6-15
Auto			11	0	4.5	3.9	6-16
V+W	JHA		X	X	X	X	6-18
Auto			X	X	X	X	6-19
Auto			5	-12	-8	4.3	6-19

CROSSTRACK ERROR SUMMARY
SID/STAR–EDM16

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		EDMOS	-1,168	-1,656	-1,441	133	5-6
VDO	RLM		3,944	488	2,913	1,091	6-2
PPS	RLM		-480	-8,388	-1,879	1,752	6-2
Auto			-32	-37,584	-499	2,701	6-7
Auto			-152	-760	-364	177	6-7
Auto			8	-340	-105	107	6-8
Auto			-248	-340	-296	-19	6-16
Auto			0	-248	-126	67	6-19
Auto			-268	-508	-351	74	6-19
Auto			-52	-108	-83	11	6-20
FD	IBD		-364	-424	-394	13	6-21
Auto		TABLE	-420	-1,784	-1,381	433	5-6
VDO	RLM		3,416	616	1,625	819	6-2
PPS	RLM		1,812	464	1,272	371	6-2
Auto			-100	-15,904	-578	839	6-7
Auto			28	-620	-325	264	6-7
Auto			128	-360	-139	200	6-8
Auto			-172	-420	-325	60	6-16
Auto			48	-348	-133	145	6-19
Auto			-120	-600	-375	139	6-19
Auto			388	-60	202	161	6-20
FD	IBD		-40	-432	-259	132	6-21
Auto		HATID	408	-2,672	-26	608	5-6
VDO	RLM		2,092	-3,996	-980	1,880	6-2
PPS	RLM		-1,376	-4,737	-2,487	1,022	6-2
Auto			416	-340	98	118	6-7
Auto			196	-72	78	70	6-7
Auto			288	8	174	68	6-8
Auto			100	-540	-211	212	6-16
Auto			7,100	-700	1,779	2,439	6-19
Auto			116	-20	56	38	6-19
Auto			348	-60	140	87	6-20
FD	IBD		216	-392	0.77	102	6-21
Auto		TDZ16	-2,600	-2,720	-2,691	26	5-6
VDO	RLM		2,168	0	1,452	622	6-2
PPS	RLM		-1,736	-4,356	-3,726	861	6-2
Auto			0	-64,352	516	1,679	6-7
Auto			108	-700	-357	273	6-7
Auto			56	-928	-398	373	6-8
Auto			0	-1,288	-808	396	6-16
Auto			X	X	X	X	6-19
Auto			208	0	105	54	6-19
Auto			88	0	49	23	6-20
FD	IBD		8	-860	-339	351	6-21

ALTITUDE ERROR SUMMARY
SID/STAR–EDM16

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		EDMOS	0	-4	-2.8	1.8	5-6
VDO	RLM		252	40	166	53	6-2
PPS	RLM		20	-104	-49	32	6-2
Auto			X	-4	3,081	54,765	6-7
Auto			4	-340	-93	164	6-7
Auto			76	-8	0.58	9.7	6-8
Auto			-4	-4	-4	0	6-16
Auto			4	0	0.01	0.22	6-19
Auto			8	-4	0.08	2.5	6-19
Auto			-176	-288	-212	29	6-20
Auto		TDZ16	156	-432	-39	88	5-6
VDO	RLM		132	-104	6.1	69	6-2
PPS	RLM		60	-120	3	38	6-2
Auto			0	-1,052	-152	231	6-7
Auto			0	-284	-120	104	6-7
Auto			0	-168	-41	45	6-8
Auto			X	X	X	X	6-16
Auto			X	X	X	X	6-19
Auto			96	-236	-87	113	6-19
Auto			76	-36	5.1	31	6-20
Auto		TABLE	8	-52	-1.9	8.6	5-6
VDO	RLM		344	72	159	69	6-2
PPS	RLM		116	-28	82	31	6-2
Auto			4	-8	-1.9	2.5	6-7
Auto			32	-8	1.9	68	6-7
Auto			0	-20	-2.5	3.8	6-8
Auto			8	-4	-0.74	2.9	6-16
Auto			4	-4	-0.20	2.3	6-19
Auto			4	-8	-1.2	2.1	6-19
Auto			92	-100	36	55	6-20
Auto		HATID	136	-68	11	32	5-6
VDO	RLM		160	-132	43	61	6-2
PPS	RLM		36	-324	-148	121	6-2
Auto			44	-184	-12	39	6-7
Auto			16	-112	2	11	6-7
Auto			20	-88	1.3	11	6-8
Auto			-60	-336	-257	75	6-16
Auto			720	-16	222	274	6-19
Auto			32	0	15	8.5	6-19
Auto			72	-104	6.4	45	6-20

TIME ERROR SUMMARY
SID/STAR–EDM16

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		EDMOS	1	0	0.25	0.44	5-6
VDO	RLM		-33	-45	-40	3.5	6-2
PPS	RLM		45	27	34	4.9	6-2
Auto			X	X	X	X	6-7
Auto			-6	-17	-13	3.7	6-7
Auto			11	0	4.1	3.4	6-8
Auto			0	0	0	0	6-16
Auto			0	0	0	0	6-19
Auto			0	0	0	0	6-19
Auto			8	4	7.6	0.59	6-20
Auto		TABLE	0	-1	-0.23	0.42	5-6
VDO	RLM		-28	-33	-30	1.3	6-2
PPS	RLM		25	16	21	2.5	6-2
Auto			-26	-32	-29	1.5	6-7
Auto			0	-6	-1.7	1.7	6-7
Auto			0	0	0	0	6-8
Auto			0	0	0	0	6-16
Auto			0	0	0	0	6-19
Auto			0	0	0	0	6-19
Auto			4	1	1.8	1	6-20
Auto		HATID	15	0	1.5	2.8	5-6
VDO	RLM		4	-28	-13	11	6-2
PPS	RLM		8	-24	-12	8.9	6-2
Auto			7	-26	-7	9.1	6-7
Auto			1	-1	-0.01	0.13	6-7
Auto			1	-1	0.05	0.3	6-8
Auto			0	-7	-3.8	2.1	6-16
Auto			0	-41	-12	15	6-19
Auto			1	0	0.58	0.49	6-19
Auto			3	0	1.5	1	6-20
Auto		TDZ16	35	15	31	6	5-6
VDO	RLM		1	-4	-2.3	1.6	6-2
PPS	RLM		24	8	19	4.1	6-2
Auto			8	-12	-1.7	5.1	6-7
Auto			1	-1	0.09	0.41	6-7
Auto			1	-4	-2.1	1.9	6-8
Auto			X	X	X	X	6-16
Auto			X	X	X	X	6-19
Auto			3	-14	6.4	4.5	6-19
Auto			1	-31	-19	15	6-20

