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AUTOMATIC TRAFFIC ADVISORY AND RESOLUTION SERVICE (ATARS) TEST AND EVALUATION PROGRAM

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PROJECT PLAN

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1. OBJECTIVES.

The mission objective of the Automatic Traffic Advisory and Resolution Service (ATARS) is to increase civil aviation safety by reducing the potential for mid-air collisions and near-miss encounters that can result from:

a. Aircraft deviations from assigned altitudes and/or routes due to pilot error or equipment malfunction.

b. Air traffic control (ATC) system errors.

c. ATC system hardware or software failures.

d. The inability of uncontrolled aircraft using see-and-avoid techniques to maintain safe separation from other aircraft.

Computer software, hardware, and man-machine interface procedures are being developed to accomplish this objective. This test plan describes the tests that are to be performed on the ATARS hardware and software. It does not address the computer simulation studies and algorithm development being performed by other organizations.

The ATARS testing is divided into six basic test areas: computer capacity, advisory service, multisite operation analysis, resolution service, alarm rate analysis, and ATARS/terminal ATC system testing. The advisory service and the resolution service will be combined and redefined into two areas:

a. Advisory and Resolution Service System Tests.

b. Advisory and Resolution Service Subjective Tests.

In each area, the following test objectives will be pursued:

a. Functional Characterization. Functional characteristics of each ATARS test area will be determined. This will involve establishing quantitative measures of each test area and defining operation in terms of performance specifications. The impact of these performance specifications on the ability to meet mission objectives will be assessed. The functional tests will include live, as well as simulated, flight data.

b. Operational Characterization. The ATARS system will be characterized by studying the results obtained from testing its overall operation. The impact of these operational characteristics on the ability to meet mission objectives will be assessed.

The test descriptions for each of these areas are discussed in sections 5.1 through 5.6, respectively.

2. BACKGROUND.

The requirement for the development of the Discrete Address Beacon System (DABS)/ ATARS was identified in the 1969 Department of Transportation Air Traffic Control Advisory Committee Study (reference 12). (The number within the parenthesis refers to the corresponding document listed in section 3.) The study required modifications to the present Air Traffic Control Radar Beacon System (ATCRBS) which would improve the surveillance accuracy and the reliability of the system. Specifically, a discrete address mode data link function was proposed which would automatically transmit traffic advisories and conflict resolution commands to the pilot. Corresponding controller alert messages would be sent to the air traffic controller. This ground-based collision avoidance algorithm, termed Intermittent Positive Control (IPC), would operate in several computers of the multicomputer DABS ground equipment.

A single-site IPC algorithm was published in October 1973 (reference 21). Flight tests of this algorithm were conducted at the DABS experimental facility at Hanscom Air Force Base, Massachusetts (references 3 and 5), from October 1974 to February 1977, by Lincoln Laboratory. Concurrent with this testing, a multisite algorithm called IPC Change 2 was developed by MITRE Corporation. This algorithm, published in September 1974 (reference 2), was implemented in the DABS experimental models installed at the Federal Aviation Administration (FAA) Technical Center, and Elwood and Clementon, New Jersey. The present ATARS program is based on the results of the Lincoln Laboratory tests (reference 1), knowledge gained from operation of IPC Change 2, and simulation studies of the single-site IPC done at the Technical Center and MITRE Corporation.

The ATARS program involves development, test, and evaluation of four versions of the ATARS algorithm: IPC Change 2, IPC Change 4, Interim ATARS, and Complete ATARS. IPC Change 4 is an intermediate step between the original IPC Change 2 and the Interim ATARS. Interim ATARS itself is an enhanced version of IPC Change 2 and includes the following features:

a. The "fixed rules" approach utilized in the IPC Change 2 master resolution is replaced with exhaustive search and command evaluation techniques.

b. A turn-sensing logic is added to make ATARS more responsive to detecting maneuvers, especially in the terminal area.

c. A site-adaptation logic for the terminal area to reduce unnecessary ATARS interaction with the ATC system.

d. A logic for vertical speed limit commands as a substitute for vertical negative commands is added in order to increase ATARS compatibility.

e. The service of ATARS is extended to ranges beyond 50 nautical miles (nmi) by limiting the resolution advisories to the vertical plane and by increasing the command time limits.

f. Protection against a dangerous maneuver by an unequipped proximate aircraft is provided by the addition of logic to check for a threatening turn or altitude maneuver by the unequipped aircraft.

g. Reducing the number of unnecessary positive commands while providing protection against altitude clearance violations is accomplished by eliminating the projection time in the calculation of vertical separation, and by reducing the immediate altitude threshold for positive commands.

h. Permitting horizontal commands for jet aircraft close to the airport is accomplished by increasing the speed threshold.

i. In order to provide increased protection in certain special cases such as DABS/ATCRBS encounters, double commands will be issued.

j. To prevent the issuance of unnecessary commands in cases of rapid vertical divergence, a special logic check is added.

k. Command preview logic is added. At the time that a controller alert is declared, the resolution logic is called to determine the command that the ATARS would give if it were issued at that time. This preview command is sent along with the controller alert message to indicate a candidate solution to the controller. When the ATARS algorithm calls for the issuance of a command, the preview command will be tested using current track data to see if it will produce a safe miss distance. If so, it will be issued; if not, the command evaluation module will be reentered in search of the best command.

The Complete ATARS algorithm contains all the improvements embodied in the Interim algorithm plus the following additional features which were recommended by the Air Separation Assurance Committee as essential for an operational ATARS system. These additional features are:

a. A domino logic is added to eliminate the possibility of resolution advisories causing chain reactions; i.e., secondary encounters.

b. The multiaircraft logic is improved to effectively handle situations when chain reactions would be unavoidable with a two-aircraft logic.

c. Epoch-based multisite coordination logic is replaced by sector-based, multisite coordination logic.

d. A logic for terrain, obstacle, and restricted airspace avoidance is added.

e. Logic is added to insure that the ATARS and Beacon Collision Avoidance System (BCAS) function compatibly.

f. Logic is added to insure that the ATARS functions properly in the seam area between an en route and terminal ATARS.

g. The ATARS/terminal ATC System interface logic (conflict alert emulator) is extended to emulate the conflict alert with respect to proximate target (PROCON) and maneuvering target (MFMANS) alerts.

Design of the Complete ATARS algorithm should be complete by April 1980 and implemented by October 1980. The test and evaluation of the Complete ATARS algorithm by the Technical Center will be performed from November 1980 to October 1981. The test and evaluation of Interim ATARS and the development of the Complete ATARS are expected to help determine the ATARS hardware requirements estimate, which will be delivered along with the DABS technical data package (TDP) scheduled for April 1980. The April 1980 delivery will include the ATARS processing time studies. In June 1980, a thorough study of the Complete ATARS hardware requirements will be complete and presented in report form.

Enhancements envisioned for the Complete ATARS include: (1) availability of traffic advisories on nonmode C transponder-equipped aircraft, and (2) use of multilateration techniques to eliminate problems with signal diffraction around obstructions. Support logic for these enhancements will be developed by June 1980. The impact of the new logic on the size of the Complete ATARS will be determined and the final computer program functional specification will be complete in June 1981. The final documentation package for ATARS will be complete in April 1982.

3. RELATED PROJECTS AND REPORTS.

The present ongoing projects that are related to this work include:

PGM NO.	NPD NO.	SUBPROGRAM NO.	TITLE	WASHINGTON SUBPROGRAM MANAGER/LOCATION
03	03-110	034-241	Experiment & Test Support for DABS	D. Hodgkins, ARD-240
03	03-110	063-222	Data Link Experiments	J. Bisaga, ARD-230
03	03-110	122-115	Interface Developments	S. Smith, ARD-112
03	03-110	142-176	ATC Applications of Message Automation	J. Horrocks, ARD-123
03	03-173	034-241	Compatibility Testing for DABS	J. DeMeo, ARD-240
05	05-172	052-241	Collision Avoidance Systems	C. Miller, ARD-240
05	05-298	034-242	ATARS	J. Scardina, ARD-252
05	05-298	052-241	Collision Avoidance Systems	W. Hyland, ARD-253
16	16-234	161-200	Advanced Human Factors (Cockpit)	P. Hwoschinsky, AEM-300
16	16-235	161-201	Advanced Human Factors (Controller)	TBA, AEM-300
21	21-253	218-153	Digital Simulation Facility	R. Murtaugh, ARD-140
RD	RD-140	122-115	Interface Development	A. Cioffi, ARD-140
RD	RD-140	142-179	Terminal Automation Test Facility	B. Golden, ARD-140

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4. SYSTEM DESCRIPTION.

The DABS/ATARS solicits position information from ATCRBS- and DABS-equipped aircraft using a ground-air-ground digital data link between the ATC system and the aircraft cockpit. The unique DABS code assigned to each aircraft allows direct communication between the ground and specific individual airborne systems.

The DABS engineering model computer system consists of two large memory units (global memories A and B), seven "ensembles" of four computers each, and data-bus lines, called TILINE™, connecting these components. Each ensemble consists of an ensemble TILINE, four identical computers, two couplers, and a priority board. Figure 1 is a simplified diagram of the DABS architecture. Since the system uses distributive processing, there is no set of DABS computers reserved exclusively for the ATARS function.

The DABS and the ATARS main memories are separate and essentially exclusive. The global TILINE A and accompanying 352K of global memory are assigned to DABS

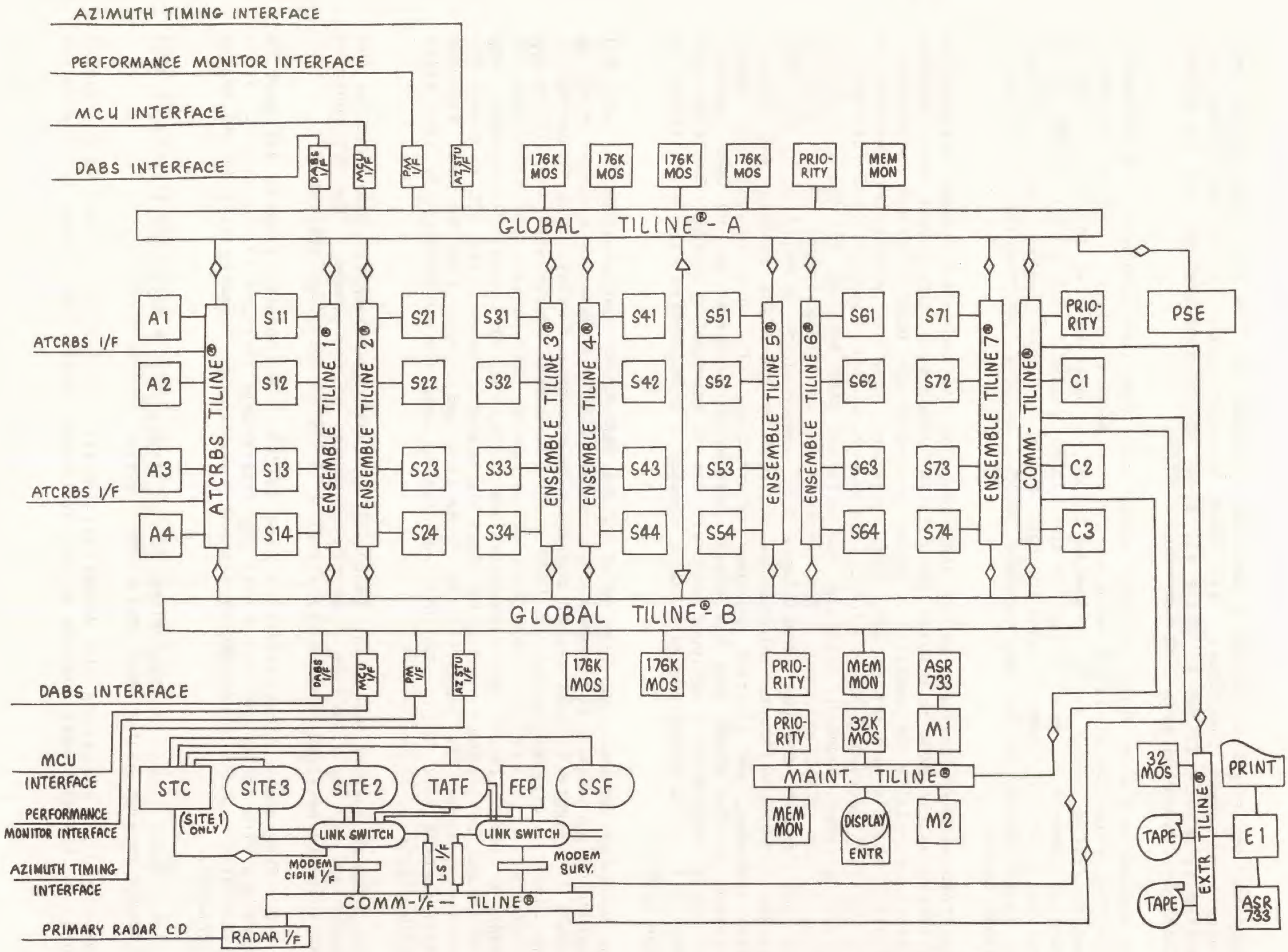

FIGURE 1. DABS COMPUTER SUBSYSTEMS: ARCHITECTURAL BLOCK DIAGRAM

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functions while global TILINE B and the accompanying 176K of global memory are assigned to ATARS functions. All ATARS messages going to ATC facilities are handled by global TILINE B, while all ATARS uplink messages are fed via global TILINE A to the DABS data link functions.

The system uses a rotating priority scheme such that each computer in an ensemble gets top priority at least once every four memory cycles. Once an ensemble computer gains access to its ensemble TILINE, it must wait as the seven ensemble couplers compete to gain access to the global TILINE. The global TILINE has a rotating priority scheme similar to that of the ensemble TILINE. Once a computer has gained access to its own ensemble TILINE, it gets top priority for access to global memory.

The ATARS software resident in the DABS computers utilizes surveillance information solicited by the DABS to monitor the data and identify aircraft that are proximate and/or potentially in conflict. ATARS processes the DABS data and continuously provides traffic advisories and, when necessary, conflict resolution commands to the aircraft receiving ATARS service via the data link. Surveillance information including range, azimuth, altitude, and a 24-bit DABS identity for the aircraft is input to the ATARS software. The identity for an ATCRBS target report includes the mode 3A code and the surveillance file number which is supplied by the DABS tracker. Nonsurveillance information utilized by the ATARS includes ATC status, pilot response, and aircraft equipage information. The only surveillance inputs accepted by the ATARS have had track correlation performed by the DABS tracker. Presently, only mode C equipped aircraft can be serviced by ATARS. The algorithm which will allow ATARS operation with nonmode C transponders will be delivered in June 1980.

Two computer systems have been added to the DABS/ATARS configuration for test and evaluation purposes. The system test console (STC) is shown as a single block in figure 1. Figure 2, DABS sensor depicting maintenance display, is a photograph of the physical arrangement of the DABS at the Technical Center with the STC in the foreground. It has the capability of receiving, displaying, and recording all DABS/ATC surveillance and communications data, sensor-to-sensor messages, and status and performance monitoring data on magnetic tape. The STC provides the console operator the capability of formatting and transmitting National Airspace (NAS)-to-DABS test data. The STC can also be used for monitoring the live ATARS flight tests to insure safety.

The program support equipment (PSE) is a stand-alone computer connected to the sensor and can be viewed as a peripheral device of the sensor. The PSE contains two software packages besides the standard TI 990/10 operating system:

a. Programmer Panel Interface Card (PPIC). A computer program designed to interface with the sensor and access any addressable location in the sensor. It is essentially a software debugging aid and a monitor for viewing data during sensor operation.

b. Quick Look. A stand-alone 990/10 program for a formatted listing of data recorded on tape by the data extraction computer in the sensor.

Data used in analyzing the ATARS system will be collected from many sources such as: (1) the DABS sensors at the Technical Center and Elwood and Clementon,

FIGURE 2. DABS SENSOR DEPICTING MAINTENANCE DISPLAY

New Jersey (see figure 3, Elwood DABS Sensor); (2) the computer performance monitoring system (CPMS); (3) subject pilot questionnaires; and (4) independent tracking facilities.

The analysis of data will be performed both manually and with the use of computers. The reduction of data to a convenient form will be done by computers. The following guidelines will be used throughout the analysis:

a. No data will be discarded because it does not fit the expected pattern.

b. Tracking data will not be filtered or smoothed when it is used to evaluate state vector accuracy.

c. All simulation methods will be validated by comparison of live versus simulated traffic data.

d. The validity of test results will be expressed with respect to a model, where applicable.

e. The validity of applying each statistical method to the data will be considered. For example, if a random variable is not normally distributed, then nonparametric methods will be used. In some cases the non-normality condition can be resolved by redefining the sample variable to be a mean of several values and applying the Central Limit Theorem, which states that the means tend toward a normal distribution.

