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TEST AND EVALUATION OF THE AIRCRAFT TRACKING AND DATA SYSTEM (ATADS)

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TEST PLAN

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Prepared for

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1. OBJECTIVES.

The objective of this test is to evaluate the Aircraft Tracking and Data System (ATADS) developed under a Systems Research and Development Service (SRDS) contract. The effort will undertake the following tasks:

a. Validation of the accuracy of the position reference system using the Technical Center's instrumentation range.

b. Verification of the reliability of the airborne package.

c. Determination of the technical and functional capabilities and limitations of the ground and airborne equipment.

d. Establishment of calibration techniques to minimize bias errors of system delay.

e. Determination of the best methods for deployment and survey of portable ground stations.

f. Familiarization and indoctrination of operation for project personnel.

The testing at the Technical Center will determine acceptance of the system for compliance with the specified performance requirements as listed in the work statement (appendix A). Upon completion of the evaluation, the ATADS will provide an airborne test bed initially for long range air navigation system (Loran)-C flight testing in the field and, eventually, for any navigation system evaluation.

2. BACKGROUND.

A multitask effort is presently in progress by various agencies to evaluate existing and future radio navigation systems to provide inputs to the Federal Radio Navigation Plan (FRP). The FRP and subsequent revisions will present policies and plans for federally (military and civil) operated navigation systems. The plan also establishes a methodology for the Department of Transportation (DOT) and the Department of Defense (DOD) to address various issues and to arrive at an initial optimum mix determination in the mid-80's. The Loran-C is being evaluated by the Federal Aviation Administration (FAA) to determine its role in the future navigation system mix.

A multiyear contract was awarded by SRDS in October 1978 to the Amex Systems, Inc. to develop an airborne data acquisition and position reference system providing a test bed to evaluate the Loran-C system performance. Phase 1 of the contract produced the Remote Area Precision Positioning System (RAPPS) designed under subcontract by the Sierra Nevada Corporation (SNC). The RAPPS 1 delivered to the Technical Center in August 1979 was used for field testing of Loran-C in Vermont during the winter of 1979.

ATADS being developed by SNC is a more accurate, improved performance, second generation, airborne position reference and data collection system. The ATADS is planned to provide the required capability for evaluation of the Loran-C system, global positioning system (GPS), and other navigation systems' performance.

3. RELATED DOCUMENTATION/PROJECTS.

a. "Test and Evaluation of Remote Area Precision Positioning System, RAPPS, Phase 1," FAA-CT-80-52, March 1981.

b. "LORAN-C in Mountainous Areas, Phase I: Vermont Tests," FAA-CT-81-22, June 1981.

c. "Data Reduction and Analysis Techniques Used in Determining the Accuracy of RAPPS 1," Technical Center Letter Report No. NA-80-32-LR, February 1980.

d. "LORAN-C Nonprecision Approaches on the West Coast by Champlain Technology Industries (CTI) During the Summer of 1979," FAA-RD-80-28, March 1980.

4. SYSTEM/EQUIPMENT DESCRIPTION.

The ATADS is an airborne data collection and multidistance measuring equipment (DME) position reference system utilizing commercial Loran-C navigation sets and a commercial L-band DME for the signal-in-space sensors. Supplied with the system are specially designed portable DME stations for supplemental use in areas without adequate signal coverage. The total system block diagram comprising the ground and airborne subsystems is shown in figure 1.

4.1 AIRBORNE SUBSYSTEM.

The airborne package contains a SESCO 8080 as the central processing unit (CPU) for the data collector and appropriate interfaces in a ruggedized case. The data collector receives data from the real-time clock, altimeter, TDL-424 and TDL-711 Loran sets, LTN-51 Inertial Navigation System (INS), and the cycler tracker. The CPU time tags each data source and formats and outputs the data to a 4-track cartridge tape recorder for storage. A Computer Devices, Inc. (CDI) terminal communicates to the SESCO 8080 via RS-232 to provide an in-flight readout of selected parameters.

The cycler/tracker, consisting of a modified King 706 DME interrogator and an 8080 microprocessor, acquires multirange data at rates up to 10 per second. The raw range data are input to the data collector via an RS-232 port. An additional RS-232 port is provided for future use. The airborne rack requires 28 volts direct current (Vdc) power except for the CDI terminal and tape recorder, which requires 120 volts (V), 60 hertz (Hz). A backup battery provides for system operation for 5 minutes after power interruption. All the components of the airborne system are mounted in an aluminum AMCO 19-inch rack.