CROSSTRACK ERROR SUMMARY
SID/STAR–EPH32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		EPH	120	-32	42	45	6-3
Auto			216	-80	17	11	6-5
Auto			296	0	137	59	6-6
PPS	JMS		-4,316	-5,392	-4,854	318	6-13
Auto			X	X	X	X	6-17
Auto		DUSTY	148	-80	38	48	6-3
Auto			148	-152	12	43	6-5
Auto			316	8	141	71	6-6
PPS	JMS		-20	-6,964	-3,298	2,206	6-13
Auto			X	X	X	X	6-17
Auto		PELIN	228	-280	57	106	6-3
Auto			25,712	-132	-31	65	6-5
Auto			120	-876	-12	146	6-6
PPS	JMS		548	-260	126	212	6-13
Auto			X	X	X	X	6-17
Auto		TD32R	-260	-788	-547	145	6-3
Auto			604	-980	-19	473	6-5
Auto			0	-1,756	-1,190	531	6-6
PPS	JMS		X	X	X	X	6-13
Auto			X	X	X	X	6-17

ALTITUDE ERROR SUMMARY
SID/STAR–EPH32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		EPH	4	-20	-5.8	6.6	6-3
Auto			64	-20	4	15	6-5
Auto			X	-40	12	484	6-6
PPS	JMS		-25	-26	-26	0.48	6-13
Auto			X	X	X	X	6-17
Auto		DUSTY	8	-20	0.07	4	6-3
Auto			4	-16	1.2	5.8	6-5
Auto			8	-12	1.1	3.2	6-6
PPS	JMS		-2	-25	-12	5.6	6-13
Auto			X	X	X	X	6-17
Auto		PELIN	20	-176	-8.4	35	6-3
Auto			20	-24	0.27	3.3	6-5
Auto			40	-24	2.3	8.7	6-6
PPS	JMS		15	-5	5.6	6.8	6-13
Auto			X	X	X	X	6-17
Auto		TD32R	112	-168	17	52	6-3
Auto			16	-112	1.3	7.1	6-5
Auto			36	-1052	-22	68	6-6
PPS	JMS		X	X	X	X	6-13
Auto			X	X	X	X	6-17

TIME ERROR SUMMARY
SID/STAR—EPH32R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
Auto		EPH	24	22	23	0.59	6-3
Auto			1	-3	-1.1	1.3	6-5
Auto			15	1	9	4.8	6-6
PPS	JMS		-25	-26	-26	0.48	6-13
Auto			X	X	X	X	6-17
Auto		DUSTY	21	1	11	5.9	6-3
Auto			1	0	0.13	0.34	6-5
Auto			1	0	0.01	0.09	6-6
PPS	JMS		-2	-25	-12	5.6	6-13
Auto			X	X	X	X	6-17
Auto		PELIN	3	0	0.40	0.62	6-3
Auto			3	0	0.01	0.18	6-5
Auto			13	0	1.9	3	6-6
PPS	JMS		15	5	5.6	6.8	6-13
Auto			X	X	X	X	6-17
Auto		TD32R	8	3	4.5	1.1	6-3
Auto			10	0	0.12	0.47	6-5
Auto			17	0	14	5.7	6-6
PPS	JMS		X	X	X	X	6-13
Auto			X	X	X	X	6-17

CROSSTRACK ERROR SUMMARY
SID/STAR–KIT13R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
PPS Auto	RLM	POSSN	X X	X X	X X	X X	6-2 6-9
PPS Auto	RLM	TD13R	3,824 984	552 0	2,505 384	1,249 397	6-2 6-9
PPS Auto	RLM	KITSP	1,284 108	-1,916 16	749 55	909 70	6-2 6-9
PPS Auto	RLM	MAGNA	576 55,624	552 -47,800	569 1,422	6.4 8,454	6-2 6-9

ALTITUDE ERROR SUMMARY
SID/STAR–KIT13R

GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
PPS Auto	RLM	POSSN	X X	X X	X X	X X	6-2 6-9
PPS Auto	RLM	TD13R	312 92	-64 -1052	16 37	154 53	6-2 6-9
PPS Auto	RLM	KITSP	284 148	-604 0	-251 27	245 43	6-2 6-9
PPS Auto	RLM	MAGNA	-48 148	-80 -8	-56 8.3	4.6 18	6-2 6-9