5. SYSTEM TEST AREAS: TEST PLAN DESCRIPTIONS.

This section contains the plans for each of the six ATARS test areas indicated in section 1. Each test area plan description has been divided into four subsections:

General describes (1) the objectives of the test, (2) a background explanation of the area being tested, and (3) the scope of the test.

Technical approach describes the techniques and equipment required to execute the tests.

Data collection and analysis indicate which data should be collected from the tests and describes the methods of analysis to be applied to the data.

Schedule provides a time frame within which the test is to take place.

An overall system schedule is contained in section 8.

5.1 ATARS CAPACITY.

5.1.1 General.

The objective for testing the ATARS computer software capacity is to develop an estimate for the hardware required to implement Complete ATARS. The estimate will be based on quantitative and qualitative analyses of Interim ATARS and its sub-modules, and on a comparison of this data to the baseline data obtained from the IPC system.

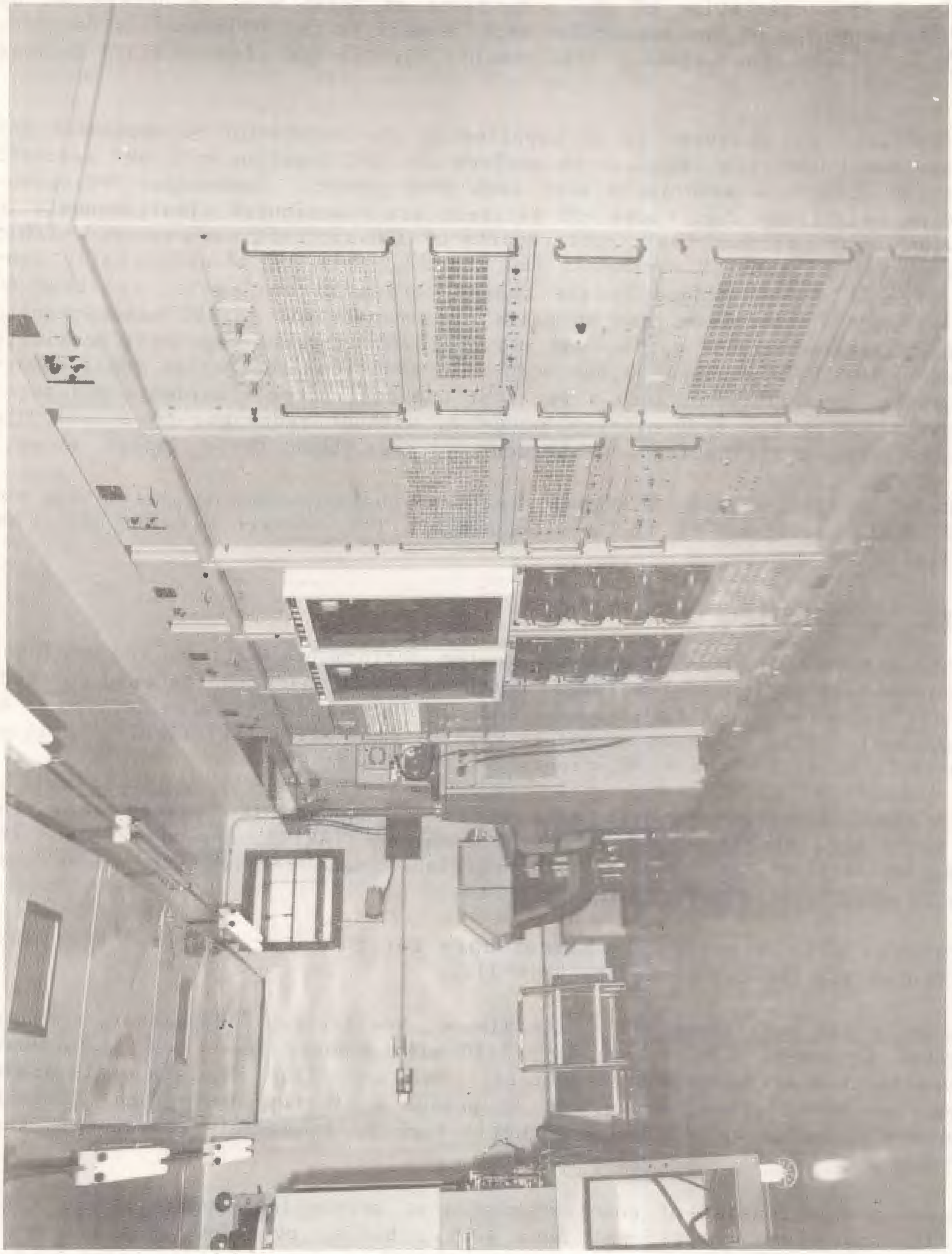

FIGURE 3. ELWOOD DABS SENSOR

The functional characteristics of the submodules of ATARS will be determined by measuring the responses of the submodules with respect to the IPC capacity requirements (reference 14). The capacity requirements for the IPC algorithm are defined below:

"The hardware and software to be supplied by the contractor to implement the IPC function shall have the capacity to perform the IPC function with 400 aircraft within the IPC data base associated with each DABS sensor. Successful IPC operation shall be maintained when these 400 aircraft are distributed simultaneously in the following ways: (a) that the target reports of 300 aircraft are received within one IPC processing cycle (2 seconds), (b) that 7,200 pairs of potentially conflicting aircraft are generated by the coarse screen in one cycle, (c) that 40 pairs of aircraft in IPC seams and 40 pairs of aircraft not in IPC seams require resolution processing in one cycle, and (d) that 200 aircraft require a proximity warning indicator (PWI) message in one scan. In addition, the design shall incorporate a growth capability in such a way that the contractor's hardware and software can be directly and economically expanded, without redesign, to accommodate 700 aircraft with distributions 75 percent greater than those listed above."

The operation for the ATARS, as a whole, will be characterized by evaluating the functional characteristics of the system against the overall mission objective (section 1.0).

5.1.2 Technical Approach.

The general approach to testing ATARS computer performance will be to develop a general purpose simulation system (GPSS) model of ATARS which can be used to study hardware and software capacity problems and to address design alternatives. An analytical model for each system submodule will be defined. Statistical techniques will be used to determine the coefficients for these models.

To test ATARS, simulated scenario data will be input to the system using the aircraft reply and interference environment simulator (ARIES, appendix 2) and the ATARS capacity driver (appendix 1). Surveillance data received from live test flights will also be provided to ATARS via DABS.

Two techniques will be used to collect data for these statistical analyses: software probes and the CPMS (see appendix 3).

The CPMS, which has been installed at the Elwood, New Jersey, DABS sensor, consists of a Digital Equipment Corporation PDP-11/55 minicomputer and a set of hardware probes to interface with the DABS computers. This interface consists of 12 probes monitoring the DABS address lines and 16 probes monitoring the global TILINES. CPMS data are recorded on a 9-track magnetic tape by an associated magnetic tape unit.

The software probes consist of counters placed at appropriate points in the ATARS software to accumulate operational data (e.g., buffer overflows and number of coarse screen pairs). The CPMS will be used to collect the additional data because its probes can be programmed for any memory address.

5.1.3 Data Collection and Analysis.

During data collection, the following two magnetic tapes will be generated simultaneously:

a. CPMS data tape.

b. The DABS extractor tape.

The CPMS generates a data tape while sampling both the DABS address lines and TILINE. The software counters will be recorded on the DABS extractor tape. The software counters will be used to evaluate the coefficients of the analytical model using statistical techniques (e.g., regression analysis and analysis of variance). The data obtained during these capacity tests will be used to determine parameters of the simulation model and will also aid in establishing ATARS hardware requirements and specifications. Once the data are collected, they will be used to functionally and operationally characterize ATARS.

Functional characterization of the ATARS submodules will consist of four basic parts:

a. Distribution of input data.

b. Functional relationship between the input data and subcomponent operating time.

c. Queue waiting time as a function of the subsystem.

d. Performance with respect to the mission objective and the desired purpose of the submodule.

Appendix 5, Coarse Screen, provides an example of this analysis format.

The coarse screen submodule of ATARS is selected for presentation since its basic operation is not expected to change substantially. Each ATARS submodule will be analyzed in a manner similar to the coarse screen analysis to establish the four functional characterizations of the submodule.

The operational characterization of ATARS capacity will be examined by use of a GPSS simulation model of ATARS. Submodule functional characteristics established above will be used. The results of this phase of the study will be:

a. Identification of time critical operations and submodules.

b. Identification of buffer space requirements.

The initial Complete ATARS GPSS model will be used in developing the June 1980 ATARS hardware estimate.

This simulation model will be based on information about Complete ATARS available at the time. More detailed information will become available as the October 1980 implementation date approaches. The final version of the Complete ATARS GPSS model will be based on this more complete information.

5.1.4 Schedule.

The delivery of IPC Change 4 and Interim ATARS analysis will be concurrent with the delivery of the computer program functional specifications (CPFS) for Complete ATARS in April 1980. A Complete ATARS hardware estimate will be delivered in June 1980.

The capacity analysis schedule, figure 4, establishes the time relationship between the various phases of this effort.

5.2 ADVISORY AND RESOLUTION SERVICE--SYSTEM TESTS.

5.2.1 General.

The purpose of the ATARS advisory and resolution service tests is to characterize the operation of these services in the DABS computers. Characterization will involve studying ATARS logic functions including the conflict alert emulator, command evaluation, turn-sensing logic, aircraft tracker, site-adaptation logic, vertical speeds, expanded range coverage, controller conflict resolution data, and domino logic for multiple aircraft encounters. In addition, there are several ATARS submodules to be tested and coordination logic to be examined.

Target reports containing DABS and ATCRBS identification, range, azimuth, altitude, and track identification are used as inputs to the ATARS algorithm. In response to target information, ATARS generates uplink advisories, conflict resolution messages, and ATC advisories. These communications are based on the relative aircraft geometry, airborne equipment configuration, flight rule conditions (control status), and aircraft speeds and altitudes.

The equipage of the aircraft is communicated to the ATARS algorithm via the normal All-Call DABS reply. Airborne equipment with ATARS capability is called "equipped;" otherwise, it is called "unequipped."

The primary objectives of these tests are to:

a. Validate the ATARS code as implemented in the DABS sensor. This will be accomplished by comparing the implemented code with expected results obtained from MITRE Monte Carlo runs on detailed studies of the algorithm.

b. Functionally characterize the major components. Specific examples of such characterization are tracker accuracy and ability to detect turns, advisory and resolution command timing, and closest point of approach analysis.

c. Operationally characterize the ATARS system. Examples of operational characterization studies are:

1. What is the command sequence in a conflict or near-miss situation?

2. How stable is the advisory and resolution service in transition from one state to another (e.g., altitude change from above 10,000 feet to below 10,000 feet)?

3. What is the impact of the turn detection logic characteristic on the advisory and resolution services?

5.2.2 Technical Approach.

The majority of the system testing will be done with the use of simulators. The large number of distinct logical paths through the resolution logic make it necessary to use simulators in order to examine a significant group of these paths. Live flight test utilizing the Technical Center pilots and aircraft will be run to corroborate the simulation results.

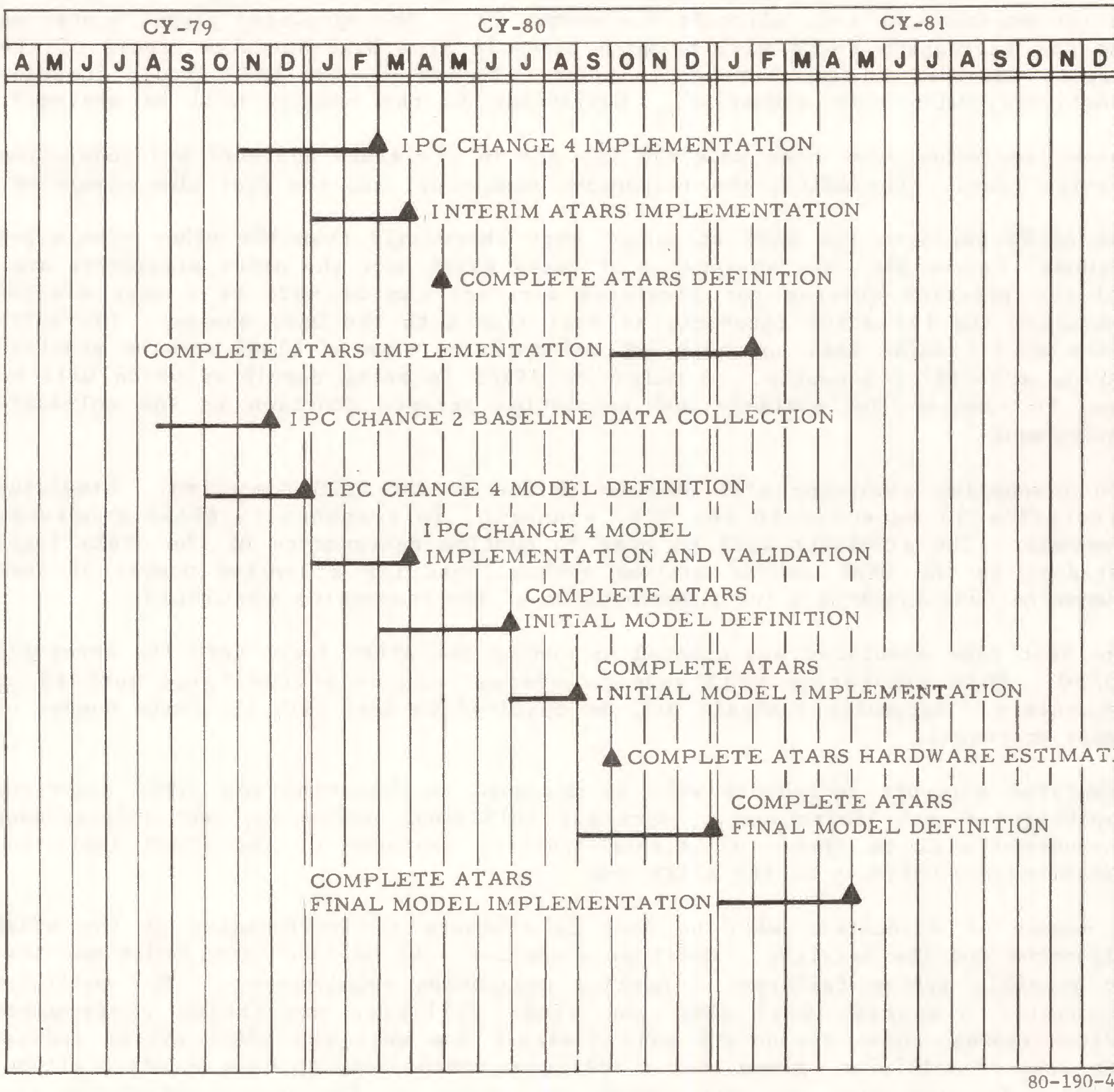

FIGURE 4. CAPACITY ANALYSIS TEST SCHEDULE

All simulation methods used to test ATARS will be examined in order to assure their significance. Support for these methods will be based on a direct comparison of how well the system functions when provided with either real targets in a live environment or with simulated targets. The Nike-Hercules tracking system is the Technical Center facility which will be used to provide very accurate information on the position of test aircraft (reference 19). The simulated target scenarios for the validation tests will be made directly from Nike-Hercules tracks of the targets examined in the live environment. Optimally, the DABS should function identically with both scenarios. Deviations in the results will be analyzed.

Three simulators have been selected for use in the ATARS advisory and resolution service tests: the ARIES, the responsive simulator, and the fast time simulator.

The ARIES emulates the DABS operation more thoroughly than the other simulation methods (figure 5). The advantages of using ARIES over the other simulators are: (1) the position updates for simulated aircraft can be made at a user desired frequency and (2) ARIES interacts in real time with the DABS sensor. The ARIES tests will provide data on the start and duration time of ATARS service provided during a conflict scenario. A multisite ARIES is being developed which will be used to examine the advisory and resolution service function in the multisite environment.

The responsive simulator will operate in one of the DABS computers. Simulated aircraft will maneuver in the test scenario, in response to ATARS generated commands. The simulator will be used to confirm performance of the ATARS logic resident in the DABS and to analyze system logic for a limited number of test scenarios (see appendix 4 for a description of the responsive simulator).

The fast time simulator was created by coding the ATARS logic into the Honeywell 66/60. This simulation will examine system responses from large numbers of encounters. Automatic analysis will be required to deal with the large number of cases processed.