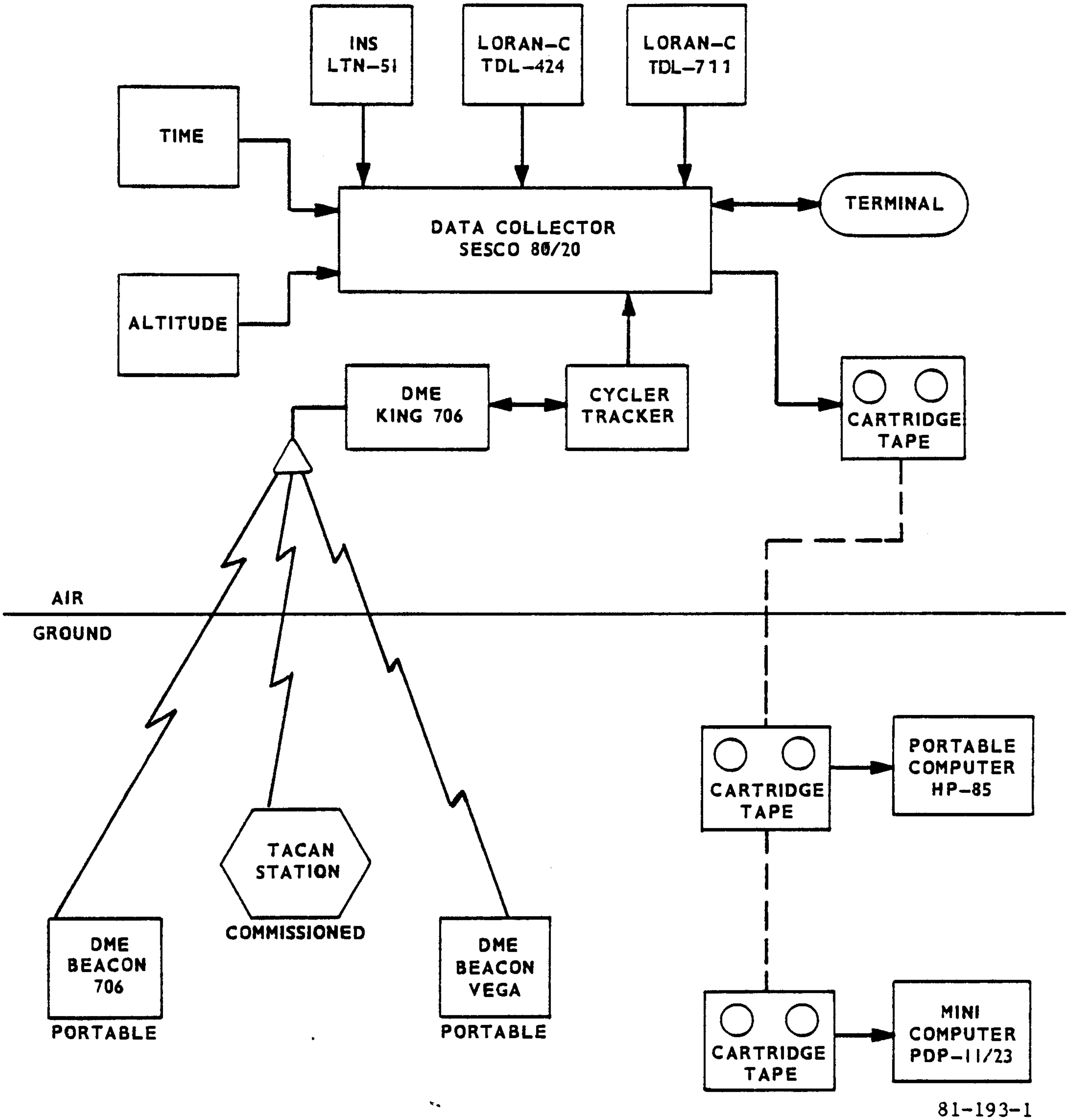

FIGURE 1. BLOCK DIAGRAM OF ATADS

4.2 GROUND SUBSYSTEM.

Supplied with the system are 11 portable DME transponders for use as supplement ground stations. Five units are Vega model 316L transponders. These are small, lightweight beacons with fast rise time pulse modulation. The remaining six are King 706 airborne units modified for use as portable DME beacons capable of normal International Civil Aviation Organization (ICAO) and fast rise pulse modulations. All the supplemental ground DME stations are capable of at least 250 watts output. Antennas supplied with the portable DME stations are omnidirectional with a gain of at least 4 decibels above isotropic (dBi).

Data reduction and analysis capability is provided in two parts by groundbased computers:

a. Field data analysis will be accomplished by a Hewlett-Packard (HP)-85 portable computer for quick-look capability of the raw flight data. The HP-85 and a cartridge tape recorder will be handcarried by the project team for immediate post-flight data analysis.

b. A PDP-11/23 minicomputer will be installed at the Center as the processor for home facility post-flight data reduction and analysis. The cartridge tape data collected on the flight tests will be converted to 9-track tape for processing on the PDP-11 peripheral magnetic tape recorder.

5. TESTING AND DATA COLLECTION.

The evaluation and acceptance testing of the ATADS at the FAA Technical Center will include laboratory, ground, and airborne tests to determine system compliance with the contract performance specifications. The criteria for the tests will address the following items in the Work Statement:

a. Validation of the specified accuracy of the position reference system using the Technical Center's instrumentation range (item 2).

b. Determination of the technical and functional capabilities of airborne equipment (items 1, 3, 4, 5, and 11).

c. Determination of the technical and functional capabilities of ground equipment (items 6, 7, and 8).

d. Execution of data reduction and analysis software on HP-85 computer to evaluate post-flight, quick-look capability (item 12).

5.1 LABORATORY AND GROUND TESTS.

Laboratory and ground tests of the total system will provide:

a. Familiarization and indoctrination of equipment operation for project personnel.

b. Checkout and verification of all system components.

c. Calibration of system delay.

d. Familiarization and indoctrination for portable DME station deployment and operation.