TIME ERROR SUMMARY
SID/STAR–KIT13R

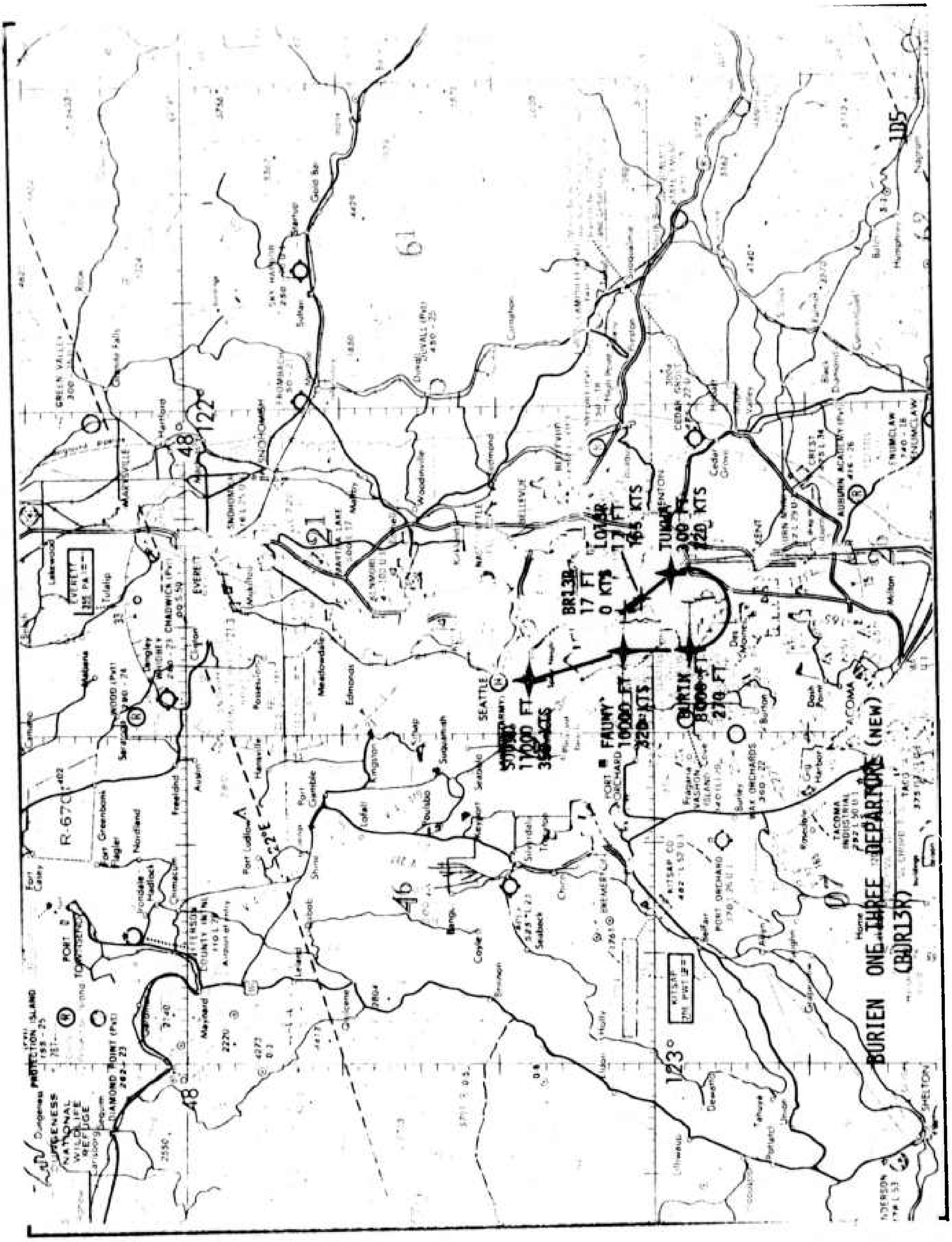
GUID option	Pilot	Waypoint	Maximum	Minimum	Average	1σ	Test flight No.
PPS Auto	RLM	POSSN	X X	X X	X X	X X	6-2 6-9
PPS Auto	RLM	TD13R	24 120	-7 0	16 28.0	9.5 21	6-2 6-9
PPS Auto	RLM	KITSP	-37 1	-50 0	-43 0.73	2.9 0.44	6-2 6-9
PPS Auto	RLM	MAGNA	-7 30	-13 0	-95 9	1.7 8.9	6-2 6-9

APPENDIX C

ADEDS PATH CATALOG ADDITIONS

The path catalog of reference 4 was used in the preparation of flight plans for the ADEDS test flights. This catalog was supplemented by the additional five paths as defined on the following pages of this appendix. These paths provided additional operational flexibility to permit test operations under a wider variety of weather and traffic conditions. These paths are categorized below.