Simulated aircraft encounters will be designed to determine the ATARS algorithm capabilities and limitations. Aircraft collision, near-miss, and safe-passage encounters will be chosen to stress specific features of the ATARS logic and establish the validity of the ATARS code.

A number of encounters will be used to evaluate the performance of the ATARS algorithm and its services. Critical scenarios will be identified which may lead to possible system failures in meeting separation requirements. The collision encounter scenarios will show the ATARS collision prevention performance effectiveness--these encounters will indicate how well the ATARS system reduces the risk of collision, given that a collision would probably have occurred without ATARS. The near-miss and safe-passage encounters are the ones in which the aircraft at closest approach are separated horizontally and/or vertically. These encounters are intended to show the alarm and false alarm performance of ATARS and to show any logic deficiencies that may develop. The test encounters to be used for system testing will include the following three basic sets:

a. Historical secenario set.

1. Fifteen National Transportation Safety Board (NTSB) documented mid-air collisions.

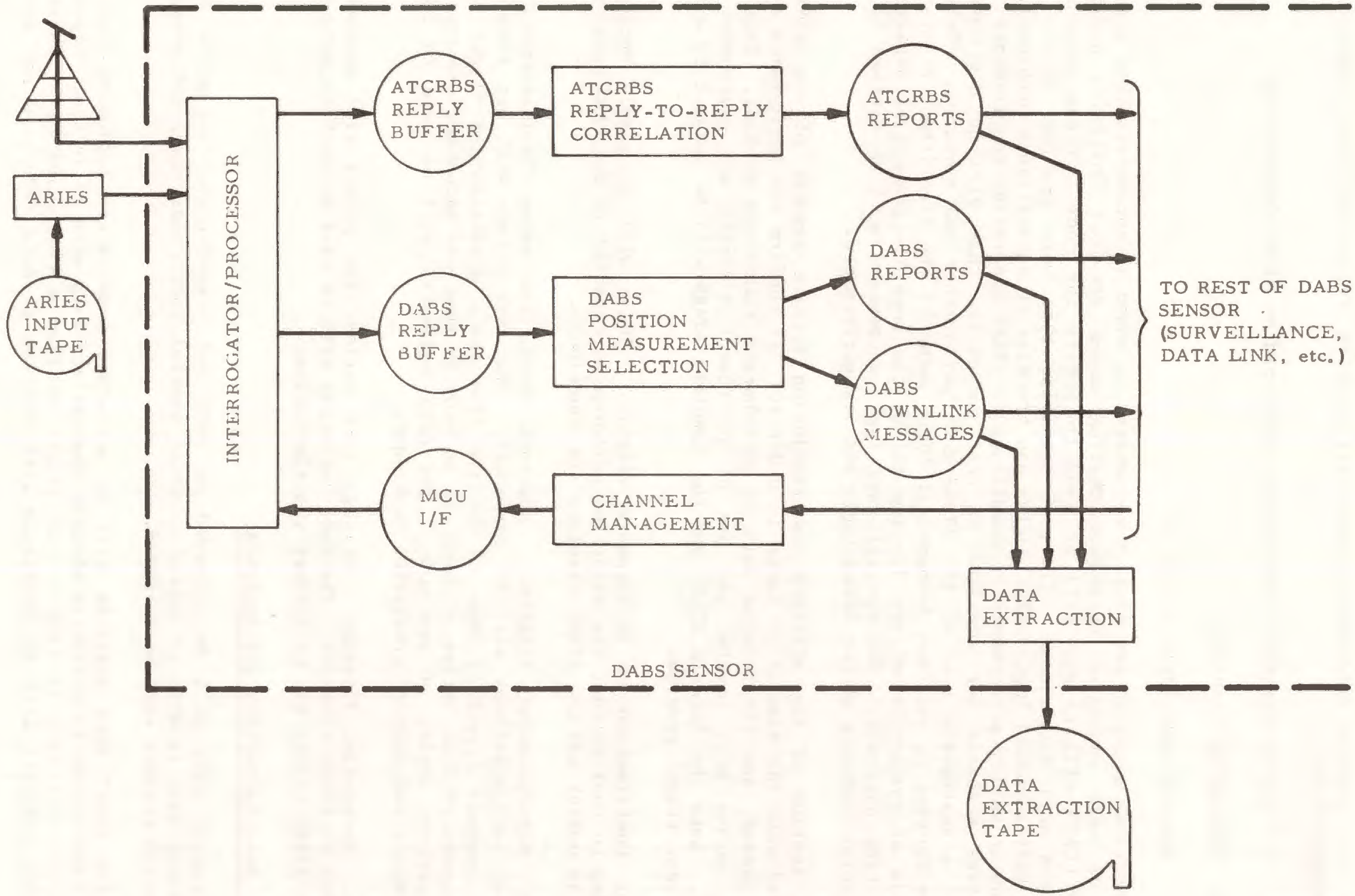

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FIGURE 5. DABS/ARIES INTERFACE

2. Lincoln Laboratory tests--all problem encounters from original IPC algorithm studies.

3. The 64 standard combinations developed by MITRE Corporation.

b. Exhaustive scenario.

c. Special case logic encounter.

The historical scenario set of test encounters is based on encounters that are well known or have undergone extensive testing under previous Collision Avoidance System (CAS) efforts and will be used to verify the code. These encounters have been well documented. Critical scenarios that were problems in the past (i.e., that revealed logic deficiencies and tracking or surveillance problems), can be rerun to verify performance or compliance to ATARS separation requirements. The exhaustive scenario set consists of test encounters that will be developed to provide a systematic test of the ATARS code performance and services. This set will be devised to exercise fundamental logic paths of the algorithm. Figure 6 is a matrix of system parameters listing all of the possible geometries between two conflicting aircraft. The special case logic encounters will be devised to test out special features of the ATARS logic and its performance.

Flight testing of the advisory and resolution service segment of the ATARS is included with the simulation tests in order to: (1) confirm the performance of the ATARS system, and (2) provide data to corroborate simulation methods. This test flight series will involve the use of government aircraft and government test pilots. Both the Interim ATARS and the Complete ATARS will be subject to a three phase test flight program.

a. Confirmation of Performance Flights. These will be simple encounters intended to confirm that the algorithm performs as expected in the DABS sensors and that the uplink and the ATARS displays are functional.

b. Nonresponsive Flights. Numerous encounters using "double-daisy" and vertical configurations will be performed. The test pilots will not respond to ATARS commands directing them to deviate from their predetermined flight paths. The purpose of this series of tests is to provide numerous encounter opportunities from various angles of approach. The data collected will be used to confirm performance and support simulation techniques.

c. Responsive Flights. In this test series, the pilots will maneuver in response to ATARS commands. The data collected will be used to confirm performance of the ATARS system and to support the simulation.

5.2.3 Data Collection and Analysis.

The primary data will be recorded on DABS and Nike-Hercules extractor tapes. Additional data related to specific tests, special test conditions, and unusual or unexpected results will be recorded.

A "quick look" data analysis will be performed immediately following each data collection effort to determine whether appropriate data were collected, regardless of whether the data is from a test flight or from a simulation run. Subsequent detailed analysis will be performed with the use of data reduction and analysis

	Test Parameters	States	Test Configurations[1]
Aircraft Conditions	DABS/ATCRBS Equipped	D=DABS Equipped A=ATCRBS Equipped	D*A[2], D*D
	ATARS Equipped	E=ATARS Equipped NE=Not ATARS Equipped	E*E, E*NE
	BCAS Equipped	B=BCAS Equipped NB=Not BCAS Equipped	B*B, B*NB, NB*NB
	Responsive/Nonresponsive	R=Responsive NR=Not Responsive	R*R, R*NR, NR*NR
	Controlled/Uncontrolled	C=Controlled UC=Uncontrolled	C*C, C*UC, UC*UC
Site Conditions	Site Adaptation	ACT FAZ	Encounter Area Types 1, 2, 3, and 4; Final Approach Zone or not.
	Multisite Conditions	S=In Seam L=Local Coverage R=Remote Coverage	L*L, L*S, L*R, S*R, S*S, R*R
Geometric Conditions	Altitude	HA=Over 10,000 ft (High) LA=Under 10,000 ft (Low)	HA*HA, HA*LA, LA*LA
	Air Speed	S1=Under 120 knots S2=Between 120 & 150 knots S3=Between 150 & 180 knots S4=Between 180 & 250 knots S5=Over 250 knots	All possible combinations (except state S5 for low altitude aircraft).
	Horizontal Crossing Angle		Intersections at 0° 45°, 90°, 135° 180°
	Vertical Rate	SC-Slow Climb FC=Fast Climb SD=Slow Descent FD=Fast Descent	All cases.
	Turning Rate	ST=Standard Rate (3°/sec, 30° Bank) FT=Fast Turn Rate (6°/sec, 30° Bank)	All cases.
	Acceleration Status	T=Turning NT=Not Turning A=Speed Increasing or Decreasing NA=Speed Constant	T*T, T*NT, NT*NT, A*A, A*NA, NA*NA
	Range from Sensor		10 nmi, 30 nmi, 60 nmi, 90 nmi

[1] Multiple aircraft configurations are assumed to be included in each test. All configurations listed in each case will not necessarily be used in the simulations.

[2] The test configuration $\alpha*\beta$ indicates that the first aircraft is in state α and the second aircraft is in state β.

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FIGURE 6. ATARS TEST MATRIX

computer programs. Each test will be run several times in order to provide the appropriate data for analysis and summarization of different aspects of the advisory and resolution service. For example, the data from appropriate simulation runs will be summarized in a format consistent with the MITRE Monte Carlo summary format (figure 7).

The ultimate concern throughout this analysis effort will be to functionally and operationally characterize the advisory and resolution service.

The functional characterization will consist primarily of a search for inconsistencies between test data and previous studies (e.g., MITRE simulation), failure to resolve conflicts, and unexpected or undesirable commands.

5.2.4 Schedule.

The various features of the advisory and resolution service will be implemented at different times and the testing will be scheduled according to delivery. Details of the schedule are in section 5. The advisory and resolution service system test schedule establishes the detailed time relationship between the various aspects of this study (figure 8).

5.3 ADVISORY AND RESOLUTION SERVICE--SUBJECTIVE TESTS.

5.3.1 General.

The purpose of these tests is to assess the utility of the ATARS information to the pilot. One aspect of the ATARS development program is the expansion of the traffic advisory service to provide more complete data on proximate and threatening aircraft in order to aid the pilot in both visual acquisition and threat assessment. These tests will identify the characteristics of the traffic advisory service that contribute to ATARS effectiveness, study compatibility of the traffic advisory service with the resolution advisory service, and to determine information necessary to provide a minimum acceptable traffic advisory service. A minimum acceptable traffic advisory is defined as sufficient information on an intruder aircraft for a pilot to confidentally use the resolution advisory service.

This study will analyze the utility of the developed system and analyze the relationship of traffic advisory services to the resolution service. The results from these tests will be instrumental in writing the ATARS National Standard and the Federal Aviation Regulations.