The laboratory checkout and evaluation of the ATADS will include controlled signal characteristic tests of the airborne DME interrogator (cycler/tracker) and portable DME beacons (King and Vega). The bench tests will provide a baseline set of data to measure and evaluate system performance and specifications with known input parameters. The laboratory configuration for these tests is shown in figure 2. A Tektronix 4051 computer will be interfaced to an EPSCO 2018 digital DME test set, counter, and plotter. The interface will conform to IEEE-488 specification. The collected data will consist of greater than 100 samples; the recorded data will consist of:

a. Time between pulse pairs (forced range).
b. Signal strength.
c. Squitter rate.
d. Pulse rise time.
e. Indicated or received range.

Data will be grouped and presented as a histogram plot of frequency of occurrence as a function of received range with b, c, and d as parametric variables. Each beacon interrogator will yield three plots.

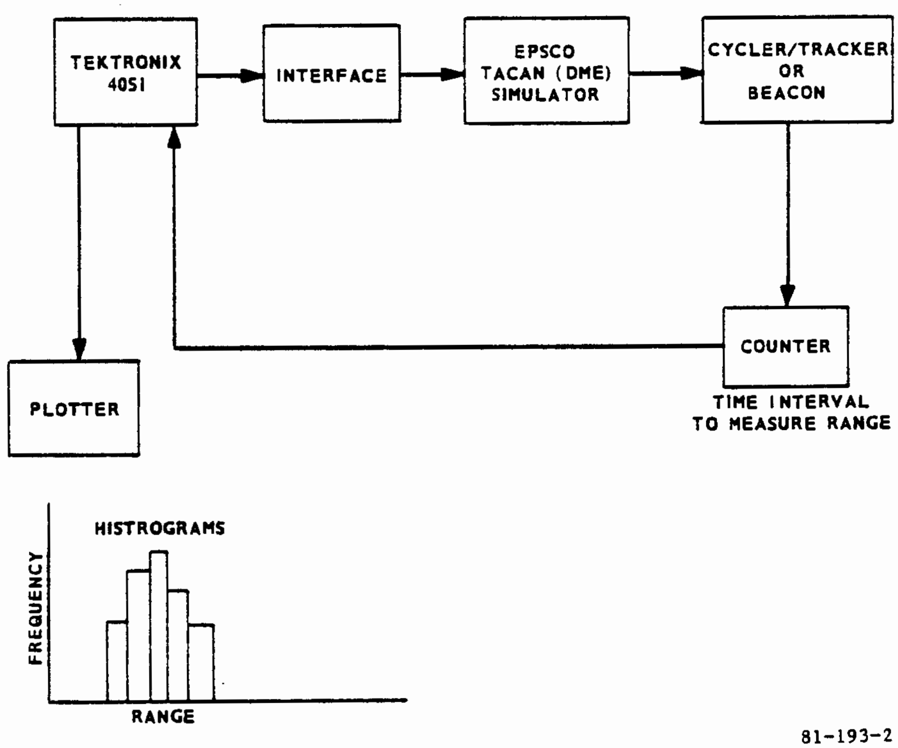

FIGURE 2. LABORATORY TEST CONFIGURATION

The tests should provide the mean and standard deviation of distance accuracy versus signal level input, high dynamic range rate, squitter rate, decoder tolerance, and leading edge pulse rise time.

Since the accuracy of the position solution is biased by system delay setting, the airborne and ground units will be bench tested to measure and confirm the exact system delay (50.0 microseconds (μs)) adjustment. The spectrum of the ground beacons in the fast time rise mode will be recorded to provide data for adjacent channel interference protection.

The portable HP-85 computer quick-look data capability can be exercised during the laboratory test phase.

The airborne package will be operated in the laboratory connected to suitable antennas for signal reception. The portable DME ground stations (at least four) will be deployed at surveyed locations on the Center's airfield. The ground and airborne equipment will be energized and monitored for an uninterrupted period of at least 36 hours to determine reliability and repeatability of operations. The recorded data will consist of raw range from each beacon placed on the airfield at known locations. The data will be analyzed and filtered according to the ATADS positioning algorithms as supplied by the contractor. Test results will be a measurement of system accuracy and repeatability under nondynamic conditions.

5.2 FLIGHT TESTS.

The specified two-mode accuracy of the ATADS will be validated by flight test data collected at the Technical Center with the Nike-Hercules radar and phototheodolite ranges used as the reference positioning systems.

Flight profiles are planned for: (1) en route flights for tests of the normal mode (ICAO ground stations) accuracy of 200 feet circular error probability (CEP), and (2) terminal/approach flights for tests of the precision mode (fast rise pulse portable DME stations) accuracy of 50 feet CEP.

In addition to the validation and operational evaluation of the ATADS performance at the Technical Center, the flight test will provide preliminary data on Loran-C performance and operation.

The recorded data will consist of:

a. Time.

b. Raw range from each DME/beacon.

c. Altitude.

d. Range from precision tracking radar at the FAA Technical Center.

e. Data from two Loran-C receivers as well as an INS as a check of ATADS data collection functional capacity.

The data will be analyzed post-flight to present ATADS position accuracy as a function of the tracking radar position. Each flight will yield a series of plots and analyzed group data showing ATADS position error both in along-track and crosstrack modes.