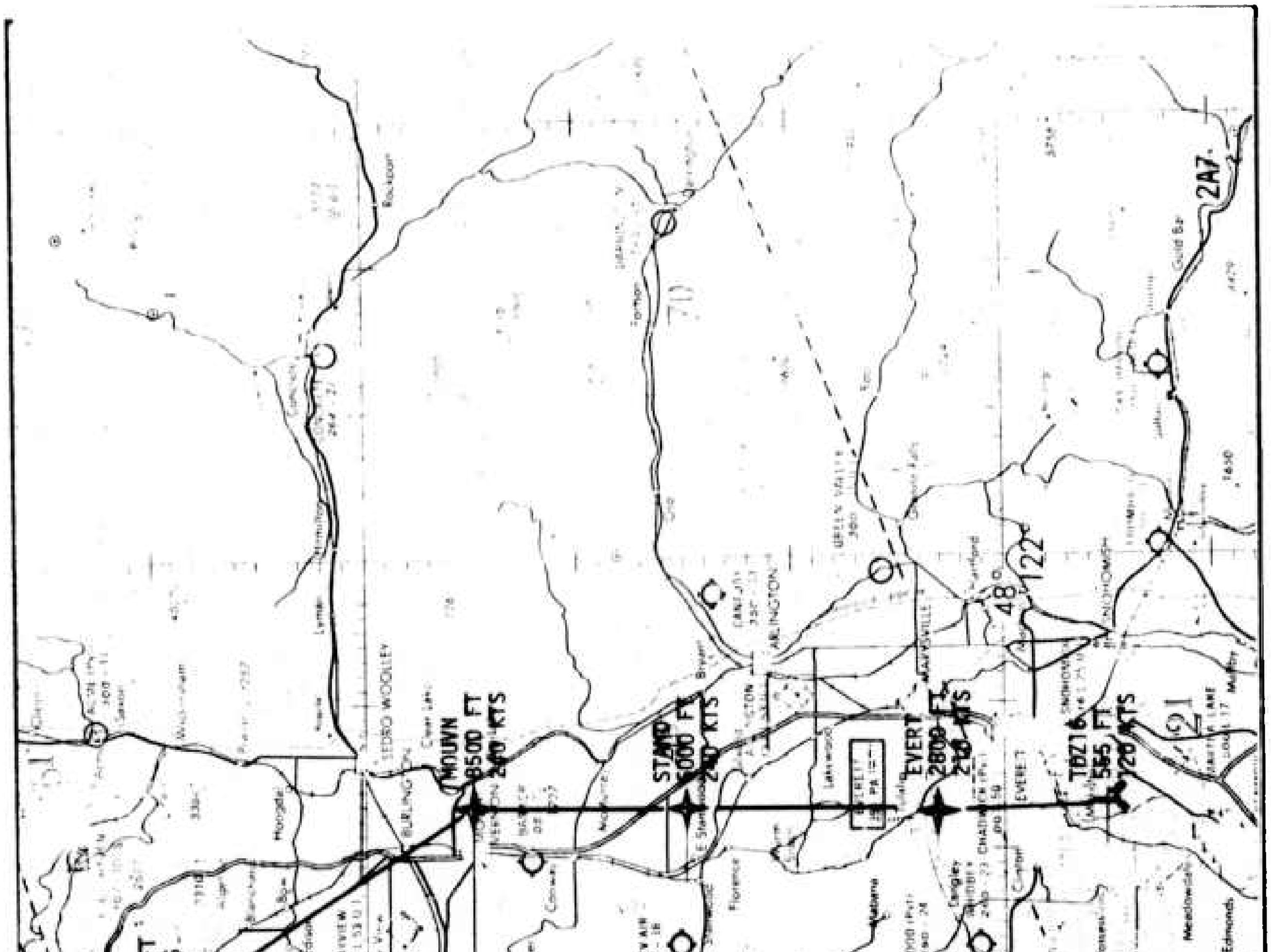
Airport	Path name	Path code	Type
KBFI	Burien one three departure	BUR13R	Departure turn
KPAE	Edison one six arrival	EDI16	Straight decelerating
KPAE	Glendale one six departure	GLE16	Close-in turn
KMWH	Connell three two arrival	CON32R	Straight decelerating
KMWH	Douglas three two departure	DOU32R	Noise abatement


BURIEN ONE THREE DEPARTURE (NEW)
(BUR13R)
SEATTLE
TACOMA
EVERETT
BELLEVUE
RENTON
KENT
SHELTON
PORT TOWNSEND
R-6701

PATH DATA SUMMARY

KBFI SID BUR13R | Total length 24.2 nmi | Elapsed time 6 min 1 sec

Waypoint	Altitude (ft)	Velocity (kt)	Segment length (nmi)	Path slope (deg)	Vertical rate (ft/min)
BR13R	17	0			
			1.00	0.0	0
CO13R	17	165			
			3.15	8.9	2,617
TUKWA	3,000	220			
			9.16	5.1	2,440
BURIN	8,000	270			
			4.50	4.2	2,380
FAUNY	10,000	320			
			6.40	1.5	928
SOUND	11,000	350			