5.3.2 Technical Approach.

The ATARS has the capability of generating advisories in all phases of flight. The DABS data link/ATARS avionics provided for these tests will generate widely ranging levels of advisory information to the pilot. To maintain the magnitude of this type of analysis within practical bounds, typical en route flight paths will be utilized and the level of ATARS information displayed to the pilot will either be kept constant or varied among a limited number of levels. The ATARS avionics will be implemented in a wide spectrum of combinations. The flight test program will collect data on a number of different display concepts. Results will be used to evaluate ATARS effectiveness for the different levels of information and display concepts and to aid in the implementation of the ATARS avionics.

```
***-------------------------------------------------------------------------------------------------------------------***
*** M C S C A S -- JOB DATE: 05/09/80 AT 16:42:24 -- RUN  1 SCENARIO  7: (G): XXX                           PAGE 137 ***
***-------------------------------------------------------------------------------------------------------------------***

ACAT1:  0   FAZ1:  0   EQUIP: BU   THTRUE:  1.49925E+02   A(DEG):  9.00003E+01   ALTOP:  1.06980E-01   VRZ:    0.00000E+00
ACAT2:  0   FAZ2:  0   MULT:   2   DSQ:     2.49974E-01   B(DEG):  0.00000E+00   TOP:    2.30000E+01   VRZDP:  4.65130E-03
ENAT:   0                                                                          TVOP:   8.00000E+00   VR2:    1.54444E-03


********************* CYCLE = 39 ********************

                 X            Y            Z            XD           YD           ZD         HCOM VCOM HMS MISS
TRUE:      9.32699E+00  8.60088E+00  6.67000E-01  2.78000E-02  0.00000E+00  0.00000E+00               0   0
TRACKED:   9.32699E+00  8.60088E+00  6.66667E-01  2.77998E-02  1.00000E-09  1.00000E-09

TRUE:      7.51926E+00  1.13532E+01  6.67000E-01  2.21464E-05  2.78000E-02  0.00000E+00               0   0
TRACKED:   7.51926E+00  1.13532E+01  6.66667E-01  2.19355E-05  2.77998E-02  1.00000E-09

*** ENCOUNTER DATA FOR PAIR 1, 2:

RANGE:   19757.3 FT        TH:          0.0 SEC      MD:      3999.9 FT      DOT:      0.12673
RZ:          0.0 FT        TV:          0.0 SEC      VMD:      171.8 FT

             CAFLG           EPIFLG         IFRFLG         EPWFLG         CMOFLG          PWIFLG    ICAFLG    CAPFLG    MTTFLG
               0                0              0              0              0               0         0         0         0
RANGE (FT):        0.0            0.0            0.0            0.0            0.0
ALT (FT):          0.0            0.0            0.0          987.5          740.6
TAU V (SEC):       0.0            0.0            0.0           45.0           32.0
TAU H (SEC):       0.0            0.0            0.0           45.0           32.0
MISS D (FT):       0.0            0.0                       54000.0

ACAT1:  0   FAZ1:  0   EQUIP: BU   THTRUE:  1.49925E+02   A(DEG):  9.00003E+01   ALTOP:  1.06980E-01   VRZ:    0.00000E+00
ACAT2:  0   FAZ2:  0   MULT:   2   DSQ:     2.49974E-01   B(DEG):  0.00000E+00   TOP:    2.30000E+01   VRZDP:  4.65130E-03
ENAT:   0                                                                          TVOP:   8.00000E+00   VR2:    1.54444E-03


********************* CYCLE = 39 ********************

                 X            Y            Z            XD           YD           ZD         HCOM VCOM HMS MISS
TRUE:      9.43319E+00  8.60088E+00  6.67000E-01  2.78000E-02  0.00000E+00  0.00000E+00               0   0
TRACKED:   9.43319E+00  8.60088E+00  6.66667E-01  2.77998E-02  1.00000E-09  1.00000E-09

TRUE:      7.51935E+00  1.14644E+01  6.67000E-01  2.21464E-05  2.78000E-02  0.00000E+00               0   0
TRACKED:   7.51935E+00  1.14644E+01  6.66667E-01  2.19355E-05  2.77998E-02  1.00000E-09

*** ENCOUNTER DATA FOR PAIR 1, 2:

RANGE:   20681.9 FT        TH:          0.0 SEC      MD:      3999.9 FT      DOT:      0.13291
RZ:          0.0 FT        TV:          0.0 SEC      VMD:      171.8 FT

             CAFLG           EPIFLG         IFRFLG         EPWFLG         CMOFLG          PWIFLG    ICAFLG    CAPFLG    MTTFLG
               0                0              0              0              0               0         0         0         0
RANGE (FT):        0.0            0.0            0.0            0.0            0.0
ALT (FT):          0.0            0.0            0.0          987.5          740.6
TAU V (SEC):       0.0            0.0            0.0           45.0           32.0
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FIGURE 7. EXAMPLE OF MITRE MONTE CARLO SUMMARY FORMAT

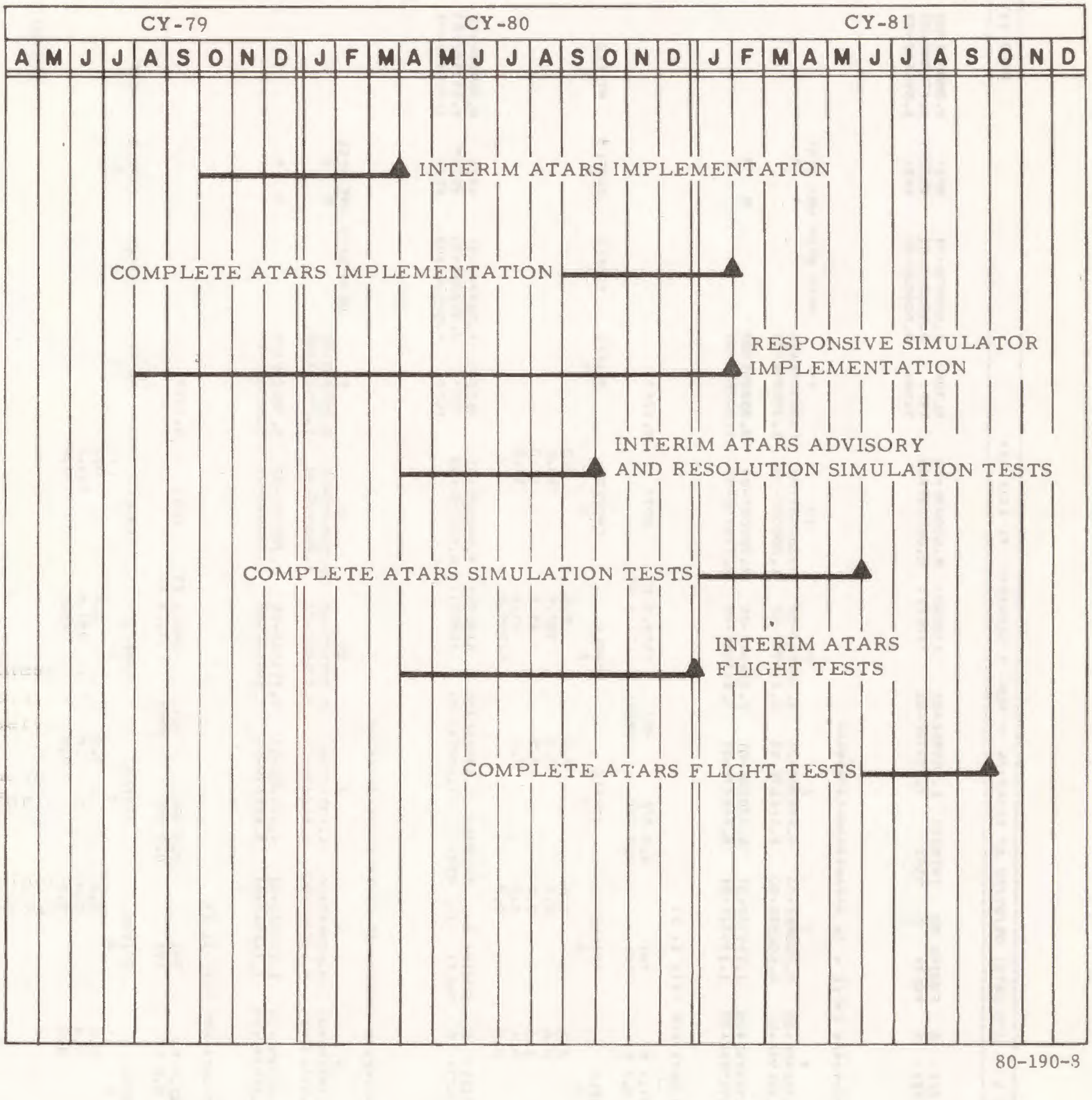

FIGURE 8. ADVISORY AND RESOLUTION SERVICE SYSTEM TEST SCHEDULE

There will be four phases of testing:

a. Phase 1 will use professional pilots (government employees) flying twin engine aircraft with a color cathode ray tube (CRT) display.

b. Phase 2 will utilize general aviation pilots (government employees) flying single engine aircraft with a small Ryan Storm Scope CRT reformatted as an ATARS display.

c. Phases 3 and 4 will be demonstration and opinion gathering flights involving nongovernment, general aviation, and professional pilots, respectively.

Approximately 20 subject pilots with varying levels of flight experience will be used in phases 1 and 2 testing. Each subject pilot will fly several established routes in a rental plane which has been specially instrumented to contain the DABS data link/ATARS avionics. During these flights a second plane will fly intercepts with the subject aircraft. The subject pilot's reaction to the conflict and ATARS messages will be observed and recorded.

The subject plane will have three occupants: the subject pilot, a pilot in command, and an observer. The observer will keep notes on the subject pilot's reaction and response to the ATARS advisories. These notes will become a fundamental part of the test data. The pilot in command will be responsible for flying the plane and will be a backup for the subject pilot, who will be concentrating on the test.

The user demonstration flights, phases 3 and 4, will be in an adaptable format. The intent is to collect opinions, judgements, and impressions from the nongovernment community to further examine user acceptance of the ATARS.

The task of evaluating human opinion is very specialized. To ensure accurate results, an independent consultant will be hired to develop the detailed test procedures and the pilot briefings for this study. Each pilot briefing will be tailored to the particular ATARS avionics that the pilot will be using in the test. This briefing will consist of a written test guide and a visual orientation to the display.

5.3.3 Data Collection and Analysis.

The data collection will consist of the responses obtained from the subject pilots and from the live flight test data recorded on the DABS data extractor tapes. Data analysis will include the following:

a. Computer programs for data reduction and analysis of the DABS extractor tapes.

b. Compiled and tabulated information obtained from the subjective opinions of the test pilots.

c. Real-time, quick-look analysis of the data collected during each of the encounters to ensure accuracy.

d. Plots of various aircraft parameters.

A series of flights will be scheduled with the subject pilots to assess the following:

a. Resolution advisory service.

1. Determine pilot concurrence with commands.

2. Determine willingness of pilots to follow commands with and without both traffic advisory service and visual acquisition.

3. Assess value of traffic advisory service as a precursor to commands.

b. Traffic advisory service.

1. Examine relationship of traffic advisories to resolution advisories.

2. Examine information required in the traffic advisory service messages in order for ATARS to perform according to its FAA planned use in:

(a) Visual acquisition
(b) Threat assessment
(c) Blunder prevention

3. Examine the pilot's use of the ATARS and compare to the FAA's planned use of ATARS.

4. Examine the value of information contained in the traffic advisory service messages.

5. Examine the pilot's reliance on the display with and without visual acquisition when receiving proximate or threat advisories.

6. Examine the time required by the pilot for effective comprehension of a traffic advisory.

7. Examine the pilot's capability to make an accurate threat assessment before the command is displayed and determine the pilot's response to command.

8. Examine the pilot's response to traffic advisory service such as:

(a) Maneuvers prior to command
(b) Contacts with ATC
(c) Visual acquisition of intruder

9. Assess visual acquisition capability:

(a) Relative to the ATARS
(b) Relative to no advisories

The test results will be valuable in:

a. Refining pilot training requirements.

b. Defining pilot instructions to utilize the ATARS--especially any differences in usage between instrument flight rules (IFR) and visual flight rules (VFR).

c. Finalizing traffic advisory service system parameters and formats.

5.3.4 Schedule.

Figure 9 provides a detailed description of the advisory and resolution service subjective test schedule.

5.4 MULTISITE ATARS TESTS.

5.4.1 General.

The purpose of these tests is to determine the operational characteristics of the ATARS in a DABS network configuration and to validate the transfer of conflict table information between adjacent ATARS functions.

The ATARS coverage areas are arranged such that adjacent sites overlap. These areas of overlap are referred to as seam areas. If one or more aircraft in a conflict are located in a seam area, coordination is required between the two ATARS functions. This is accomplished by exchanging the appropriate conflict table information via the communication lines between the sites.

All intersite communications are handled for the ATARS by the DABS via the Common International Civil Aviation Organization (ICAO) Data Interchange Network (CIDIN) communications channel. The ATARS submodule outgoing conflict tables places seam conflict table information in the conflict table output buffer. The DABS module CIDIN OUT transfers the contents of this buffer to the outgoing communcations buffer, and from there it is transmitted over the communcations lines. Incoming messages arrive at the incoming communications buffer and are transferred to the incoming conflict table buffer by CIDIN IN, where they are accessed by the sub-module incoming conflict tables (see figure 10). Multisite testing will examine these ATARS functions for the actual exchange of the tables. The contents of the conflict tables will be examined later to determine their effectiveness in solving the conflict situation.

5.4.2 Technical Approach.

Two series of tests will be carried out on the multisite function of ATARS: verification tests and system tests. Verification tests will examine the ATARS capability of exchanging conflict table information between sites and the accuracy and timeliness of these transmissions. However, the validity of the data within the conflict tables, performance of the system at capacity load, and the ability of ATARS to convert incoming conflict table information to internal pointer format will not be addressed by these tests.

Specifically, the ATARS multisite function will be divided into five areas, each of which will be examined for accuracy and timeliness of performance. The timing aspect of these tests will be analyzed using the CPMS (appendix 1).

System tests (not discussed here) will be used to verify that maneuver commands issued by two adjacent ATARS functions during an aircraft's transition through a seam area are clear and consistent. These tests will be defined in a test plan to be published in mid-1980.

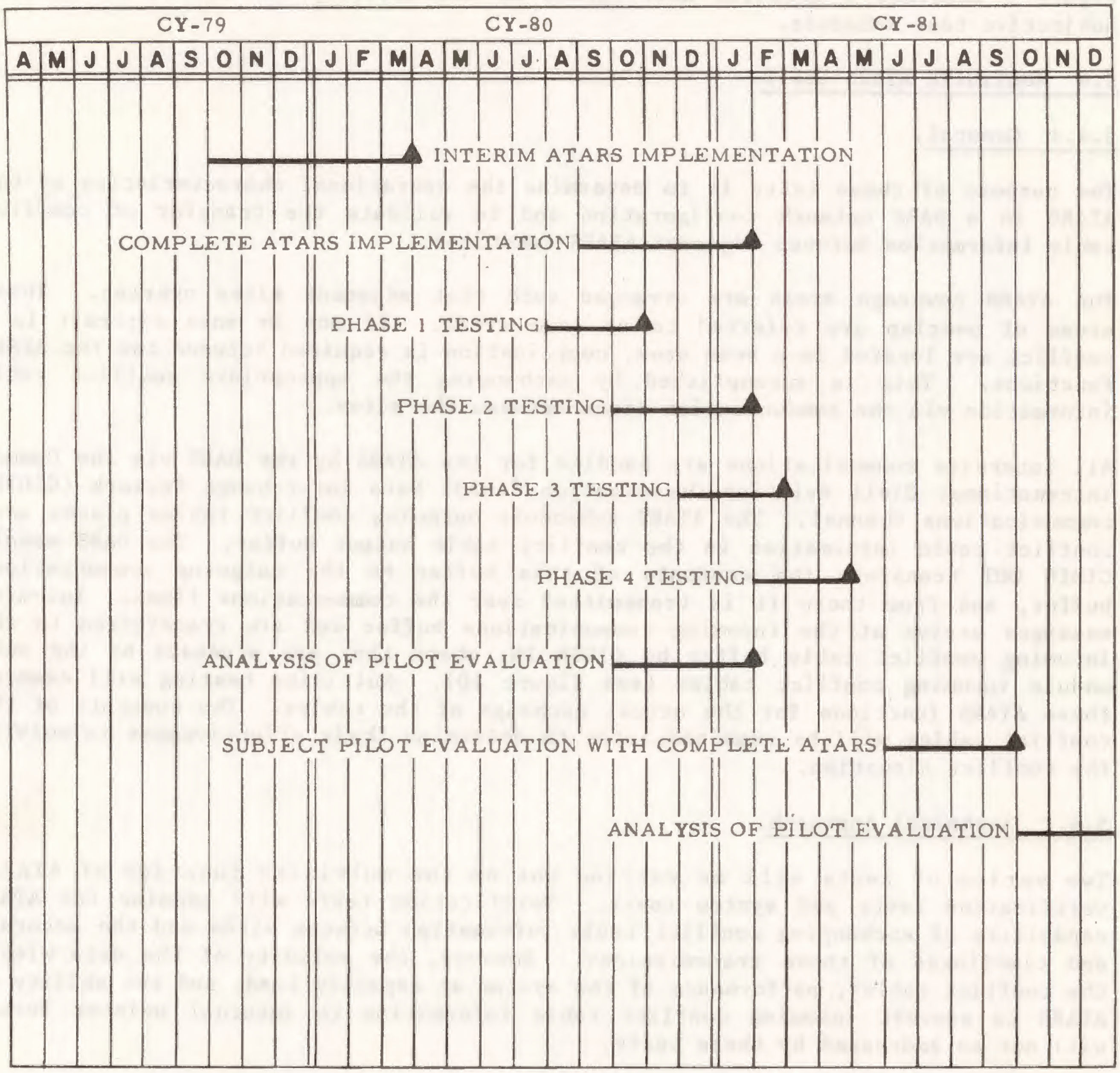

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FIGURE 9. ADVISORY AND RESOLUTION SERVICE SUBJECTIVE TEST SCHEDULE

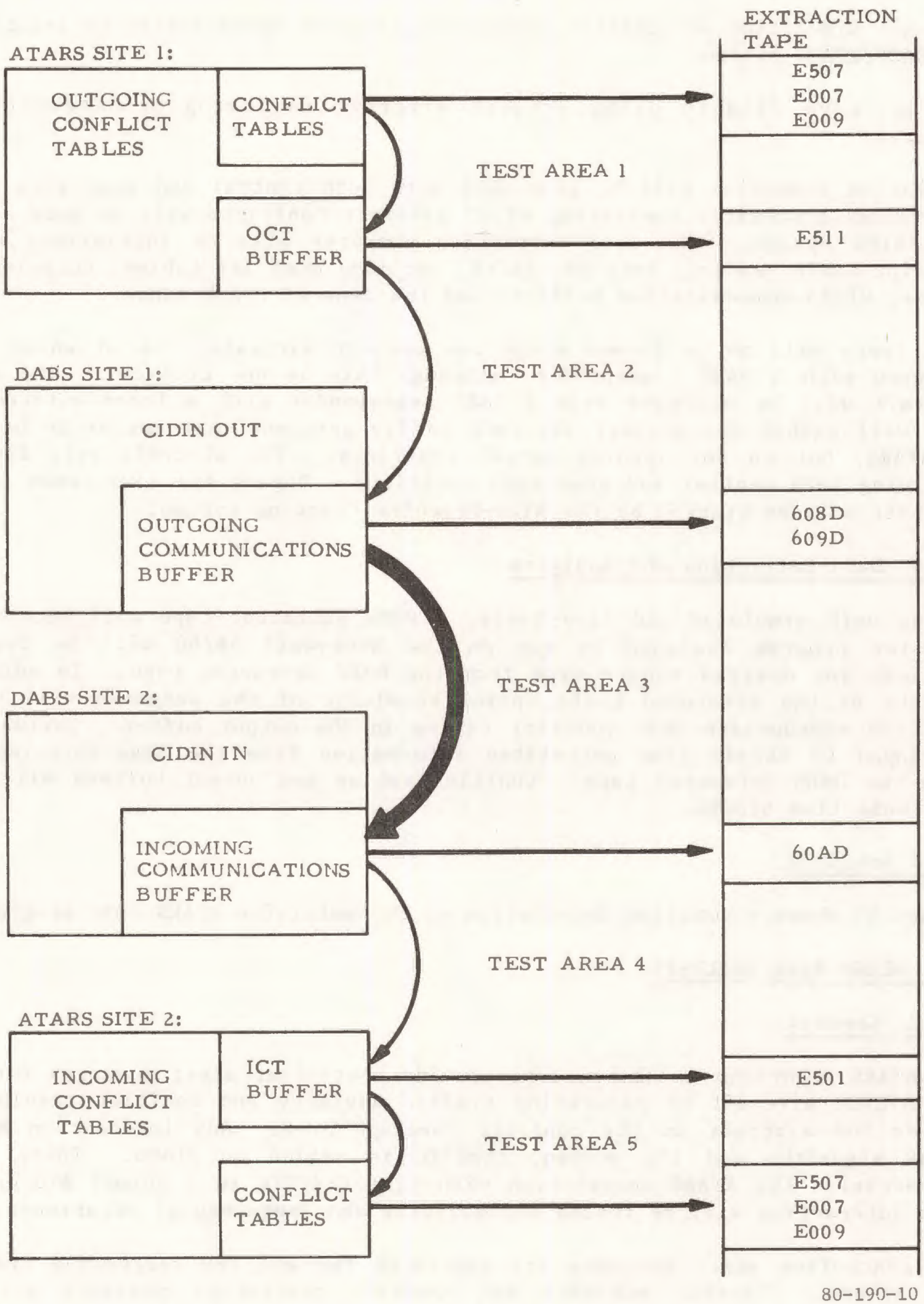

FIGURE 10. ATARS MULTISITE CONFLICT TABLE COMMUNICATIONS

Verification testing will consist of two approaches:

a. Simulation of conflict scenarios using the ARIES system to input data into the DABS/ATARS system.

b. Live flights using project aircraft following predetermined flight patterns.

Simulation scenarios will be generated with both central and seam area conflicts. An available scenario consisting of 27 aircraft conflicts will be used as input to the ARIES system. The data extraction computer will be initialized to collect conflict table headers, entries, pairs, incoming conflict tables, outgoing conflict tables, CIDIN communication buffers, and the central track store.