5.2.1 En Route Flight Tests.

The en route flight configuration will test the dynamic accuracy of the normal mode when six or more ICAO DME ground stations are received. The CV-580 aircraft will fly at constant medium altitude (8,000 to 12,000 feet above ground level (AGL)) to assure signal coverage from all available commissioned tactical air naviation aid (TACAN)/DME ground stations. The usable range of the system will be determined in this mode. The functional capability of the auto scanning feature of the cycler/tracker will be evaluated. Degradation of accuracy, if any, due to signal strength, station drop out, DME data rate, maneuvering, and geometric dilution of precision (GDOP) will be assessed.

Orbital flights around the Atlantic City (ACY) very high frequency omnidirectional radio range and tactical air navigation aid (VORTAC) at 10 to 15 nautical mile (nmi) radius will provide a flight pattern of ideal GDOP. The VORTAC/DME ground stations located in various directions around ACY include Millville (MIV), Coyle (CYN), Robbinsville (RBV), Sea Isle (SIE), and Woodstown (OOD). Figure 3 shows the location of the local VORTAC's. At least eight orbits of usable data (ground tracking and airborne data collection) are required for a proper statistical sample. Examination of data after initial flights will determine if adjustment in altitude is necessary for signal coverage.

Radial flights will be flown from ACY westerly to OOD, northerly to CYN, southerly to SIE, and return to ACY. This radial flight profile will test the multi-DME positioning system with less than ideal GDOP and provide data on system response during en route course changes. Four round robin flights will provide sufficient data for analysis of these parameters.

Reduction of the data of the first flight series will determine if any rerouting of the flight test pattern will be necessary for adequate signal coverage.

The Nike-Hercules radar will provide reference tracking for the orbits and radial flightpaths.

5.2.2 Terminal/Approach Flight Tests.

Data will be collected during the terminal phase of the flight tests that occur before transition to approach and landing. This phase of the flight tests will provide data to evaluate the total system under the maximum dynamic conditions such as aircraft banking, acceleration, and signal dropout due to terrain blockage and antenna shielding. System performance with the mix of the portable (precision) DME ground stations and VORTAC/DME ground stations (normal) will be assessed. Nonprecision approaches will be made to the main runway (13-31) at the Center to validate the accuracy of the position system when using the four portable DME ground stations (precision mode). Portable DME stations will be located for best GDOP possible. Figure 4 is a layout of the runways at the Atlantic City Airport showing candidate locations for the portable DME stations.

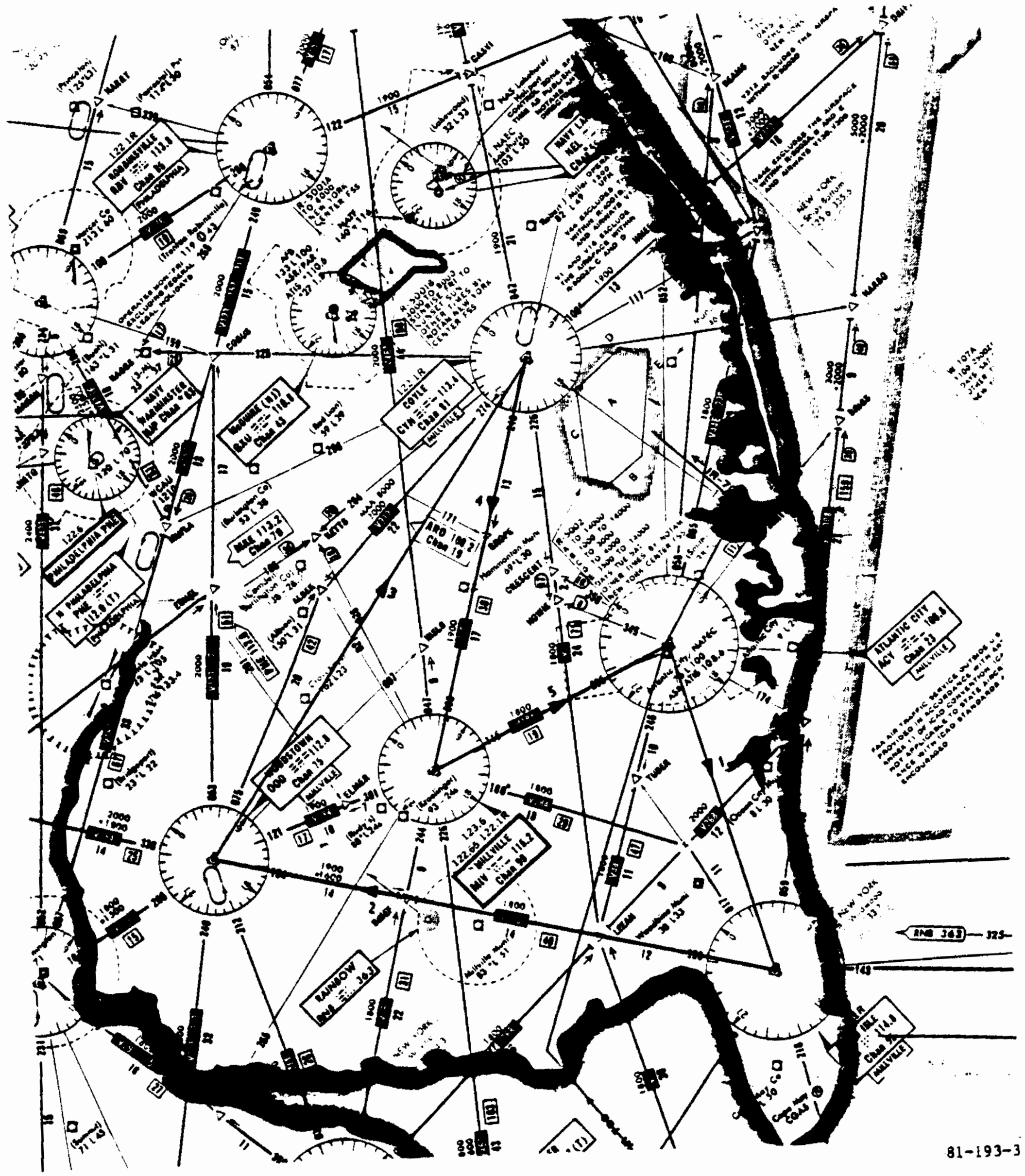

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FIGURE 3. LOCAL VORTAC STATION LOCATIONS