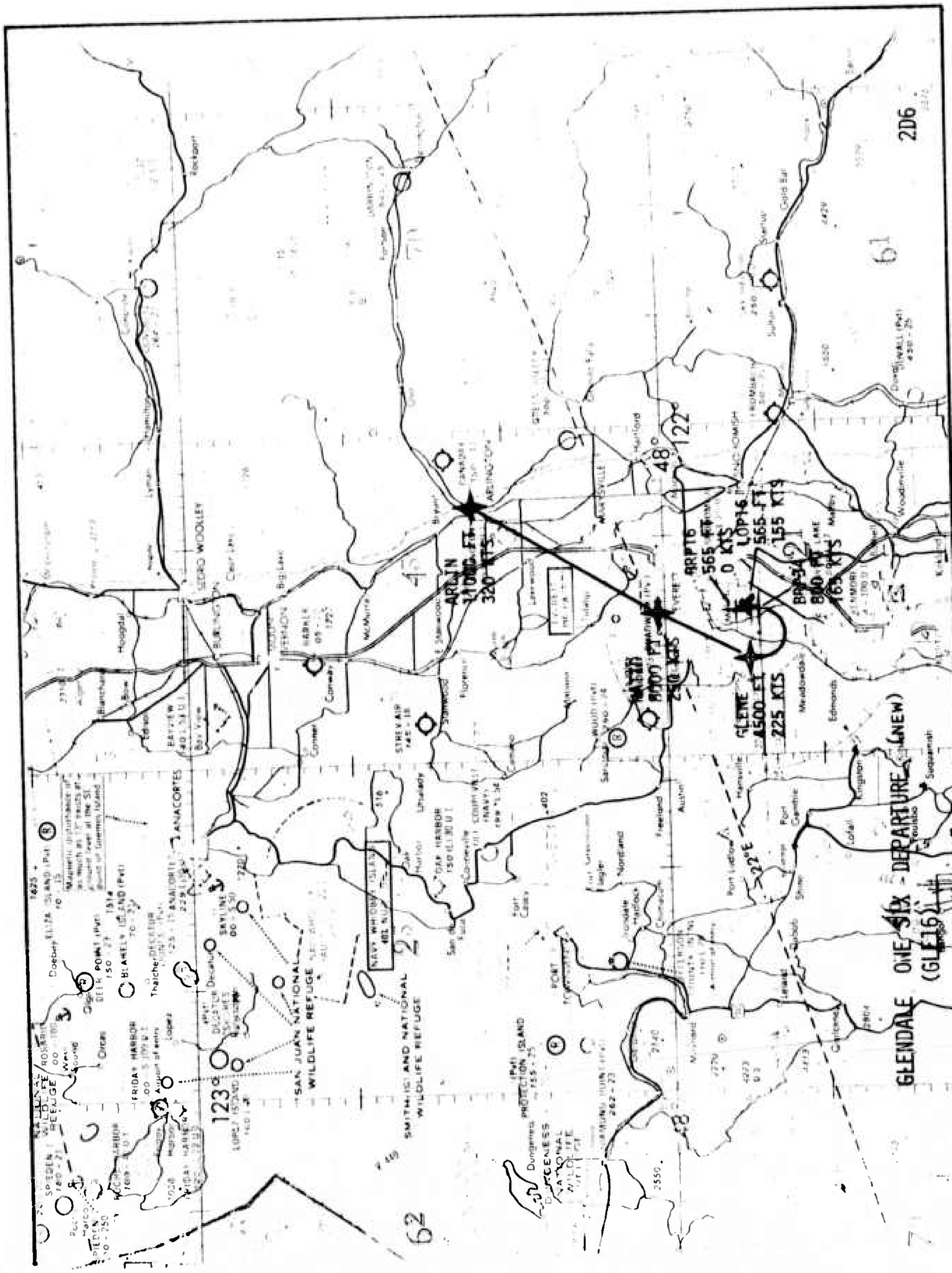


EDISON ONE SIX ARRIVAL (NEW)
(EDI16)
EDISN
11000 FT
280 KTS
MOUWN
8500 FT
240 KTS
STAMP
5000 FT
240 KTS
EVERT
2800 FT
210 KTS
SAN JUAN NATIONAL WILDLIFE REFUGE
SMITH ISLAND NATIONAL WILDLIFE REFUGE
MATIA ISLAND NATIONAL WILDLIFE REFUGE
JONES ISLAND NATIONAL WILDLIFE REFUGE
ANACORTES
SEDRO WOOLLEY
BURLINGTON
FRIDAY HARBOR
EVERETT
SNOHOMISH
MARYSVILLE
ARLINGTON
2A7

PATH DATA SUMMARY

KPAE	STAR	ED!16	Total length	44.4 nmi	Elapsed time	11 min 52 sec

Waypoint	Altitude (ft)	Velocity (kt)	Segment length (nmi)	Path slope (deg)	Vertical rate (ft/min)
EDISN	11,000	280			
			14.8	-1.6	792
MOUVN	8,500	240			
			10.1	-2.3	976
STAND	6,000	240			
			11.85	-2.5	1,061
EVERT	2,800	210			
			7.62	-2.8	1,040
TDZ16	565	120			