Live tests will be performed using two project aircraft, one of which should be equipped with a DABS transponder, although this is not critical. The other test aircraft will be equipped with a DABS transponder with a fixed altitude offset. This will enable the project aircraft to fly patterns that appear to be conflicts to ATARS, but do not involve actual conflicts. The aircraft will fly patterns involving both central and seam area conflicts. During the live tests the project aircraft will be tracked by the Nike-Hercules tracking system.

5.4.3 Data Collection and Analysis.

During both simulated and live tests, a DABS extractor tape will record data. A computer program designed to run on the Honeywell 66/60 will be developed to retrieve any desired record type from the DABS extractor tape. In analyzing the results of the simulated tests, prior knowledge of the scenario will be used to find the appropriate seam conflict tables in the output buffer. Software will be developed to obtain time correlated information from the Nike-Hercules tape and from the DABS extractor tape. Conflict tables and output buffers will be listed for these time blocks.

5.4.4 Schedule.

Figure 11 shows a detailed description of the multisite ATARS test program.

5.5 ALARM RATE ANALYSIS.

5.5.1 General.

The ATARS algorithm is designed to provide controller alert messages for both DABS and ATCRBS aircraft by generating traffic advisory and conflict resolution advisories for aircraft in the conflict coverage area. Any interaction between the ATARS algorithm and the present traffic is called an alarm. These tests will characterize the ATARS interaction with live traffic in a normal ATC environment. This interaction will be tested for validity and frequency of occurrence.

The controller alert messages are generated for all IFR controlled traffic: DABS and ATCRBS. Traffic advisory and conflict resolution messages are generated only for DABS traffic that is ATARS equipped. For ATCRBS replies, the IFR/VFR status is determined by the ATARS algorithm as follows:

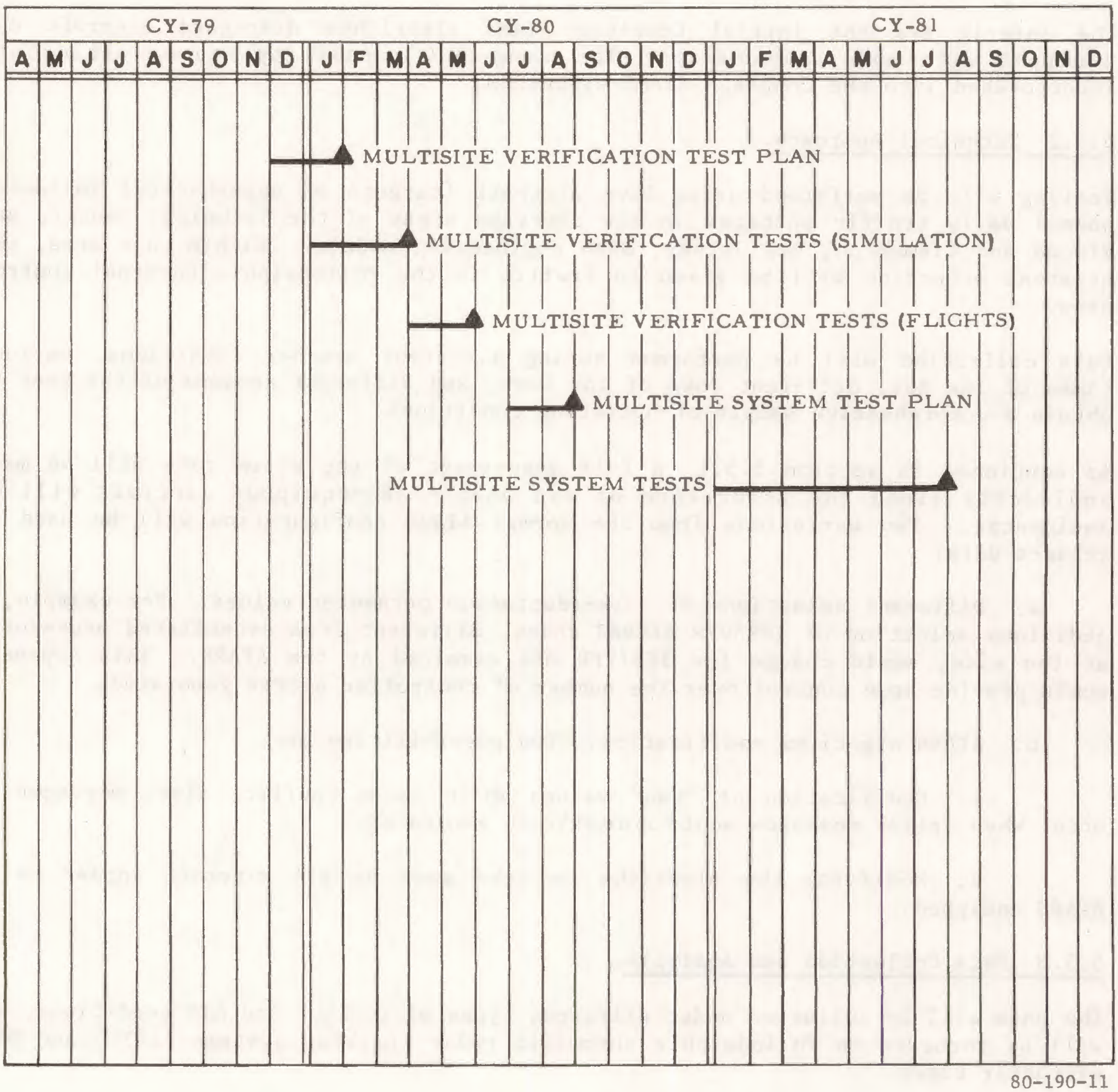

FIGURE 11. MULTISITE TEST SCHEDULE

a. VFR Status. All 1,200 codes and any ATCRBS codes identified as VFR in site adaptation.

b. IFR Status. All replies not designated VFR as per "a" above.

The Interim and the initial Complete ATARS algorithms disregard aircraft not equipped with mode C encoders. The nonmode C capability may be ultimately incorporated into the Complete ATARS algorithm.

5.5.2 Technical Approach.

Testing will be performed using live aircraft (targets of opportunity) following normal daily traffic patterns in the coverage areas of the Technical Center, and Elwood and Clementon, New Jersey, DABS engineering models. Within this area, the greatest attention will be given to traffic in the Philadelphia terminal control area.

Data collection will be performed during different weather conditions, various times of the day, different days of the week, and different seasons of the year to obtain a comprehensive sample of operating conditions.

As mentioned in section 5.5.1, a full assessment of the alarm rate will be made indirectly since the occurrence of the DABS/ATARS-equipped aircraft will be incidental. Two variations from the normal ATARS configuration will be used to collect data:

a. Different selections of site-adaptation parameter values. For example, a judicious selection of IFR/VFR ATCRBS codes, different from established procedures at the site, would change the IFR/VFR mix examined by the ATARS. This approach would provide some control over the number of controller alerts generated.

b. ATARS algorithm modification. Two possibilities are:

1. Modification of "tau" values which cause conflict alert messages to occur when uplink messages would normally be generated.

2. Modifying the algorithm to make some or all aircraft appear to be ATARS equipped.

5.5.3 Data Collection and Analysis.

The data will be collected under different types of weather and ATC conditions, and will be recorded on Philadelphia automatic radar tracking systems (ARTS) and DABS extractor tapes.

The extractor tapes will be reduced on the Technical Center's Honeywell 66/60 general purpose computer. The collection of data reduction programs that will be developed include:

a. A "quick look" program which will be run immediately after each test to determine the quality of the data collected.

b. A "summary statistics" program which will summarize the types and number of alarms during the test. The summary statistics will include the total number of alerts in the test series, the alert rate (number of alerts per hour), classification of alerts and validity of various types of alerts, and alert rate by area sector.

c. An "alarm summary" program which will plot the aircraft tracks before and after each alarm and summarize the DABS and ARTS performance test data. This program will also produce a conflict summary comparable to the MITRE Monte Carlo simulation summary.

Other computer software programs will be developed as additional requirements are identified. A detailed functional analysis will be performed on every alarm using the output from the "alarm summary" program. These results, together with ATC and weather condition information, and in some instances the ATC voice recordings, will be used in the analysis.

Monthly summaries of operation and periodical special studies will be prepared and published.

5.5.4 Schedule.

Figure 12 shows a detailed description of the alarm rate analysis test program schedule.

5.6 ATARS TERMINAL ATC SYSTEM TESTS.

5.6.1 General.

The majority of the system test areas are concerned with equipment evaluation (sections 5.1 through 5.2, 5.4 through 5.5). The remaining test areas (sections 5.3 and 5.6) are primarily concerned with the operation and upgrading of the man-machine interface involved in the ATARS system function (reference 17).

Knowledge and operational experience gained during testing will be used to identify the impact of ATARS on:

a. The controller's responsibilities.

b. ATC procedures.

c. Terminal ATC software development requirements.

These tests are intended to evaluate ATARS as an efficient, effective, and safe adjunct to the ATC system.

For IFR and certain controlled VFR aircraft, the primary responsibility for control and maintenance of separation lies with the controller at the ATC facility. In support of this controller responsibility, the DABS sensor makes available to the controller all relevant information it possesses: surveillance data, command notifications and previews, and the use of its data link. Communications between the ATC facility and the DABS is effected by means of an interface consisting of a one-way DABS-to-ATC ground communications link for surveillance reports and two-way ground communications for message exchange. The ground communications link can support information transfer in both directions, but information exchange is defined from terminal ATC to DABS only for protocol and surveillance-related

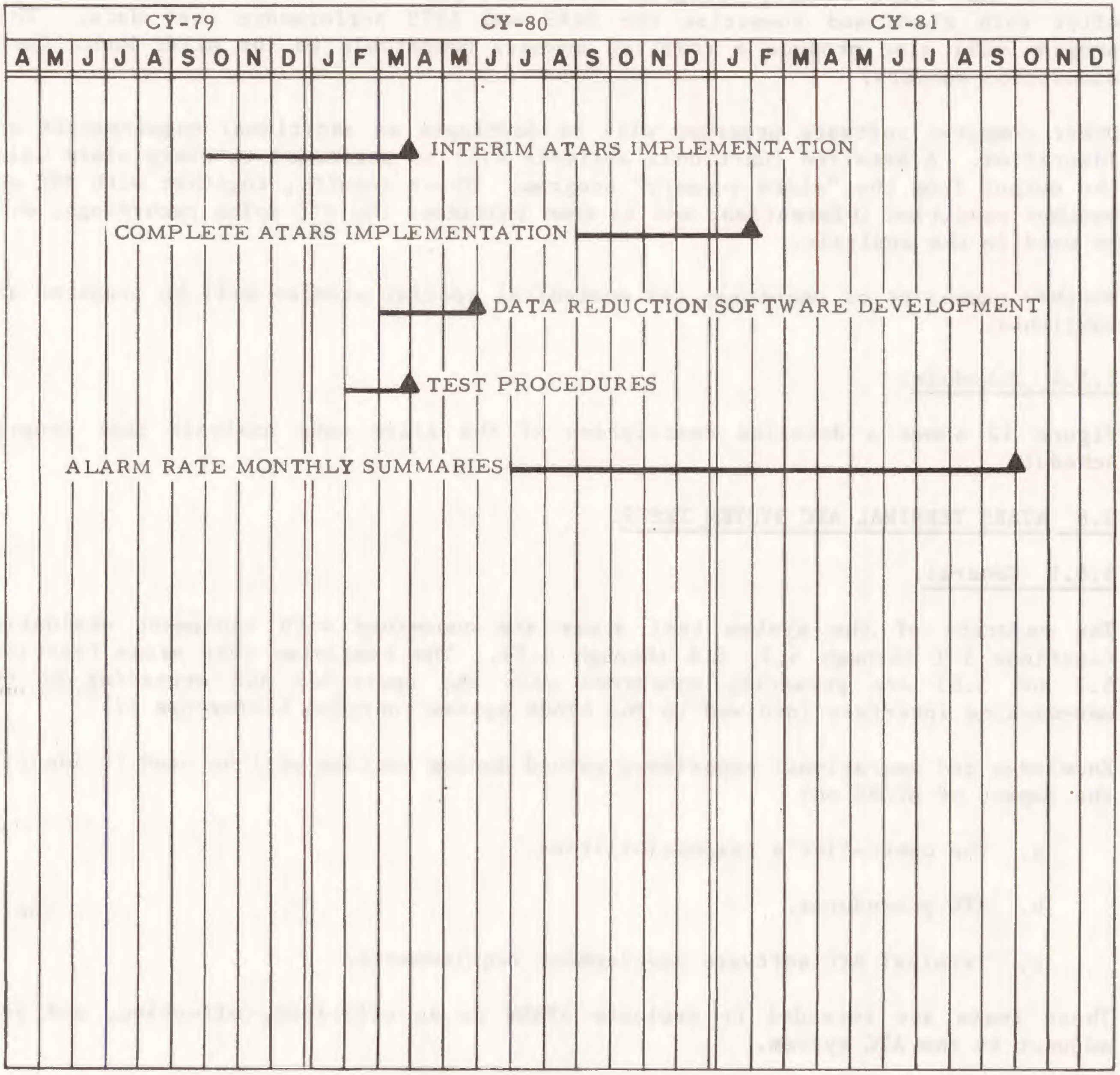

FIGURE 12. ALARM RATE TEST SCHEDULE

communications. As presently defined, the ATARS processing algorithms require only one-way communications (e.g., from the ATARS to terminal ATC).

Interaction between the ATARS and ATC facility takes place by means of an ATARS-generated message referred to as "controller alert message," which describes the state of a conflict between two aircraft.

ATARS will use logic that emulates the conflict alert function now operational at single-beacon ARTS III sites. The product of the ATARS conflict alert emulator is referred to as the "controller alert" to distinguish it from the ARTS-generated "conflict alert."

5.6.2 Technical Approach.

The initial test configuration is shown in figure 13. In this configuration DABS surveillance data, interrogations, and replies, will be supplied by a DABS sensor simulator which operates in response to a traffic scenario.

In one validation configuration (figure 14), the ATC Simulation Facility (ATCSF) will interface with an interactive ARIES. The ATCSF will produce target reports according to a prepared scenario as real-time inputs to ARIES. The ATCSF will respond, via a maneuver module, to ATARS commands generated by the DABS/ATARS engineering model (EM). The ATCSF pilot/computer interface will be identical to that of the initial test configuration (see figure 13).

The DABS surveillance functions, the ATARS algorithms, and the interface between DABS and ATARS will be precisely those of the engineering model, except for the software modifications required to service all interrogations and replies through an interactive ARIES. The surveillance and surveillance-related communication links between the EM and the Terminal Automation Test Facility (TATF), which exist for use with the terminal DABS/ATC technical tests, will be enhanced to allow for the communcation of ATARS information to the TATF.

The TATF software requirements for the ATARS/terminal ATC system validation tests will be the same as those for the initial configuration.

The validation configuration (ATCSF/EM/TATF) will be used in the later stages of ATARS/terminal ATC system tests to support results obtained from the initial configuration.

An independent consultant will assist in the preparation of test procedures, scenarios, and analysis methods. Test results will be presented as findings of fact and interpretation. Unsubstantiated statements of opinion will not be part of the report.

Reasonable suggestions, proposals, or ideas will be subjected to thorough testing to determine their efficiency, efficacy, and safety in the ATC system.

5.6.3 Data Collection and Analysis.

The DABS extractor tape of each test series will be saved. This will provide the capability of examining the procedure being tested in detail. In addition, there will be observer reports, operational notes, controller questionnaires, and debriefing summaries. For each test, this data will be maintained and catalogued.

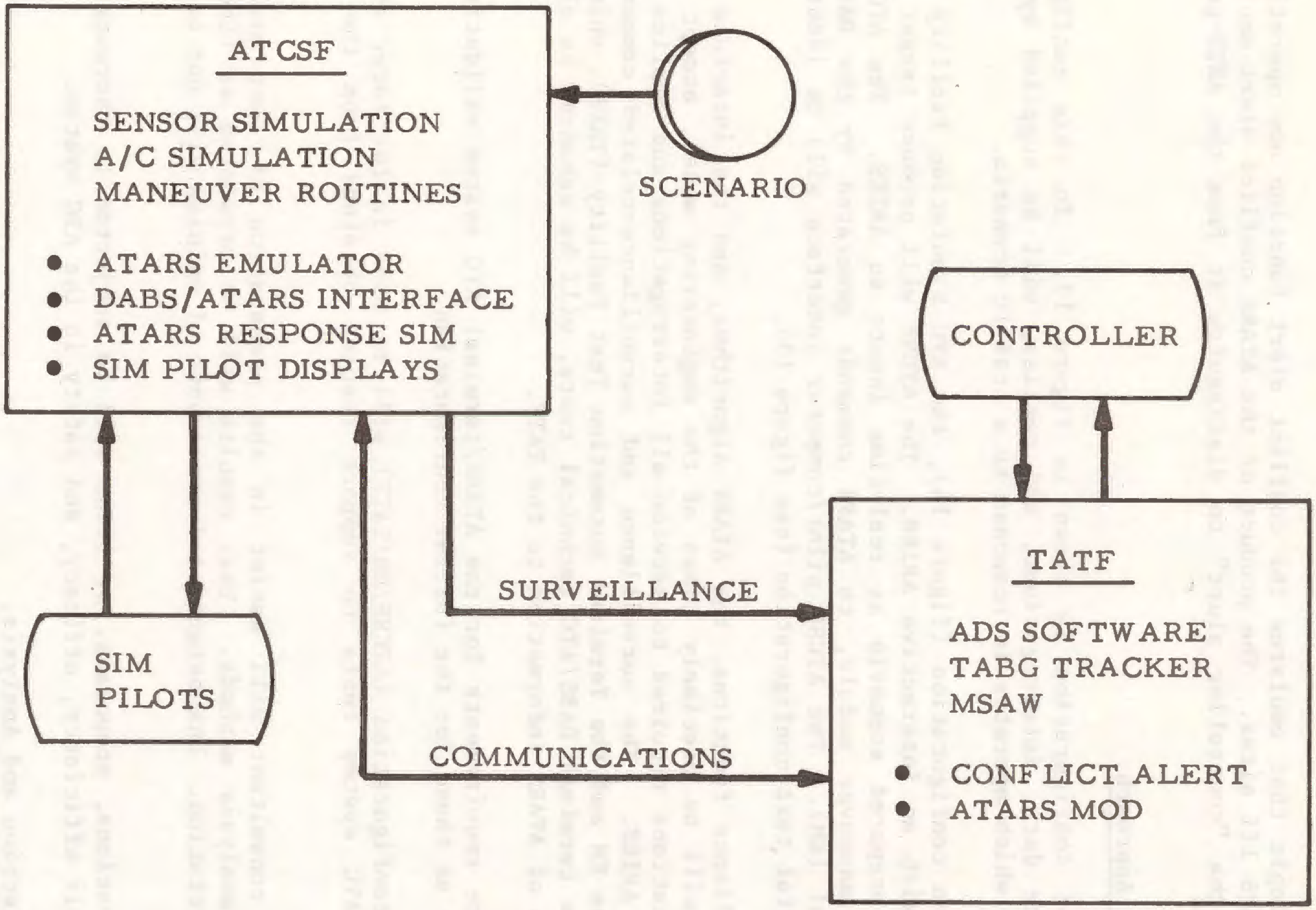

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FIGURE 13. PRINCIPAL TEST CONFIGURATION

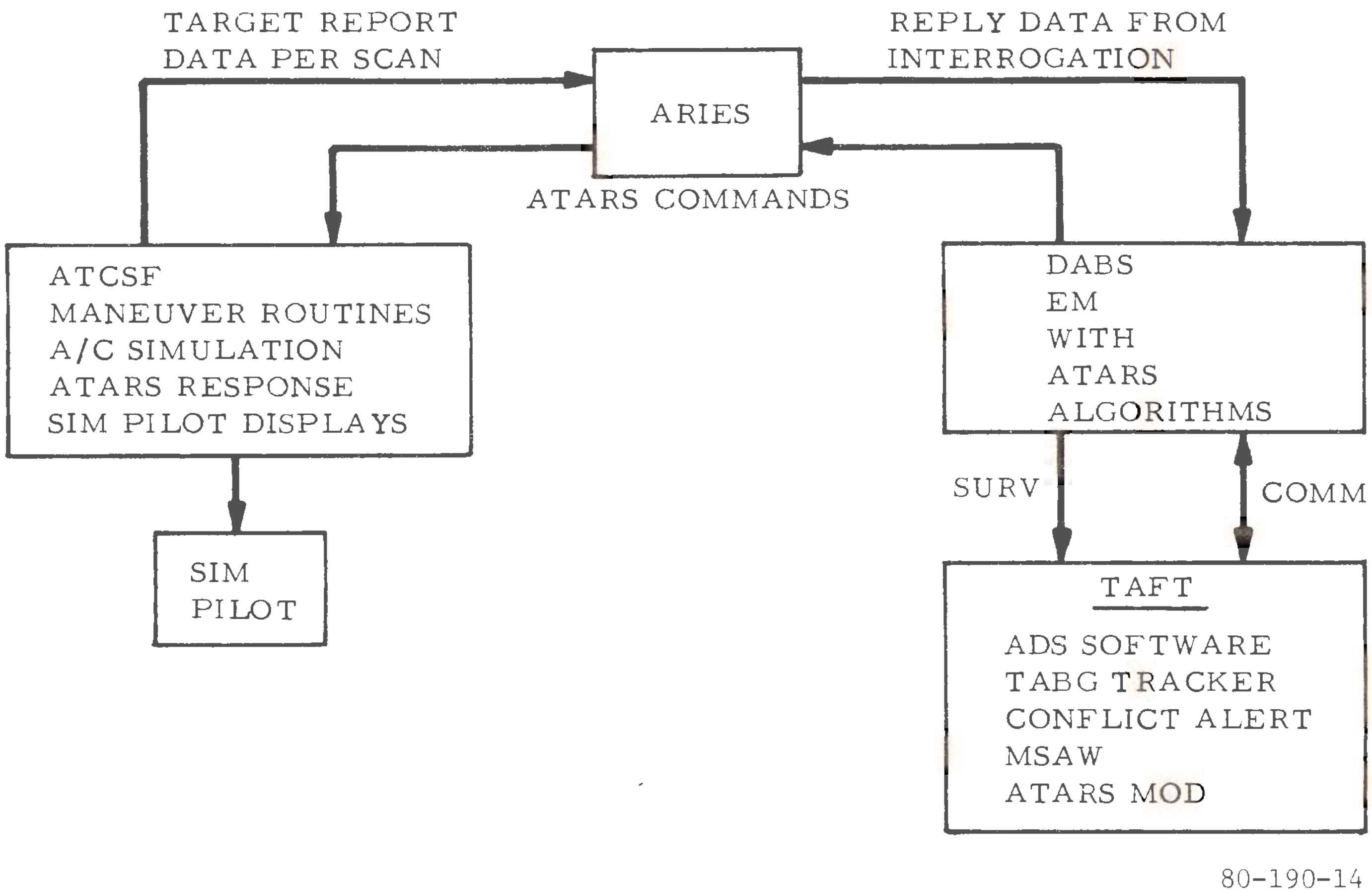

FIGURE 14. ATCSF/EM/TATF CONFIGURATION (VALIDATION)

Provisions will be made in the TATF software to allow for four test modes characterized by increasing amounts of information transfer from ATARS to terminal ATC. The information sent to the controller will vary from "no messages from ATARS" to a complete evolution of an encounter from warning to command.

The four proposed test modes are as follows:

a. No messages from ATARS. In this mode, the contents of the ATC controller alert message generated by ATARS are ignored by the ATC system. Automated controller aids in detecting conflicts are limited to the provisions of the ARTS conflict alert function.

b. Command notifications displayed in the ATC system. Pilot and controller, almost simultaneously, learn of a positive or negative command notification from ATARS.

c. Command notifications and controller alerts displayed in the ATC system. This mode alerts the controller to the acquisition of the encounter by ATARS in advance of a command to the pilot. This mode will be executed with the ARTS conflict alert (CA) function turned OFF, and again with conflict alert turned ON.

d. Controller alerts with command previews displayed in the ATC system. In this mode, the controller alert will be accompanied by a command preview, valid at the time the alert is issued. This mode will be executed with ARTS CA turned OFF, and again with CA turned ON.

Application tests will be run with the ATARS and the TATF configured with the Philadelphia and Atlanta TRACON adaptations. Realistic traffic samples compatible with the adaptation will be simulated. Traffic samples with varying traffic densities and varying percentages of DABS-equipped aircraft will be used. Runs will be made simulating IFR and VFR conditions.

A set of procedures for handling each encounter situation will be developed. Procedures will take the form of scripted pilot/controller exchanges, controller decisions, and pilot actions. Procedures will, most likely, be in a system error incident report format with supporting voice recordings, enhanced further by data reduction and analysis documentation.