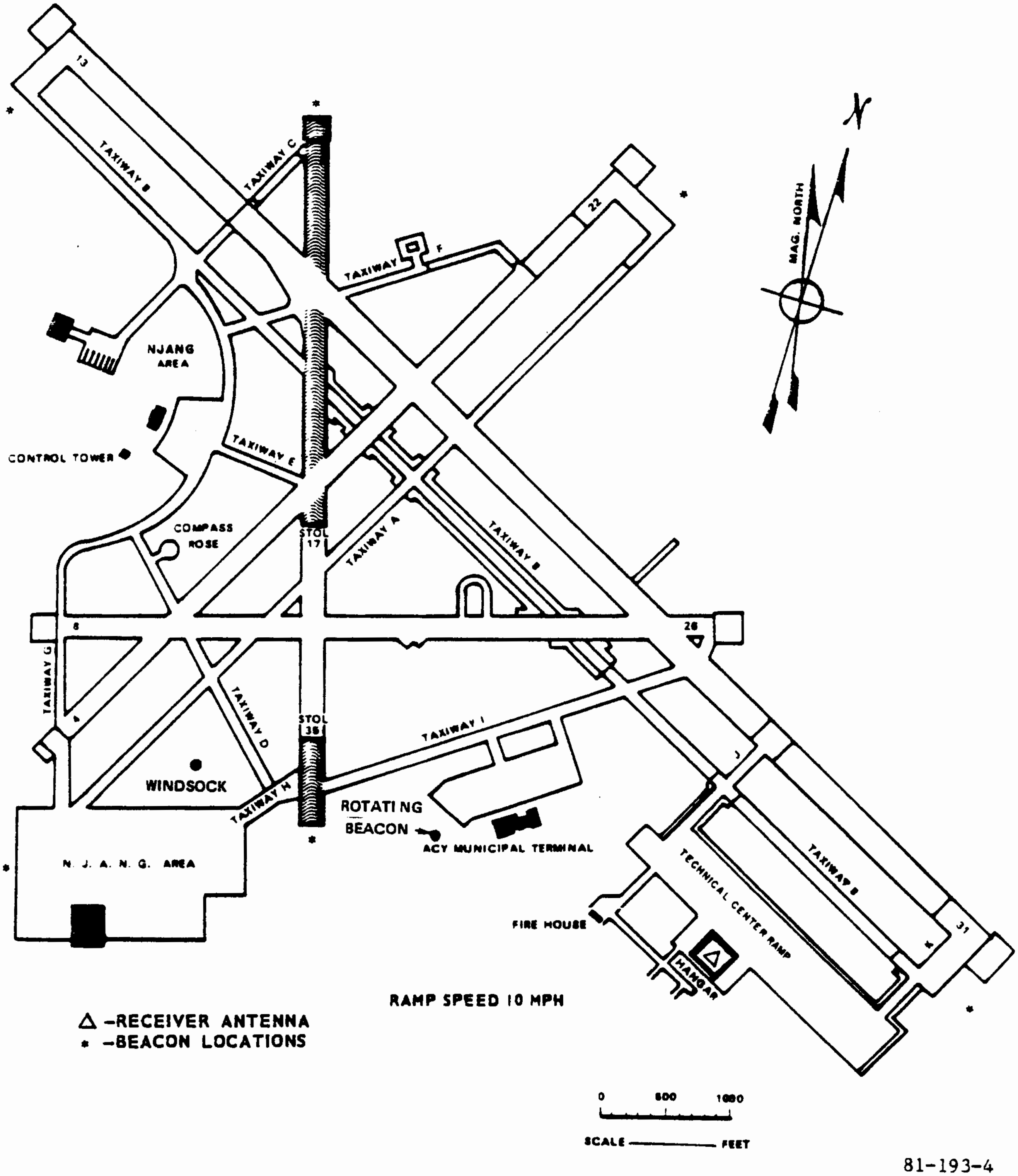


FIGURE 4. ATLANTIC CITY AIRPORT RUNWAY MAP

The approach will commence at least 10 nmi from touchdown at normal glidepath and speed for the CV-580. The usable range of the lower power portable stations, the scan of the preprogrammed precision stations, and the effect of station siting on the airfield will be evaluated by the approach flight profiles. Twenty good data runs are required for a sufficient statistical sample. The phototheodolite range will be used to track the aircraft for the approach flight testing.

The number of flight hours required to achieve confidence of the accuracy and repeatability of the system is estimated to be 10 hours en route, and 6 hours for the terminal and approach profiles.