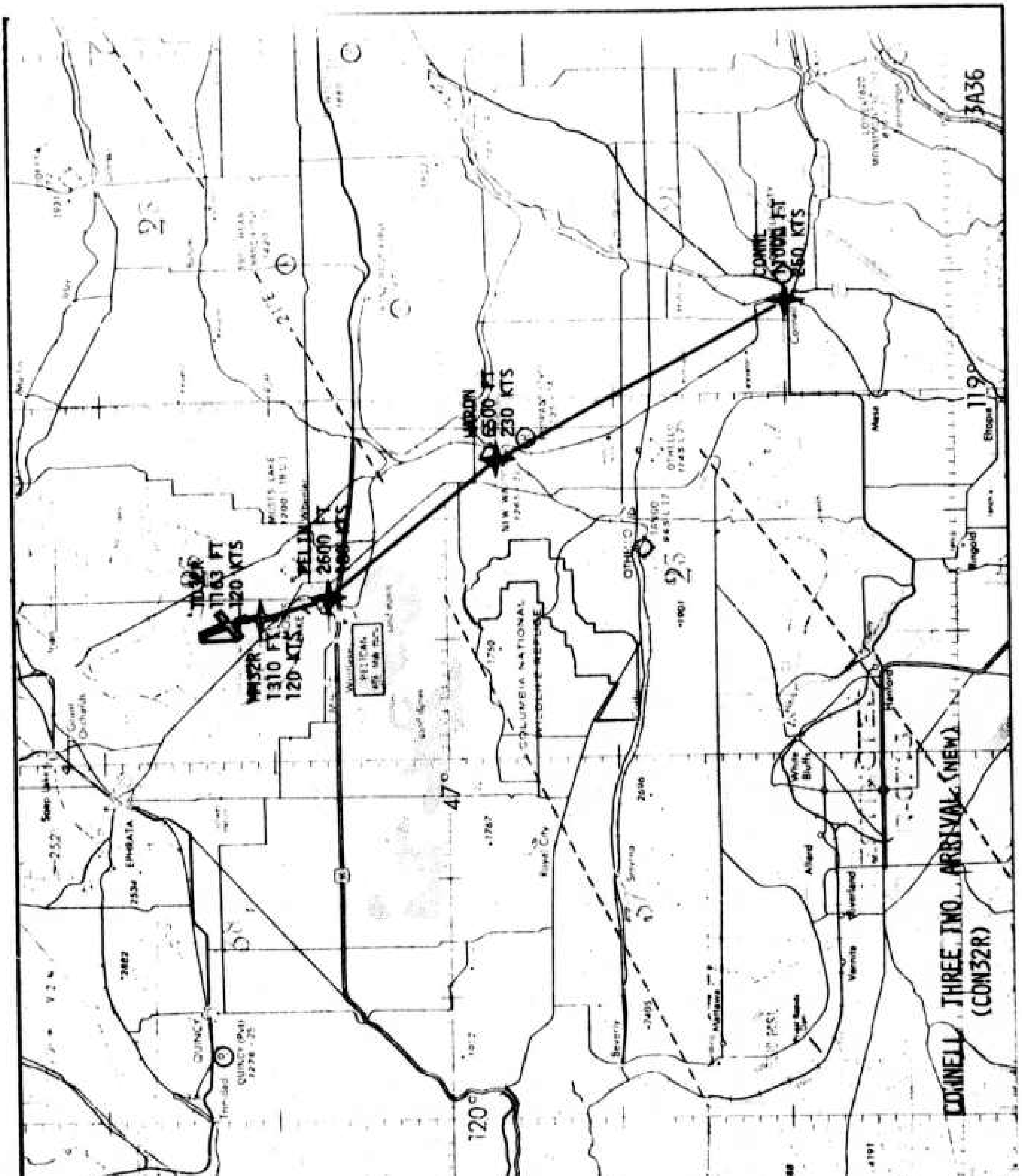

GLENDALE ONE SIX DEPARTURE (NEW)
(GLE16)
ARLIN
320 KTS
GLENE
4500 FT
225 KTS
LOP16
565 FT
155 KTS
2D6
SAN JUAN NATIONAL
WILDLIFE REFUGE
SMITH ISLAND AND NATIONAL
WILDLIFE REFUGE
ANACORTES
SEDRO WOOLLEY
123°
122°
48°
22°E

PATH DATA SUMMARY

KPAE	SID	GLE16	Total length	26.5 nmi	Elapsed time	7.02 min

Waypoint	Altitude (ft)	Velocity (kt)
BRP16	565	0
COP16	565	155
BRP34	800	165
GLENR	4,500	225
HATID	8,000	250
ARLIN	11,000	320

Segment length (nmi)	Path slope (deg)	Vertical rate (ft/min)
1.00	0.0	0
0.48	4.6	1,344
5.44	6.4	2,555
6.30	5.2	2,304
13.30	2.1	1,188

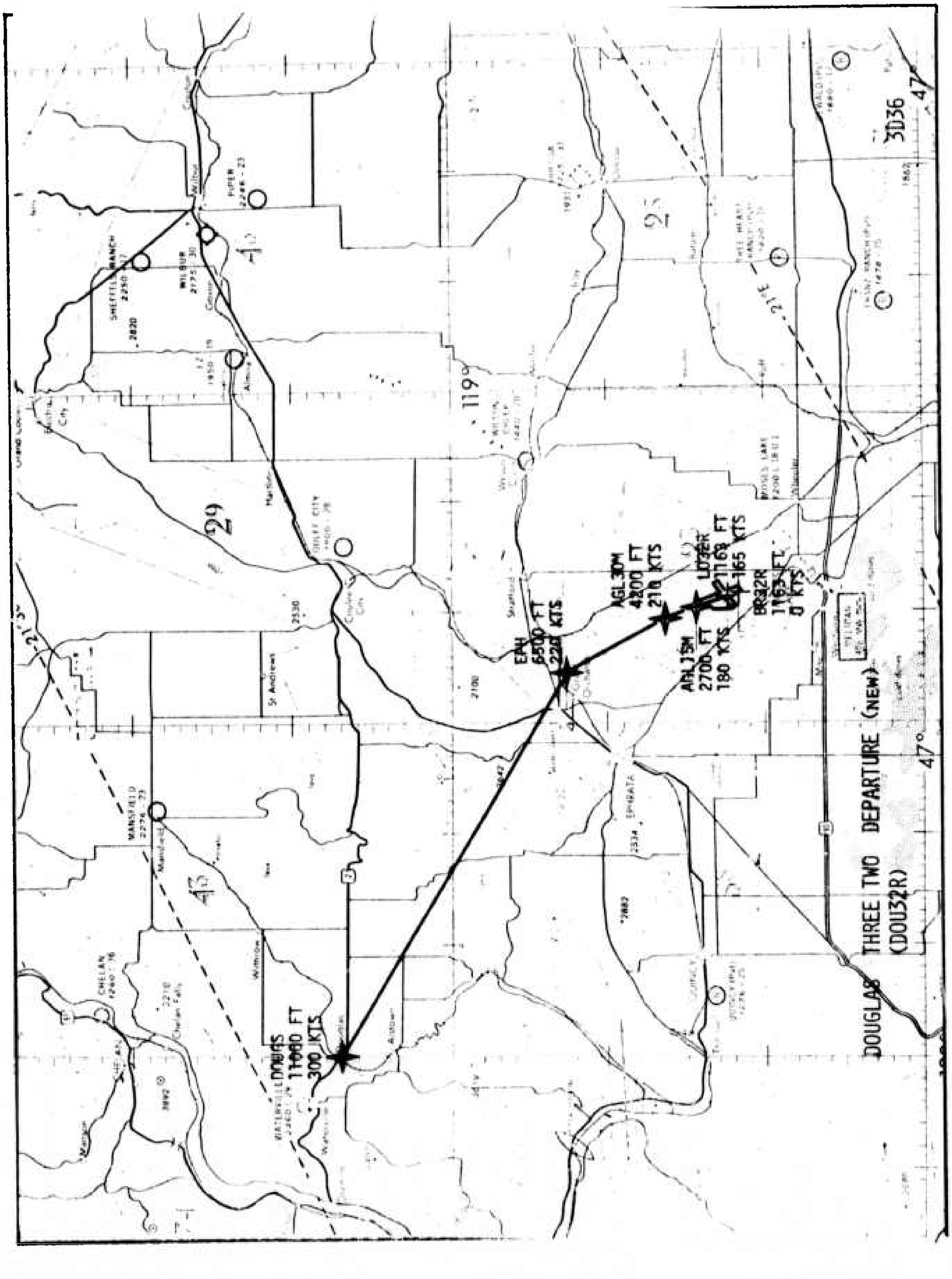


CONNELL THREE TWO ARRIVAL (NEW)
(CON32R)
CONNL
260 KTS
WARDN
2600 FT
230 KTS
PELIN
2600 FT
TD32R
1163 FT
120 KTS
WA32R
1310 FT
120 KTS
COLUMBIA NATIONAL
WILDLIFE REFUGE
EPHRATA
QUINCY
Royal City
OTHELLO
Hanford
White Bluffs
Eltopia
Mesa
Ringold
Allard
Vernita
Riverland
Beverly
Schawana
Boylston
Soap Lake
Coulee City
47°
120°
119°
3A36