For each test mode, all selected scenarios, together with their documented formal procedures, will be designated the "reference system design" and used in subsequent demonstrations and tests.

Certified Philadelphia and Atlanta controllers will work the same scenarios without prior knowledge of the script, having been briefed only on ATARS operation and the functional specifications of the baseline ARTS.

5.6.4 Schedule.

Figure 15 shows the schedule for the terminal ATC system/ATARS testing.

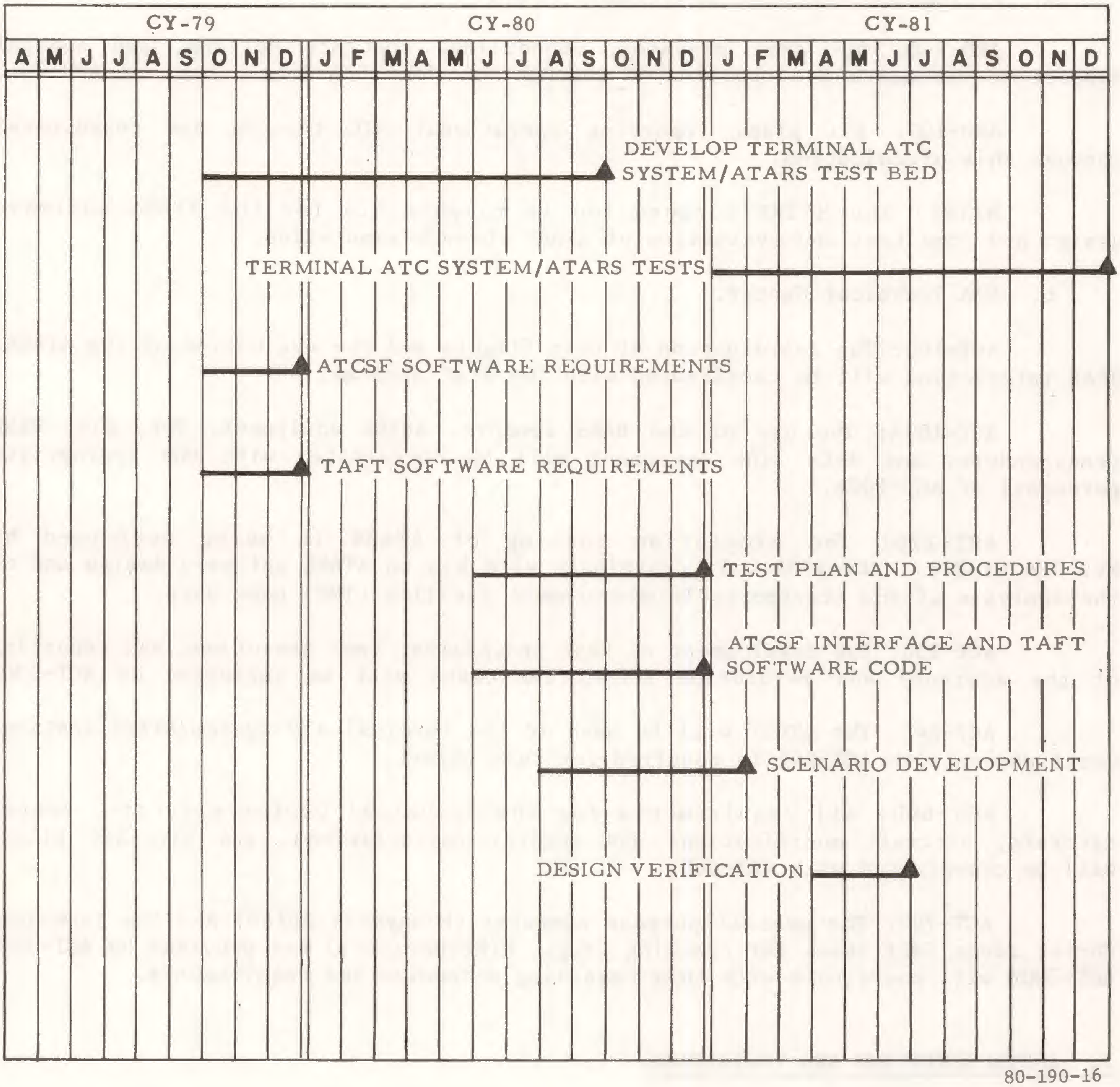

FIGURE 15. ATARS/TERMINAL ATC COMPATIBILITY TEST SCHEDULE

6. COORDINATION AND AREAS OF RESPONSIBILITY.

The various areas of responsibility and coordination requirements are explained individually.

a. System Research and Development (SRDS).

ARD-240: All test planning, scheduling, contract dollars, and special support requirements are coordinated through Dr. John Scardina, Chief of ARD-241.

ARD-100: All plans regarding operational ATC testing are coordinated through this organization.

MITRE: The MITRE Corporation is responsible for the ATARS software design and some test and evaluation of ATARS through simulation.

b. FAA Technical Center.

ACT-100: The coordination of test flights and the evaluation of the ATARS/BCAS interaction will be coordinated with the BCAS program.

ACT-100A: The use of the DABS sensors, ARIES equipment, PSE, STC, DABS transponders, and data link equipment will be coordinated with the appropriate personnel of ACT-100A.

ACT-220: The simulation testing of ATARS is being performed by Mr. Jim Windle. ACT-100A will coordinate with him on ATARS software design and on the analysis of the transportable measurement facility (TMF) tape data.

ACT-230: The development of test procedures, test execution, and reporting of the advisory and resolution subjective tests will be supported by ACT-230.

ACT-240: The ATCSF will be used in the terminal ATC system/ATARS testing. Coordination with ACT-242 is required for this effort.

ACT-600: All requirements for the Technical Center aircraft, rental aircraft, aircraft modifications and special installations, and aircraft pilots will be coordinated with ACT-600.

ACT-700: The general purpose computer (Honeywell 66/60) and the Technical Center range facilities for tracking (e.g., Nike-Hercules) are provided by ACT-700. ACT-700A will coordinate with them regarding schedules and requirements.

7. INSTRUMENTATION AND FACILITIES.

Several different types of instrumentation and facilities are required to support this project. A brief description of the requirements follows:

a. Instrumentation Requirements.

1. DABS and ATCRBS transponders, in some cases with fixed altitude, will be required for installation in test aircraft and fixed ground locations.

2. DABS data link displays and equipment will be required in test flights. Several different types of data link equipment will be delivered and each type must be made available for our testing.

3. VFR transmitters and receivers for use in air/ground coordination during test flights will be required.

4. The CPMS will be required in hardware capacity studies.

Each instrument tested will be maintained, serviced, and where appropriate, calibrated by the supplier.

b. Facilities.

1. Tracking of test aircraft by the Nike-Hercules tracking radar will be required. The output required is an unsmoothed, unedited tracking tape with aircraft location in latitude, longitude, and altitude above sea level.

2. The DABS sensors at the Technical Center, and Elwood and Clementon, New Jersey, and adjoined support equipment, including ARIES.

3. The general purpose computer (Honeywell 66/60) will be used throughout testing for data reduction, analysis, and test scenario development.

4. Two Technical Center aircraft will be required in most tests. The aircraft will be equipped with ATCRBS and DABS transponders, tracking transponders, special communication equipment as required, and DABS data link equipment.

5. Two rental aircraft will be required for the subjective testing. They will be equipped with a DABS transponder and DABS data link equipment.

6. The TATF and ATCSF will be required in the ATC/ATARS testing. The TATF will also be required for some multisite testing.

c. New York Air Route Traffic Control Center (ARTCC).

1. All test flights which are above 5,000 feet will be coordinated with the New York ARTCC. Complex tests may require that a Technical Center representative be on site during testing.

d. Approach Control.

1. All test flights are planned to be in the Technical Center area. Tests in this area will require coordination with some or all of the following approach controls: Philadelphia, Dover, McGuire, and Atlantic City.

8. SCHEDULE.

Figure 16 is a graph indicating the duration of each part of the project.

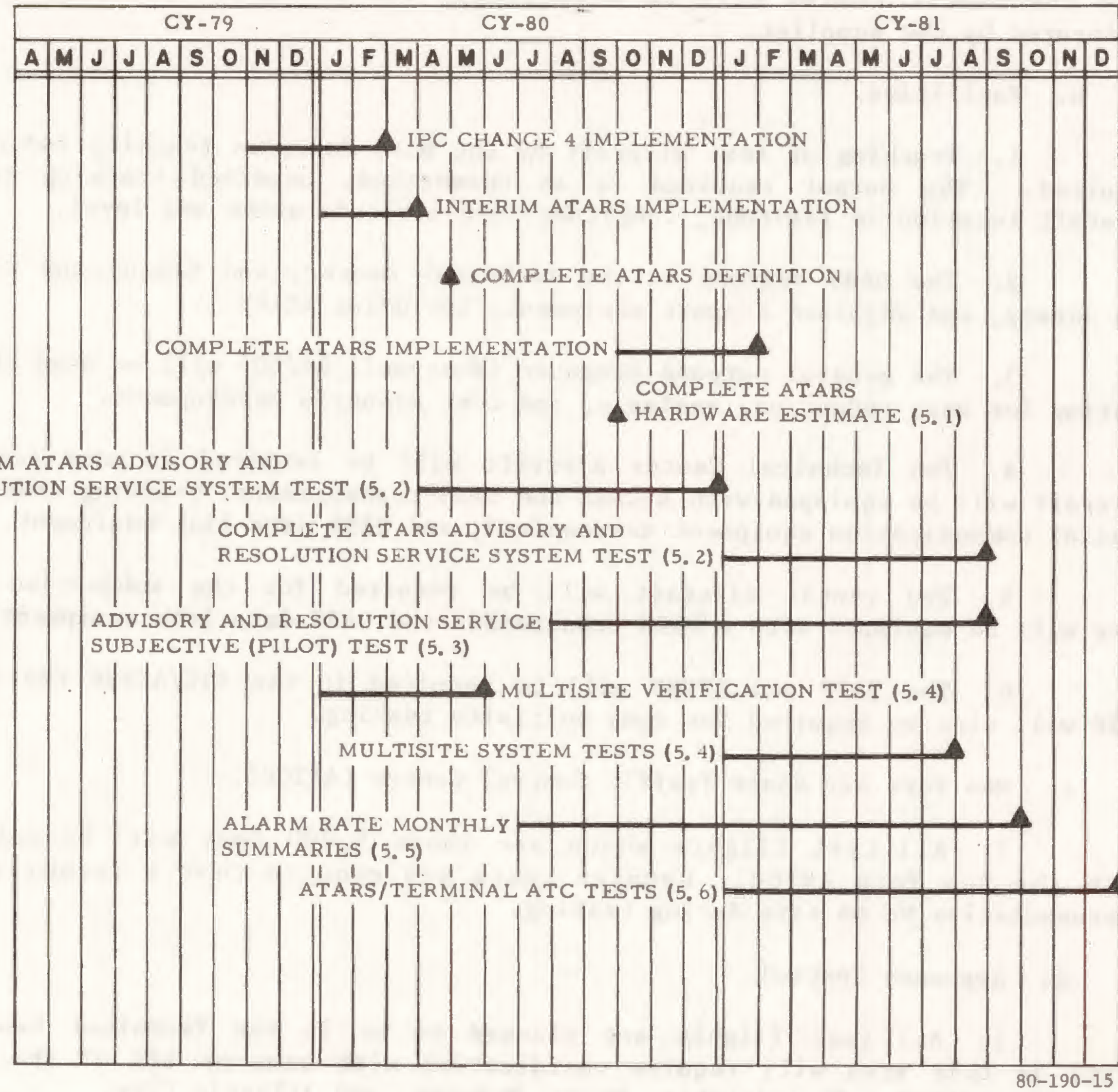

FIGURE 16. ATARS COORDINATION SCHEDULE

APPENDIX A--THE CAPACITY DRIVER

The capacity driver is a computer program that resides in the DABS computers. Its purpose is to provide simulated DABS input to the ATARS system that will exercise ATARS at its capacity limit as defined in the DABS engineering requirement, section 3.4.9.4 (reference 14). The capacity driver replaces portions of the DABS software in the computers. Therefore, the ATARS is tested in isolation from its environment: the effect of a capacity load on the interaction between the DABS and the ATARS cannot be tested using this technique.

The capacity driver software is located on the DABS load tape and will be loaded following the loading of the DABS/ATARS software. Loading procedures for the capacity driver input scenario tape are the same as those for DABS replay mode.

The following is an excerpt from the ARCON Technical Report, "Tape Format for Capacity Simulator Input Data" (reference 5).

A1. TAPE FORMAT FOR CAPACITY SIMULATOR INPUT DATA.

A1.1 INTRODUCTION.

The capacity simulator input tape shall consist of fixed-length, 1,000-word physical records. The first two physical records will contain header information. The remaining physical records will each contain 200 equal-length, five-word logical records representing target reports. The formats for the first two physical records and the format for target report physical records will be given here.

A1.2 HEADER FORMAT.

a. Physical record number 1 (1,000 words):

Words (1. . .30): Title of run (ASCII).

Word (31): Total number of input aircraft for the run, (maximum = 400).

Word (32): Desired duration of scenario in seconds, with LSB (least significant bit) = 1/16 seconds (s) (maximum = 1,800 seconds).

Word (33): For the first input aircraft:

Where:

RSP (pilot response flag) = 00 for NO RESPONSE
= 01 for WILCO
= 10 for UNABLE

IET = 1 for ATARS equipped DABS aircraft.
= 0 for not equipped DABS aircraft and all ATCRBS aircraft.

IFR = 1 for IFR aircraft.
= 0 for VFR aircraft.

DAB = 1 for DABS aircraft.
= 0 for ATCRBS aircraft.

DIT = DABS CODE (0-7) for a DABS aircraft.
= 0 otherwise.

Word (34): For the first input aircraft:

= DABS CODE (8-23) for a DABS aircraft.
= ATCRBS CODE (0-11), right justified, with zero fill, for an ATCRBS aircraft.

Words (35. . .1,000):

Repeat the format of words 33 and 34 for each additional input aircraft (numbers 2 through N) after which the remaining (1,000-32-2*N) words shall be made all zeroes.

b. Physical record number 2 (1,000 words):

Words (1. . .N):

= pilot command response delay time in seconds with LSB = 1/16 s (when RSP = 1 or 2).
= 1800 s with LSB = 1/16 s (when RSP = 0).

Words (N + 1. . .1,000):

= 0

A1.3 TARGET REPORT PHYSICAL RECORDS (1,000 WORDS EACH).

a. Logical Record (1):

Word (1):

Where:

NLT = 1 for a null report (miss) to suppress a report.
= 0 otherwise.

STT = 1 for an initiate track report (first report only) (NLT = 0).
= 0 otherwise.

DRT = 1 for a drop track report (last report only); also set NLT = 1 for a drop track report.
= 0 otherwise.

TRK = the aircraft surveillance file number for report (must agree with input aircraft number).

Word (2), RHO:

= the two-way sensor aircraft slant range in range units (RU) where 1 RU = 61.456 feet (ft).
= LSB.

Word (3), ANG:

= the aircraft azimuth, clockwise from the north mark, in azimuth units (AU's) where 1 AU = 360°/16,384 = 0.022° = LSB.

Word (4), ALT:

= the aircraft mode C altitude in units of 100 feet.

Word (5), TIM:

= time relative to run start in seconds when report occurs for the aircraft at position (RHO, ANG, ALT) with LSB = 1/16 s.

b. Logical Records (2. . .200):

Words (6. . .1,000):

Repeat the format of logical record 1 for each additional target report until the physical record is full. All target reports in a physical record must be ordered in increasing time (TIM) order.

The process of filling physical records should continue until a TIM appears in a target report which is equal to or exceeds the scenario duration time in word 32 of tape physical record 1. At this point, the rest of the physical record being written should be zeroed out and no more need be written. It is implied here that each successive physical record occurs in TIM order as do the target reports within a physical record.

APPENDIX B. AIRCRAFT REPLY AND INTERFERENCE ENVIRONMENT SIMULATOR

The following is an exerpt from the Lincoln Laboratory Project Report, "The Aircraft Reply and Interference Environment Simulator (ARIES), Volume 1: Principles of Operation" (reference 15).

B1. INTRODUCTION AND SYSTEM OVERVIEW.

B1.1 INTRODUCTION.

The Aircraft Reply and Interference Environment Simulator (ARIES) is designed to simulate a radar beacon environment of up to 400 transponders, plus high rates of interfering beacon replies ("fruit") for the purpose of testing the operation of beacon interrogators under heavy load. In particular, the ARIES is designed to test a new class of interrogators being developed for the Federal Aviation Administration as part of the Discrete Address Beacon System (DABS). In this document these will be called "sensors."

DABS provides increased capacity, better azimuth measurement precision, and reduced interference between sensors due to reduced interrogation rates, as compared with the current beacon system (the Air Traffic Control Radar Beacon System--ATCRBS). In addition, for aircraft equipped with DABS transponders, the system provides ground-to-air and air-to-ground data transmission capabilities which are the basis for future automation of various air traffic control functions.

Due to the large target capacity of a DABS sensor, it is not possible to find a current air traffic environment that is dense enough to fully test it under heavy load conditions. (DABS has been designed for the anticipated worst case environments of the 1980's and beyond.) Furthermore, there currently exist only a few DABS transponders, so it is not possible to provide any significant loading of the DABS. The complexity of a DABS sensor precludes simply extrapolating performance from a less dense benchmark test. For this reason, and the desire to be able to repeat the identical test several times, an environment simulator has been built which appears to the sensor under test to be a dense beacon environment, plus a dense interference environment typical of what might be encountered in the future. The ARIES is intended to provide this environment during the test and evaluation phase of the DABS development program. It can also provide a long term capability of being able to recreate various scenarios for purposes of continued sensor software development and debugging (the ARIES is intended primarily to provide a load test for the DABS sensor; it is not designed to be able to test all the system features of a DABS sensor). Capabilities which are costly to implement, and have little effect on the sensor's behavior under load, have not been implemented. Those capabilities which have been implemented can, of course, be used for general system testing whether heavily loaded or not. A large portion of the DABS sensor can be tested in this fashion.

The ARIES equipment consists of interrogation receiving circuitry, reply generation circuitry, and a computer and associated peripheral equipment to control the system. This equipment is housed in two standard racks.

B1.2 THE ARIES SYSTEM SUMMARY.

B1.2.1 Capabilities.

The ARIES is capable of simulating a beacon environment of up to 400 transponders. There can be any mix of ATCRBS and DABS transponders. Not all DABS interrogation and reply types are handled. Those that are handled and the special data bit protocols that are simulated are described in section B1.2.2.2.