The digital data from the clock, altitude encoder, INS, Loran TDL-424, Loran TDL-711, and the DME tracker will be stored on the system 4-track cartridge tape recorder. The data rate from all the sources is no faster than 1 per second, except for the DME range and identification data which are approximately 10 per second. Table 1 is a summary of the format and data rate of each source. The capacity of the Quantex model 5100 is 4.32 million bytes unformatted, which results in approximately 5 hours flight recording time for the dual drive system.

The cartridge tape collected flight data will be converted to 9-track International Business Machines (IBM) compatible format for merge with reference tracking.

TABLE 1. ATADS DATA SOURCES

Source	Data Type	Interface	Data Rate	Bytes
Terminal Input	Header Info	ASCII	300 baud	
Clock	Time of Day	Parallel	160 bits/sec	20
Altitude Encoder	Alt. in 100 feet	Grey Code	16 bits/sec	2
INS	14-32 Bit Words	ARINC 561	448 bits/sec	56
Loran-424	14-32 Bit Words	ARINC 571	448 bits/sec	56
Loran-711	157 Bytes	FAA	1256 bits/sec	157
DME Range	32 Bit Word	ARINC 568	320 bits/sec	40
A/D 2 Chan	Binary	Parallel	128 bits/sec	16
			2776 bits/sec	347 bytes/sec

Note: Quantex Model 5100
Capacity - 4.32 megabytes, unformatted
Flight time approximately 5 hours (dual drive)

6. DATA REDUCTION AND ANALYSIS.

The accuracy of the normal mode (en route) and the precision mode (approach) of the system will be determined by the position difference of the Nike (en route) and phototheodolites (approach) reference tracks and airborne digital data. A Datametrics digital clock will provide time synchronization with the ground ranges to facilitate merge of the data. The software required for data reduction should be similar to the algorithm used for RAPPS 1 to compute the position solution from multiple range measurements and merge with the reference trackers. Final analysis of the positional accuracy of ATADS will require software to compute the multi-DME position solution using Kalman filtering techniques.

Also planned, in the ATADS Statement of Work, is a ground-based data reduction subsystem consisting of minicomputer hardware and software to analyze the flight data output. The data reduction subsystem capability will not be available for the flight validation tests at the Center. Prior to scheduled delivery of the home facility computer and software, the data resulting from the described flight and ground tests will be analyzed using in-house resources resident in ACT-100. When the system is delivered by the contractor, it will be developed as the home facility computer for processing and analysis of the data.

The capability for quick-look data in the field immediately after flight tests is provided by an HP-85 portable computer. The lightweight computer and cartridge recorder can be set up easily and operated to produce plots and analysis of the flight data to determine the success or failure of the mission.

The prime result of the merge and analysis of the digital flight data is to yield a measure of the accuracy of the ATADS position system. The post-flight processing of the data will require the following software and hardware for the merge and analysis:

a. High-level and low-level language software executed on a minicomputer to unpack, format, and convert the Quantex cartridge tape to a 9-track tape. Format of the 9-track tape is planned to be IBM compatible.

b. FORTRAN program to merge ground station data (FAA data tape) and compute multi-DME position solution using Kalman filtering techniques. Dual 9-track tape units and the PDP-11/34 computer are required for program execution.

c. FORTRAN program to merge reference ground tracking data with airborne filtered position solution for validation of system accuracy specifications. The program can be run on the PDP-11 or Honeywell 66/60.

d. High-level language software to unpack and tabulate Loran-C parameters and to merge and analyze Loran-C track errors. The program to run on Honeywell 66/60 computer.

e. Program in basic language for the HP-85 portable computer for quick-look field data reduction.

The sequence of the data processing required that the cartridge tape be converted to 9-track tape, then the Kalman position solution, and, finally, the merge with the reference tracker. After conversion of the cartridge tape is accomplished, the individual programs can be executed separately or concurrently. A chart of the data processing is shown in figure 5.

The processing of the data for the test and evaluation phase of the ATADS at the Technical Center will require Programs a through e. The subsequent operational use of the ATADS on the home facility computer subsystem will require the use of Programs a, b, d, and e.

7. INSTRUMENTATION AND FACILITIES.

The Navigation Laboratory in the Technical Center's Flight Operations Building will be used for the checkout and static testing of the ATADS ground and airborne equipment. The home facility data reduction computer will also reside in the hanger.

The validation of the accuracy of the ATADS at the Center will require the Nike radar and the phototheodolite range.

Site selection and survey on the Technical Center are required for four DME supplemental ground stations. The JMR-4 Satellite Surveyor will be used to verify accuracy of portable DME ground stations.

The Honeywell 66/60 computer is required for the data merge and analysis.

8. COORDINATION AND AREAS OF RESPONSIBILITY.

The SNC has the responsibility to design, fabricate, interface, and deliver the necessary ground and airborne components to produce an integrated aircraft tracking and Loran-C data collection system. The completed system operation will be demonstrated and accepted by the FAA according to the Work Statement agreement. The SRDS contract representative will be responsible for the conduct of the contract, Government furnished equipment (GFE) supplied to the contractor, and the delivery of the system to the Technical Center.

ACT-100B.2: Plan and coordinate test effort, document the project plan, conduct laboratory and flight tests to validate the position reference accuracy and evaluate the operational capabilities, analyze the lab and flight data, and document and report results.

ACT-640: Provide the aircraft (CV-580), flight crew, and aircraft coordination/scheduling.