PATH DATA SUMMARY

KMWH STAR CON32R | Total length 36.6 nmi | Elapsed time 10 min 30 sec

Waypoint	Altitude (ft)	Velocity (kt)	Segment length (nmi)	Path slope (deg)	Vertical rate (ft/min)
CONNL	11,000	250			
			19.1	-2.2	973
WARDN	6,500	230			
			12.5	-2.9	1,180
PELIN	2,600	180			
			4.23	-2.9	923
MM32R	1,310	120			
			0.74	-1.9	403
TD32R	1,163	120			


DOUGLAS THREE TWO DEPARTURE (NEW)
(DOU32R)
DOUGS
11000 FT
300 KTS
EPH
6500 FT
220 KTS
AGL30M
4200 FT
210 KTS
AGL15M
2700 FT
180 KTS
LU32R
165 KTS
BR32R
1163 FT
0 KTS
119°
47°
3D36

PATH DATA SUMMARY

KMWH SID DOU32R — Total length: 40.00 nmi — Elapsed time: 10 min 27 sec

Waypoint	Altitude (ft)	Velocity (kt)	Segment length (nmi)	Path slope (deg)	Vertical rate (ft/min)
BR32R	1,163	0			
			1.00	0.0	0
CO32R	1,163	165			
			1.80	8.0	2,348
AGL15	2,700	180			
			2.35	6.0	2,235
AGL30	4,200	210			
			7.00	3.1	1,207
EPH	6,500	220			
			27.8	1.5	796
DOUGS	11,000	300			

APPENDIX D

NAVIGATION AND DISPLAY SYSTEM FAILURES/INCIDENTS SUMMARY

This appendix provides a summary of all failures and incidents encountered during the ADEDS flight test of the navigation and display equipment. The items are presented chronologically and, where appropriate, corrective action taken is identified.

NAVIGATION SYSTEM FAILURES/INCIDENTS DURING FLIGHT TEST

NAV No.	Date	Symptoms	Diagnosis/remarks	Corrective action	Date corrected	Litton failure report
69	12/15/73	Keyboard lockup on NCDU 002. Corrected by turning TAM switch to Test and back out of Test.	Suspect NCU power interrupt problem. See NAV 88.	None.	–	–
70	12/15/73	INS SN 406 flashing warn.	Servo card problem after cable disconnect.	Servo card replaced.	1/4/74	19364
71	12/15/73	INS SN 094 flashing warn in align mode; two occurrences. Then INS steady warn in NAV; several subsequent occurrences.	Servo card problem after cable disconnect.	Servo card replaced.	1/4/74	19363
72	12/18/73	INS not accepting runway HDG input.	Software error.	Reprogram.	1/4/74	–
73	12/19/73	INS velocity and acceleration output incorrect.	Software error.	Reprogram.	1/4/74	–
74	12/19/73	INS SN 039 excessive NAV errors and Schuler oscillations.	Gimbal problems and quantizer 1/256 ft/sec noise problem. (See NAV 87.)	Litton unable to isolate. System replaced by SN 748.	1/22/74	–
75	1/4/74	Unable to locate when tape control in OFF position. Loads and locates in 50,000. Must go to fill to locate.	Suspect MCU bad connection.	–	–	–
76	1/8/74	High Schuler velocities in INS No. 1 SN 094 after flight. (Ref. NAV 81).	Apparent gyro mechanical problem. Y-gyro changing bias.	Same as NAV 81.	–	–
77	1/8/74	No across-track acceleration from No. 1 or No. 2 INS during flight.	Software error.	Insert patch from SN 094, SN 406.	1/9/74	–
78	1/8/74	Flashing star and circle symbology on EADI during flight.	Problem could not be isolated although NCU I/O suspected. Similar problem later isolated in display PCU.	None.	–	–
79	1/11/74	NCDU 003 hung up after "H" key is pressed. Goes away after "H" key is pressed repeatedly again.	Defective "H" key.	Replaced key.	1/21/74	–
80	1/11/74	NCDU 003 hung up after power interrupt.	Caused by NCU power interrupt problem. See NAV 88.	–	–	–
81	1/11/74	INS No. 1 SN 094 has Schuler velocity of 16K (Ref. NAV 76).	Sent back to Litton for repair.	Repaired gimbal and Y gyro. Problem recurred. See NAV 93.	1/15/74	18325
82	1/14/74	NCDU 003 hung up. Cycled power and got snowflake problem.	Possibly high frequency (12 MHz) on 4 MHz oscillator.	Added 22 pf capacity to oscillator output on A7 card. See NAV 67.	1/14/74	–

NAVIGATION SYSTEM FAILURES/INCIDENTS DURING FLIGHT TEST (Concluded)