Along with simulated traffic, the ARIES can generate a simulated fruit environment. The arrival times of fruit replies are not based on the traffic model. To do this would also require modeling the nearby interrogators that cause these interferring replies to be generated. Instead, fruit is modeled as a random process with Poisson statistics. The operator can control the average fruit rate by setting parameters in a file on the system disk.

For both the simulated transponder (controlled) replies and fruit replies, the ARIES provides the necessary signals to accurately simulate the monopulse off-boresight angle. Also, an omnidirectional signal is provided so that side-lobe replies can be simulated. These signals are connected to the DABS sensor via an interface specific to the ARIES. Inside the sensor they are summed with similar signals from the sensor's own antenna. This allows a simulated environment to be superimposed on a live environment, if desired.

In addition to the beacon data, the ARIES provides simulated digitized radar data in the output format of a production common digitizer (PCD). The radar targets correspond to the simulated beacon targets. The reported coordinates are those that would be seen by a primary radar whose antenna rotates with the beacon antenna about the same axis.

Finally, the ARIES is also capable of multisite operation, in order to exercise the multisite network aspects of DABS. This is accomplished by locating an ARIES at each sensor site. The traffic model at each site is coordinate adjusted so that each sensor sees a view of the environment consistent with that of the other sensors. The ARIES sites are linked by communications lines which allow them to maintain time synchronization and consistent transponder internal state data for DABS targets that can be seen by more than one site.

Each of the above mentioned features of the ARIES is described in more detail in the following sections.

B1.2.2 Simulated Transponders.

B1.2.2.1 Interrogation/Reply Cycle.

Interrogations are received by the ARIES from the DABS sensor at 1030 megahertz (MHz) and processed by the receiver circuitry. The receiver transfers a data block to the computer giving the type of interrogation, the time of arrival, the boresight azimuth of the antenna, whether the interrogation was a front antenna or back antenna interrogation, and any data content. The azimuth data is provided by the azimuth decoder/simulator which can operate in either of two modes. In the decoder mode, azimuth change pulses (ACP's) and azimuth reference pulses (ARP's) are received from the sensor's antenna system, and used to increment and reset an azimuth register, respectively. The ACP's and ARP's are then "daisy-chained" back to the sensor. In effect, the ARIES is inserted into these lines between the antenna and the sensor. In the simulator mode, ACP's and ARP's are produced by the ARIES and sent to the sensor. ACP's and ARP's from the antenna, if an antenna is connected, are ignored. Thus, the ARIES can be run with a sensor that is not connected to an antenna system. The decoder mode is needed for the case where live data from the sensor's own antenna and simulated data from the ARIES are to be superimposed.

B1.2.2.2 Interrogation and Reply Types Handled by ARIES.

The ARIES is capable of processing both mode A and mode C ATCRBS/All-Call interrogations. (The system software is not designed to process ATCRBS interrogations without the P4 pulse. The reply modes, as mentioned above, are mode A or mode C ATCRBS replies from simulated ATCRBS transponders and All-Call replies from DABS transponders. ARIES is not capable of simulating military emergency codes, which consist of several sequential ATCRBS replies.

B1.2.2.3 Radar Report Generation.

As targets in the ARIES track file enter the antenna beam, a simulated radar report is prepared for them by the computer. The range and azimuth coordinates are used to generate the beacon reports. This data is transferred to the radar report generator, which outputs the data to the sensor in a format identical to that of the output interface of a PCD. The data is transferred to the sensor just after the targets have left the beam.

A system-wide blip/scan ratio can be specified by the operator and, in conjunction with the random number generator, is used to determine whether a given target will have a radar report on a given scan.

The interface is capable of transferring over 120 target reports per second.

B1.2.2.4 Fruit Reply Generation.

The ARIES is capable of generating ATCRBS fruit replies at rates up to about 50,000 replies per second. No DABS fruit is generated, although an independent fruit generator does exist. These high rates are required to test the performance of the DABS sensor's reply processing circuitry at the interference levels at which it is capable of operating. Because of the high rates required, the entire reply generation process is performed in hardware. The computer specifies to the fruit generator the average fruit rate desired, the fraction of the replies that are to appear in the main lobe as opposed to the side lobes, a particular ATCRBS reply code, and the fraction of replies that is to have this code. The latter two items allow a particular code to be emphasized in the otherwise randomly generated stream of reply codes. One likely candidate for emphasis might be, for example, the nondiscrete visual flight rules (VFR) code 1200.

B1.2.2.5 The Traffic Model.

The traffic model is stored on the system disk. Each logical record specifies the position and velocity of one aircraft at a particular time, as well as such items as its altitude and identity codes and those items of state information mentioned in B1.2.2.2 as being controlled by the traffic model. These records are sorted in increasing time order.

The data in the traffic model can be created in a variety of ways. However, for purposes of system tests of the DABS sensor, the Los Angeles Basin standard traffic model for 1982 will be used. Report FAA-RD-73-86 and the references mentioned in that document describe the generation and format of this model. A program has been written which will take any model in the format of the Los Angeles model and convert it to the appropriate format for input to the ARIES. This program also allows the user to control certain transponder state information (i.e., the downlink request bit, the pilot acknowledgement bits, etc.). Options are provided for generating these either randomly or under user control on a target-by-target basis.

B1.2.2.6 Multisite Operation.

In order to exercise a network of DABS sensors, an ARIES must be located at the Technical Center and Elwood DABS sensors. These ARIES sites are then connected together by means of telephone links. The links are required for two purposes. First, they are needed in order to start the simulations in synchronism at all sites and to verify that this synchronism is being maintained. Second, DABS transponders have certain states (i.e., lockout) that are controlled by interrogations from the sensor and cannot be precomputed as part of the traffic model. If a transponder is visible to more than one site it is necessary to assure that this state information is consistent among all sites. Therefore, if a transponder is told to lockout All-Call interrogations at one site, the ARIES at that site will inform all other ARIES of this occurrence so that the transponder appears to be locked out at all sites.

B1.2.2.7 Data Recording.

The ARIES records a limited amount of data in real time, primarily for debugging purposes. However, data are recorded indicating which targets replied to any ATCRBS/All-Call interrogation and whether or not a reply was generated for each discrete interrogation (and if not, why not). More extensive recording is available for a limited number of targets. This includes a record of all targets that were considered for an ATCRBS/All-Call reply and, if they did not reply, an indication of why. For DABS targets, all of the interrogation data block, except the unused message fields and the entire reply block, are recorded. Thus, a significant amount of information is available about the interrogations transmitted by the sensor and the replies that were generated by ARIES. This could potentially be used in analyzing the sensor's performance.

These data are normally recorded on magnetic tape. However, there is an option to record on the disk. Due to the limited size of the disk file allocated for this purpose, only a few minutes of recording of a dense environment is possible. If the recording process reaches the end of the file it moves back to the beginning of the disk file and begins overwriting the old data.

APPENDIX C. COMPUTER PERFORMANCE MEASUREMENT SYSTEM (CPMS)

The CPMS consists of a Digital Equipment Corporation PDP-11/55 minicomputer and a set of hardware probes to interface with the DABS computers. This interface consists of 12 probes monitoring the DABS address lines and 16 probes monitoring the global TILINES. CPMS data are recorded on an associated magnetic tape unit.

The CPMS requires as input a start address and stop address for each probe and a cycle period for the entire system.

During each of the cycle periods the CPMS will provide the following information for each address probe:

a. Elapsed time sample. This is the amount of time between the execution of the start address and stop address for only the first occurrence of the pair.

b. Elapsed time accumulator. This is the total time spent between the start and stop times for all occurrences of the pair during the cycle period.

c. Address iteration count. This is a count of the number of times the start address was executed, the number of times the stop address was executed, or the number of times the start/stop pair was executed.

d. Address sample. This is the first valid address to appear in the address lines during the cycle period.

For each TILINE probe the CPMS will provide elapsed time sample, iteration count, and elapsed time accumulator.

A description of the CPMS data formats is shown in figures C1 and C2.

SIX TIE-LINE PROBES

<table>
<tr><td colspan="5">KEY (5)</td><td>E.T.S. (11)</td></tr>
<tr><td colspan="6">ITERATIONS (16)</td></tr>
<tr><td colspan="6">E.T.A. (24) LSB</td></tr>
<tr><td>A</td><td>B</td><td>C</td><td>D</td><td></td><td>E.T.A. MSB</td></tr>
</table>

A - LEAD EDGE BUT NO TRAIL EDGE (E.T.S.)

B - OVERFLOW ON ONE TIME SAMPLE (E.T.S.)

C - 100% HIGH (E.T.S. AND E.T.A.)

D - E.T.A. IN PROGRESS AT END OF CYCLE

	LSB	MAXIMUM
E.T.S. - ELAPSED TIME SAMPLE	25 ns	51 µs
- ITERATIONS	16 BITS	64K
E.T.A. - ELAPSED TIME ACCUMULATOR	25 ns	400 ms

FIGURE C1. CPMS DATA FORMAT

TWELVE ADDRESS PROBES

<table>
<tr><td colspan="3">KEY (5)</td><td colspan="2">C.T.S. (11)</td></tr>
<tr><td colspan="5">E.T.A. (16)</td></tr>
<tr><td colspan="5">ADDRESS SAMPLE (16)</td></tr>
<tr><td>B</td><td>C</td><td>A</td><td colspan="2">A.I.C. (13)</td></tr>
</table>

A - LEAD EDGE BUT NO TRAIL EDGE (E.T.S.)

B - OVERFLOW ON ONE TIME SAMPLE (E.T.S.)

C - 100% HIGH (E.T.S. AND E.T.A.)

	LSB	MAXIMUM
E.T.S. - ELAPSED TIME WITHIN ADDRESSES	1 μs	2 ms
- ADDRESS SAMPLE	16 BITS	64K
A.I.C. - ADDRESS ITERATION COUNT	13 BITS	8K
E.T.A. - ELAPSED TIME ACCUMULATOR	1 μs	64 ms

A.I.C. MODES

1.	START ADDRESS	10
2.	STOP ADDRESS	11
3.	START/STOP ADDRESS PAIRS	00 OR 01

FIGURE C2. CPMS DATA FORMAT

APPENDIX D. RESPONSIVE SIMULATOR

The following is an excerpt from the ARCON Technical Report, "DABS Aircraft Target Simulator for ATARS--Functional Specification" (reference 3).

D1. INTRODUCTION.

The purpose of the aircraft target simulator is to provide target reports to the Automatic Traffic Advisory and Resolution Service (ATARS) software. The intent is to test as much of the ATARS logic as possible, in a controlled environment, with an accessible and easy to use method. The simulator will be able to test many situations, and do it in a shorter time span than otherwise would have been possible.

The simulator software will exercise the correlation and tracking logic and the conflict detection and resolution logic of the ATARS software. Additionally, the response of the ATARS software to certain failure conditions can be tested. This includes failure of the ATARS to receive target reports in certain user-defined intervals, failure of an aircraft to comply with ATARS positive commands, and failure of a pilot to reply to the receipt of an ATARS positive command. The simulator will perform the above for the single site case.