ACT-650: Provide aircraft engineering and install ATADS rack in CV-580. Provide antennas at suitable locations.

ACT-750: Develop software for post-flight merge of ground range and airborne data.

ACT-753: Provide the ground range tracking, Nike radar, and phototheodolites with operating crew. Provide computer program to merge collected data.

ACT-754: Provide JMR-4 satellite surveyor.

ACT-63B: Provide photos/illustrations for reports.

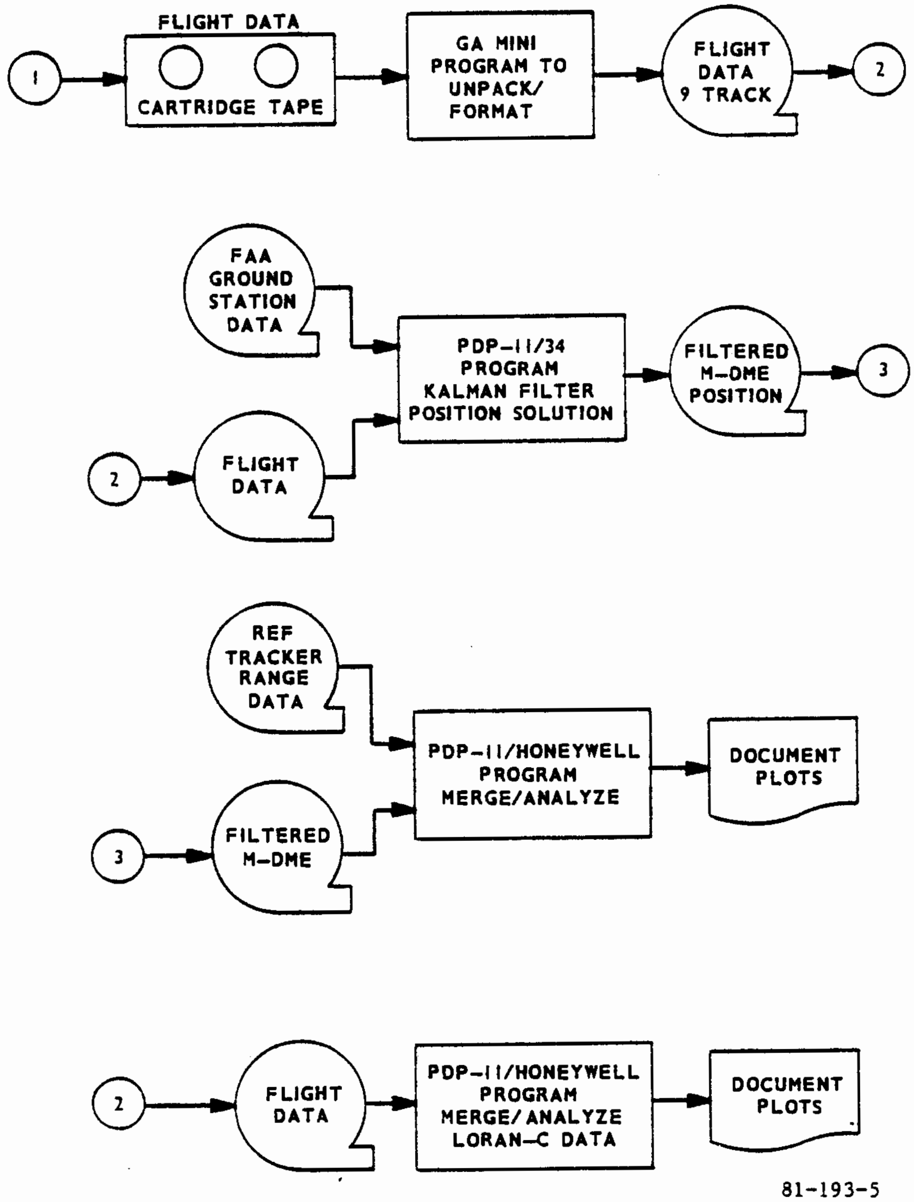
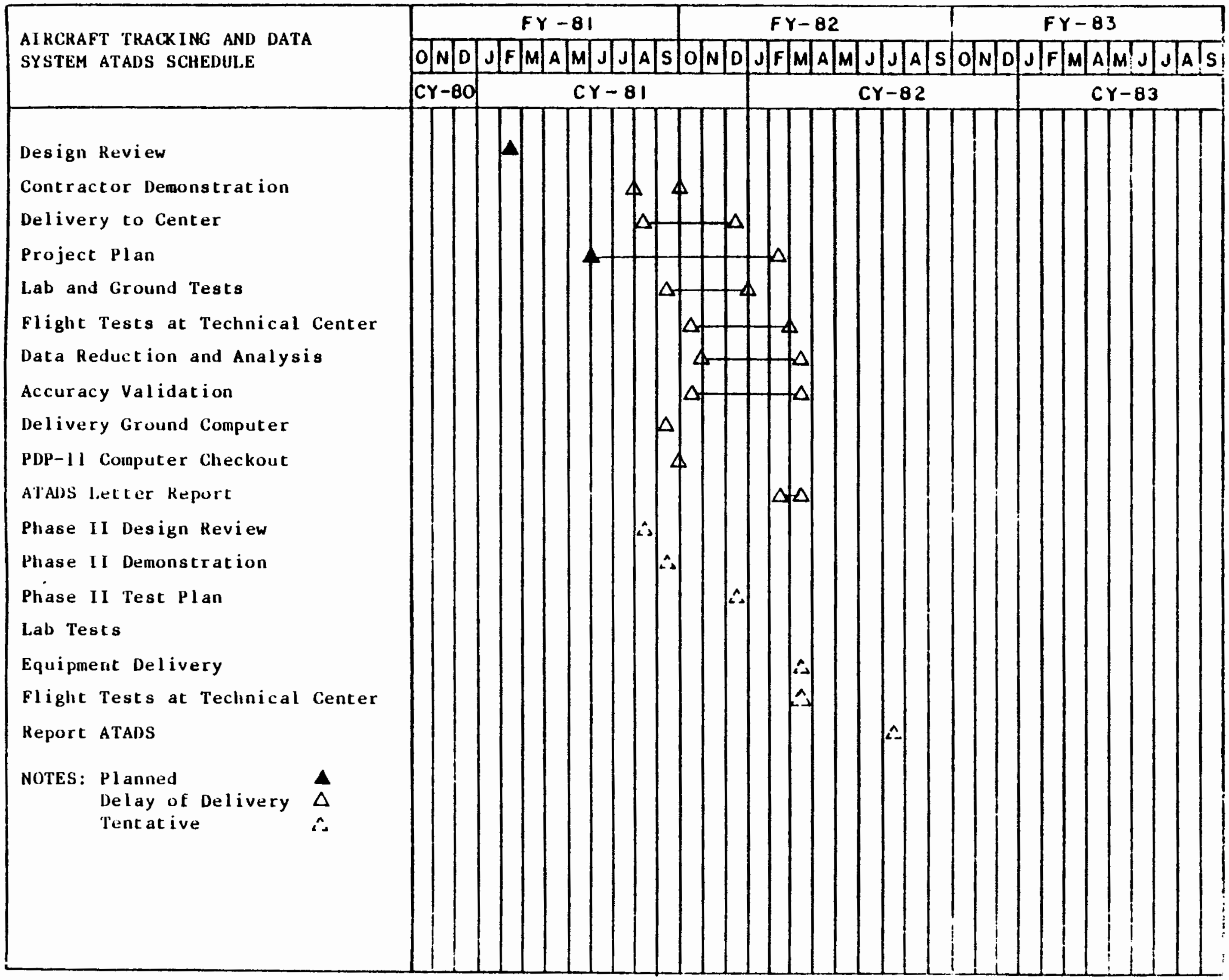