NAV No.	Date	Symptoms	Diagnosis/remarks	Corrective action	Date corrected	Litton failure report
83	1/16/74	NCU locked up when brought up with MCU. Brought up without MCU and unit worked OK. Brought up with MCU again and NCU worked normally.	Possible bad connection to MCU.	–	–	–
84	1/17/74	INS SN 094 has vertical acceleration offset of 0.14 ft/sec^2. Also has high granularity of VGSDOT.	Offset is normal VGSDOT problem due to INS software.	Software modified.	1/22/74	–
85	1/18/74	INS SN 094 and SN 406 have high Schuler velocities after flight.	Diagnosed as due to the noise in acceleration outputs modified for 1/256 ft/sec.	Reduced quantizer sensitivity from 1/256 to 1/64 ft/sec (INS SN 406, 094, 748).	1/21/74	18374
86	1/22/74	Power interrupt problems. The power interrupt sequence works during the slow loop but not during the fast loop.	1. Inhibit mask (LOC 23) does not inhibit. Design error. 2. Out instruction 37000-704 erroneously inhibits interrupts like a 37000-706 instruction.	Corrected by software change to bypass the hardware design errors.	1/29/74	–
87	1/29/74	NCU fail after 10 sec when Comp. No. 8 SN 3001 installed.	Comp. No. 8 SN 3001.	–	–	–
88	2/1/74	Both MFD SPBP buses transmit incorrectly.	SPBP TX SN 6002. (BMI) replaced.	–	–	–
89	2/4/74	INS True Heading output rate is incorrect. Update rate is 500 to 900 msec when it should be less than 250 msec.	INS software error.	Software corrected. New tape loaded.	2/19/74	–
90	2/8/74	High GS error (up to 50 kt) on INS No. 2 SN 748. Occurs in flight after turns. Many subsequent occurrences.	When system is aligned forming N or S, velocity error occurs in the E-W.	–	–	–
91	2/11/74	NAVAID No. 1 Autotune via NCU does not work consistently; 2 x 5 outputs from location 65 appear on output lines only intermittently.	Radio navigation interface card SN 3019 bad. (BJ1 is card position).	Card replaced.	–	–
92	2/13/74	MCU will not reset or locate.	Bad contact.	All cards and plugs resealed.	2/13/74	–
93	2/13/74	INS SN 094 Schuler groundspeed errors of up to 18 kt in flight.	Persistent problem. Recurrence of NAV 81.	–	–	–
94	3/14/74	INS SN 766. Warn in NAV and ATT shutdown in flight.	–	–	–	–
95	3/15/74	INS SN 094 warn in NAV and ATT in flight.	–	–	–	–

DISPLAY SYSTEM FAILURES/INCIDENTS DURING FLIGHT TEST

No.	Date	Symptoms	Diagnosis/remarks	Corrective action	Date corrected
132	12/13/73	The MFD HVPS failed.	–	The spare HV supply was substituted.	12/13/73
133	12/13/73	The A/P symbol on the EADI was jumping up and down along the total vertical dimension of the tube.	One of the HSG +5 V PS had a 1-V ripple during this period. PS need replacing.	–	–
134	12/16/73	The T-NAV light on the MFD MCP does not light up white.	–	IC No. 3D (MCA2-55) was replaced in the EADI MCP.	12/20/73
135	12/17/73	With the MFD Valid signal to the NCU toggling, the display goes down.	Unresolved.	–	–
136	12/18/73	DH does not go to 990.	Ref. 140.	–	2/1/74
137	1/3/74	Could not draw a conic unless the first and last memory location of the circle library was zero.	Pulled PCU Bd A-14 and reinstalled it and problem went away.	–	–
138	1/4/74	HSG PS Bit flag was being set when powering on camera.	Verified ±15 Vdc was approximately 2 to 3 V.	–	–
139	1/7/74	Address readout changed on SCU while sampling a specific address.	Unresolved.	–	–
140	1/9/74	DH and pitch reference do not reach their lower and upper limits.	Ref. 136 regulated internal power supplies in the EADI. MCP was not regulating.	Resistors were changed to ensure full biasing of zeners.	2/1/74
141	1/10/74	Had an illegal device code of 00FF.	Unresolved.	–	–
142	1/14/74	Have flashing rectangle about 1/2 in. above horizontal line.	Occurs randomly, but often.	–	–
143	1/16/74	The EADI and MFD fail lights are on when PCU power is off.	They are being lighted through EADI MCP.	A diode was added to the 28 V/amp return in the EADI MCP.	–
144	1/17/74	Jumping of pitch map on both pots and INS pitch inputs.	Verified the ±15 V power supplies were being overloaded.	Installed a larger capacity power supply.	4/5/74
145	1/18/74	SCU paper tape reader take up reel did not function correctly.	The take up reel motor was replaced, the drive electronics was substituted and finally the complete tub assembly was substituted, which solved problem.	Installed a new clutch on the ADEDS tub.	4/15/74

DISPLAY SYSTEM FAILURES/INCIDENTS DURING FLIGHT TEST (Concluded)

No.	Date	Symptoms	Diagnosis/remarks	Corrective action	Date corrected
146	1/18/74	Tags jump vertically for 10 min after applying power to system.	–	Replaced IC 8F on HSG Bd 123D5748 (SN54181J)	4/5/74
147	1/21/74	Had a problem which looked like interrupt prevent was not working properly.	Removing PCU Bd A-17 and reinserting it, the problem went away. Verified test for interrupt prevent was not programmed in the SGMA ROMs.	Reprogrammed SGMA	–
148	1/23/74	The invalid cross was blinking on the EADI along with some table data.	SGMA ROM chips are being reprogrammed.	–	–
149	1/25/74	The 8K core memory would not run in the tester during a cold start.	–	New sense and inhibit boards were installed and memory timing was changed.	1/29/74
150	2/9/74	In adjusting +5 V (1) power supplies in the PCU PS, the adjustment screw did not function mechanically.	Replaced PS. Determined the PS was being overloaded.	Add another +5 V PS.	4/8/74
151	2/9/74	Powering the NCU up and down sometimes caused a PCU memory parity.	–	Installation of new memory sense and inhibit boards.	3/4/74
152	2/12/74	MFD display did not come up.	The HSG Bd No. A-48 had been inserted incorrectly.	Reseated the Bd and it worked OK.	2/12/74
153	2/15/74	Pressing of the PC button and then hitting clear lights up ADDRESS button.	Unresolved.	–	–
154	2/26/74	The pitch map was jumping or stepping in roll.	–	Found a broken wire on the sin/cos LOOPUP Table board and also in the PCU chassis wiring going to that board.	3/3/74
155	2/27/74	Had an intermittent problem of symbols closing.	Unresolved.	–	–
156	3/11/74	On certain map scales the first character in a tag was missing.	Unresolved.	–	–