The simulator software will establish user selected initial flight paths for up to 30 aircraft. Aircraft will follow these predefined flight paths unless ATARS produces a positive avoidance command such as: climb, dive, turn right, turn left and dive. At this point, aircraft designated as compliant by the user will execute the appropriate ATARS maneuver until command issuance stops, ending the command period. Aircraft labeled as noncompliant by the user will obey the original flight plan. After an ATARS command period, an aircraft will level off and maintain its heading and ground speed until another ATARS command is received or the user defined scenario end time is exceeded. The simulator will provide a real time aircraft target acquisition and test tool with high flexibility and usefulness.

D1.2 DESCRIPTION.

D1.2.1 Discrete Address Beacon System (DABS)/Air Traffic Control Radar Beacon System (ATCRBS) Aircraft (Equipped/Unequipped).

The simulator will differentiate between DABS and ATCRBS aircraft as they relate to different correlation procedures in the ATARS tracking logic. Additionally, it will allow for "equipped" and "unequipped" designations for each aircraft relating, respectively, to the presence or absence of an ATARS display. This classification is used by ATARS to select the appropriate collision avoidance method. DABS aircraft can be either equipped or nonequipped. ATCRBS aircraft are always designated as nonequipped. The simulator will not be able to handle aircraft without altitude reporting capability, nor aircraft associated only with radar returns (aircraft not equipped with transponders).

D1.2.2 Visual Flight Rules (VFR)/Instrument Flight Rules (IFR) Aircraft.

The simulator will be able to distinguish between VFR and IFR aircraft during the simulation tests and shall be able to generate VFR/VFR, VFR/IFR, and IFR/IFR encounters to be handled by ATARS.

D1.2.3 Compliant/Noncompliant Aircraft.

The simulator will be able to label each aircraft as being compliant or noncompliant, based on user inputs previous to a run. The compliant aircraft shall execute maneuvers in accordance with positive ATARS commands. Noncompliant aircraft will maintain their predefined courses.

D1.2.4 Pilot Response Status (WILCO, UNABLE, NO RESPONSE).

The simulator will accept a user input value indicating the pilot response status for each aircraft. The possible replies are WILCO, UNABLE, and NO/RESPONSE. One use of this facility is to treat the case where two equipped aircraft are in conflict and no timely pilot reply is received from one of the aircraft under ATARS control. Thus, a test can be made of the special ATARS resolution logic utilized in this case for the issuance of additional commands to the second aircraft.

D1.2.5 Target Report Suppression.

The user of the simulator will be able to suppress the generation of target reports for an aircraft for a specified time window. The ability of the ATARS logic to "coast" a track may, thus, be examined.

D1.2.6 Target Aircraft Capacity.

The simulator will initially allow for up to 30 aircraft as inputs to a test run. This provides a software test environment for encounters involving more than two aircraft, as well as for possible simultaneous encounter problems. The total number of aircraft that can be handled can be expandable upward from 30, if desired. In fact, an ATARS "capacity" test run is anticipated where up to 400 simultaneous flight plans will be inputted.

D1.2.7 Implementation.

The aircraft simulator will be written in structured FORTRAN. It will also be entered into the data base registry program which was developed by Texas Instruments (TI), Incorporated. This will give the program access to the data base necessary for it to carry out its functions. This will be accomplished by incorporating it into the mission software where it will reside on an available DABS computer. The simulator will be complied, link edited, and given the address of the above DABS computer where it will be executed.

D1.3 INPUTS AND UNITS.

A description of simulator inputs followed by a listing of the units for data input is presented in the following sections.

D1.3.1 For Each Aircraft n.

a. Initial state vector

(x_{In}), (y_{In}), (z_{In}), (t_{In}), $(\dot{x}_{In})$, $(\dot{y}_{In})$, $(\dot{z}_{In})$

Note: (t_{In}) is $\geq$ 0. and is relative to the scenario start time ($t=t_o$).

b. Complete initial flight plan specified by segmentally inputting in the order of their occurrence a series of path segments of two types:

Type 1. For flight path segments which are linear and for which the velocity is constant. The values needed for such a segment are:

A/C No.	Seg. Type	Seg. No.	Final Coordinates of Segment k (t_{nk} relative to $t=t_o$)			
(n ,	1 ,	k ,	x_{nk}	y_{nk}	z_{nk}	t_{nk}

Note: For k=1 $(\dot{x}_{In})$, $(\dot{y}_{In})$, and $(\dot{z}_{In})$ are ignored.

Type 2. For flight path segments which are curved and for which the speed is constant. The values need for such a segment are:

A/C No.	Seg. Type	Seg. No	Turn Dir. and Track Rate of Turn in (x,y) plane	Total Turn Angle in (x,y) plane	Track Rate of Climb or Descend
(n ,	2 ,	1 ,	$\pm(w_T)_{n1}$	β_{n1}	$\pm(\dot{z}_T)^{n1}$

Use positive input value for right turn.

Use to completely specify the z component of the velocity pos. = > climb.

c. Total number of initial flight plan input segments m_n

Note: If an input flight plan for an aircraft ends before the scenario ends, the simulator will extend the flight plan by maintaining the last specified heading, speed, and altitude rate of the aircraft.

Note: The ground speed for any Type 2 segment is assumed the same as that for the immediately preceding segment. If no preceding segment exists, the ground speed found from the initial state vector is used.

d. (t_{Sn}) Time relative to $t=t_o$ user wishes to drop track.

e. Aircraft characterization and identification parameters.

1. VFR/IFR flag
2. DABS/ATCRBS A/C indicator
3. DABS/ATCRBS ID
4. ATARS display equipped/nonequipped

f. ATARS response characterization.

1. ($\underline{w_{An}}$) ATARS maneuver rate of turn

2. ($\underline{\dot{z}_{Un}}$) ATARS maneuver rate of climb

3. ($\underline{\dot{z}_{Dn}}$) ATARS maneuver rate of descent (pos. number)

4. (Δt_{Cn}) Time between receipt of ATARS command and compliance (Ignored for noncompliant aircraft)

5. (Δt_{Pn}) Time between ATARS command cessation and initiation of post-ATARS course.

6. Pilot ATARS response message indicator $\underline{r_n}$ = (WILCO, UNABLE, NO RESPONSE)

7. Time between ATARS command initiation and receipt of pilot response message = (Δt_{Rn})

8. ATARS command compliance flag $\underline{c_n}$ (need not be consistent with item f)

Aircraft executes the ATARS command maneuvers

$\underline{c_n}$

Aircraft obeys original flight plan

g. Target report generation indicators $\underline{g_n}$, $\underline{(t_{Gn})}$, $\underline{(\Delta t_{Ro})}$

All scenario target reports for aircraft n sent to the ATARS

$\underline{g_n}$

No target reports sent to the ATARS in a particular time window, for aircraft n.

$\underline{(t_{Gn})}$ Time relative to $t=t_o$ for initiation of target report nongeneration for aircraft n.

$\underline{(\Delta t_{Rn})}$ Duration of target report nongeneration for aircraft n.

D1.3.2 For Each Scenario Run.

a. Initial total number of aircraft

b. Altitude of sensor h_s

c. Scenario end time t_f

d. Title for output

e. Units

The units to be used for user inputs follow:

Variables	Units
time	seconds
x_{nk}, y_{nk}, (x_{In}), (y_{In})	nautical miles
z_{nk}, h_s, (z_{In})	feet
nl	degrees
(w_{Tnl}), (w_{An})	degrees/second
$(\dot{x}_{In})$, $(\dot{y}_{In})$	knots
$(\dot{z}_{In})$, $(\dot{z}_{Un})$, $(\dot{z}_{Dn})$, $(\dot{z}_{Tnl})$	feet/minute

D1.3.3 Mathematical Equations Used to Generate Aircraft Target Reports.

Simple difference equations will be used to generate target reports. Target reports will be sent to the ATARS each time the antenna is pointed at a target unless target reports are suppressed. The position of target aircraft $n(x_n, y_n, z_n)$ will be found in a Cartesian coordinate system where the y direction (y) is true north, the x direction (x) is true east, and the z direction (z) is toward the zenith. The origin lies at zero altitude and passes through the sensor location at altitude h_s. No adjustments for spherical earth geometry will be made.

Once the (s_n, y_n, z_n) position of a target aircraft is determined, a calculation will be made to find its slant range from the sensor P_n, its sensor azimuth 0_n (measured clockwise from true north), and altitude from the zero reference h_n. These values will be used to form a target report. The following equations will be used:

$$\rho_n = \sqrt{x_n^2 + y_n^2 + (z_n - h_s)^2}$$

To ATARS

$$\theta_n = \tan^{-1} (x_n/y_n)$$

$$h_n = z_n$$

D1.3.4 Output.

Output items are given here.

a. Image of all input data (this includes a title for the run).

b. Target reports.

c. ATARS-generated positive commands.

Note: For the present, ATARS-generated controller alert messages, negative commands, and other Proximity Warning Indicator (PWI) uplink messages which do not affect the state of motion of aircraft will be recorded only.

APPENDIX E. COARSE SCREEN

The coarse screen submodule of the ATARS processes all of the aircraft tracked by the ATARS. The output of this submodule is the collection of pairs of aircraft that are potentially in conflict. Linked lists of aircraft ordered by the X-coordinate, called the X-list and the EX-list, are used as input, and the output is recorded in the potential pairs list (PPL). More detailed processing of the PPL is used for all ATARS functions.

The expected performance of the coarse screen submodule should:

a. Shorten processing time by elimination from the PPL all those pairs of aircraft that could not possibly be in conflict.

b. Put all pairs of aircraft that are in potential conflict on the PPL.

c. Complete functioning in sufficient time to allow the other ATARS functions to finish in a timely manner.

d. Place only accurate data in the PPL.

Input characteristics determined by the scenario:

IFR/VFR distribution
Equipped/unequipped distribution
Aircraft density
X-list and EX-list aircraft distribution

Input operations per cycle:

Number of backward searches (BS)
Number of forward searches (FS)

The BS and FS are determined by the input characteristics above.

Queue waiting conditions:

a. Waiting for free space in the PPL (entries in the PPL are deleted by master resolution).

b. Waiting for subject aircraft. (The X-list and EX-list must be updated by the latest tracking data before a subject aircraft can be selected. The subject aircraft is compared with each object aircraft in its vicinity to determine if a potential pair exists.)

c. Waiting for object aircraft. (The submodule will wait until X-list and EX-list have been updated sufficiently to disclose an appropriate object aircraft, to be compared with the subject aircraft.)

The queue waiting time (QWT) is the sum of the wait conditions above. The total service time (ST) is the time required to perform all necessary forward and backward searches.

Functional characterization will consider the following:

a. Distribution of input data. The distribution of input data with respect to the IFR/VFR-equipped/unequipped aircraft and X-list/EX-list will be summarized for each test scenario.

b. Functional relationship. A detailed functional model for coarse screen will identify the number and type of aircraft examined by the submodule in a processing cycle and establish a functional relationship between this input information and service time. For example, linear regression can be used to establish service time as a function of BS, FS, and the number of potential pairs (a measure of the distribution of aircraft).

c. Queue waiting time. When functional modules have been established for the list and EX-list update modules and for the detect module, QWT can be adequately modeled.

d. Performance with respect to the Mission Objective. The coarse screen operation can be examined with respect to the following:

1. Total processing time - Does it process pairs faster than the detect module?

2. Complete set of potential pairs - Does the number of pairs of aircraft requiring ATARS, as determined by the detect module, increase when the coarse screen parameters are "opened up?"

3. Timely operation - Is the total operating time, T = ST + QWT, less than the cycle time? Do all system functions finish within the cycle?

4. Accuracy of the PPL - Is the aircraft data in the PPL accurate?