FIGURE 5. DATA PROCESSING FLOW CHART

9. MILESTONE SCHEDULE.



APPENDIX A

AMEX REVISED ARTICLES I, II, AND XI
COVERING AIRCRAFT TRACKING AND DATA SYSTEM (ATADS)

Article I, Statement of Work:

Phase 1B: Ruggedized Airborne Tracking and Data Collection System for Loran-C Testing.

AMEX shall accomplish the following software/hardware items:

1. Provide microprocessor hardware and software which will:

a. Control data from the following systems:

(1) Teledyne TDL-711 (RDU data).
(2) Teledyne TDL-424 (RDU data).
(3) Multidistance measuring equipment (DME) Tracking System.
(4) Systems clock.
(5) Inertial navigation system.

b. Time tag each piece of information from the systems measured.

c. Provide real-time hard copy output of significant parameters from each subsystem to a Computer Devices, Inc. (CDI) miniterminal to show that the subsystems are working.

d. Provide for input of headers for each flight.

e. Provide for entry of events marker.

2. Provide SESCO 8080 microprocessor hardware and operating software and one airborne KDM 706 for use as a tracking system. This system shall:

a. Provide 200 feet CEP position accuracy with six International Civil Aviation Organization (ICAO) type ground stations and 50 feet CEP accuracy when using four fast rise time ground beacons.

b. Sequence through 10 DME stations, either preprogrammed on one PROM chip, or automatically selected from 1 to 10 stations, or mix of both.

c. Provide DME information at the rate of 10 stations per second.

d. Time tag each piece of distance information along with the channel number.

3. Use a WWV clock to sync all clocks of the system via portable Datametrics unit.

4. Use a CDI miniterminal for data entry/display.

5. Record all data on a ruggedized cassette type recorder including an auxiliary RS-232 port.

6. Provide six KDM-706 interrogator receivers modified for ground operation with the following specifications/modifications:

a. Temperature range -40° C to +70° C.

b. Accuracy ±15 feet.

c. Dynamic range of -80 to -35 decibles above 1 milliwatt (dBm), as measured with a signal generator with a pin diode modulator.

d. Rise time of 200 nanoseconds.

e. Output display/indicator of radiated power and test point jacks to monitor transmit and receive video signals.

7. Provide five DME ground antennas with a gain of approximate 4 decibels (dB).

8. Provide packaging of 6 above for operation of 12 or 24 volts of direct current (Vdc) and 120 volts of alternating current (Vac) 60 hertz (Hz).

9. Perform confidence checkout of the system at Reno, Nevada.

10. Provide 2 weeks of field support in the following manner:

a. One week at the Technical Center for acceptance tests of Phase 1B and Phase II.

b. One week in Vermont during Loran-C testing.

11. Provide all equipment mentioned in items 1 through 5 above in a rack for airborne installation and shockmount CDI miniterminal atop rack.

12. Provide HP-85 software "quick look" for post-flight data analysis.