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MULTISITE TESTING OF THE DISCRETE ADDRESS BEACON SYSTEM (DABS)

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16. Abstract

This report contains results of tests performed in an environment of multiple Discrete Address Beacon System (DABS) sensors, one each located at Clementon and Elwood, New Jersey, and the Federal Aviation Administration (FAA) Technical Center, Atlantic City Airport, New Jersey. These DABS sensors were tested in various degrees of intersensor communication that ranged from a full network of connected sensors to a fully nonnetted configuration.

The multiple DABS sensors were tested in four major areas: network management, surveillance processing, data link processing, and intersensor communications.

It is concluded that the performance of the DABS sensors in multisite configurations meets or exceeds the requirements specified in the DABS engineering requirement (FAA-ER-240-26).

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INTRODUCTION

PURPOSE.

This report is one of a series of test reports issued by the Federal Aviation Administration (FAA) Technical Center on the performance of the Discrete Address Beacon System (DABS). An earlier report (FAA-RD-80-36/FAA-NA-79-52, "Discrete Address Beacon System (DABS) Baseline Test and Evaluation") addressed the results obtained from tests performed on a single DABS sensor operating in a stand-alone mode. The subject of the current test activity is the performance of the DABS operating in a multiple sensor environment. The DABS system was evaluated with respect to four functional areas: network management, aircraft surveillance, performance of the air/ground data link, and sensor-to-sensor communications. The multiple sensor environment for these tests was configured with various degrees of intersensor communication that ranged from a full network of landline telephone communication among the sensors to a fully nonnetted configuration.

Analysis was undertaken with two objectives in mind: (1) the evaluation of system performance, and (2) the verification that the network concept is workable.

BACKGROUND.

The necessity for the development of the DABS was identified in a 1969 study conducted by the Department of Transportation's Air Traffic Control Advisory Committee. The study recommended that the present Air Traffic Control Radar Beacon System (ATCRBS) be upgraded to provide the capability for communicating with discretely addressable airborne transponding equipment. The existence of a unique, discrete address would allow individual interrogation of each aircraft so equipped, and would support the idea of a private two-way communications channel (or "data link") between the airborne unit and the ground. The study further recommended the development of a ground-based collision avoidance system that would use the data link to send traffic advisory, threat assessments, and maneuver commands to aircraft on potential collision courses.

The subsequent development of the DABS has followed the plan which is detailed in the Engineering and Development Program Plan FAA-ED-03-1. The first phase began in January 1972, with a contract award to the Massachusetts Institute of Technology (MIT) Lincoln Laboratory for development of an experimental model of DABS. This effort demonstrated the feasibility of the concept and resulted in the development of a set of engineering requirements (FAA-ER-240-26) that were used to procure three DABS Engineering models.

DISCUSSION

DESCRIPTION OF EQUIPMENT.

THE DABS CONCEPT. The DABS, in addition to being compatible with the present ATCRBS system, provides six basic improvements. These improvements are: (1) upgrade of ATCRBS surveillance by employing a monopulse processing technique, (2) discrete interrogation of DABS equipped aircraft, (3) air-ground data link for support of ATC automation, (4) increased surveillance capacity, (5) improved tracking accuracy, and (6) redundant surveillance coverage in the event of adjacent sensor failure.

Existing ATCRBS transponders require no modification in order to continue at their current level of functioning in the new DABS/ATCRBS environment, thus, allowing for an economical transition from the present ATCRBS environment to the DABS environment of the future. Immediate benefits arising from improved ATCRBS surveillance are realized totally from changes in the ground-based equipment. The addition of monopulse processing provides greater accuracy and increased resolution of two closely spaced ATCRBS replies, and fewer replies are required to accomplish the tasks of target detection and code validation. The pulse repetition frequency (PRF) of the interrogation is reduced which, in turn, results in a corresponding reduction in the level of asynchronous replies (fruit).

For DABS equipped aircraft, each transponder is assigned a unique address and, in the normal mode of use known as roll-call, responds only to interrogations containing that discrete address. Aircraft are initially detected in a sensor's surveillance area by their responses to All-Call interrogations in which the transponder reports its discrete code. Upon receipt of the correct number of All-Call responses from an aircraft, the sensor places the aircraft in roll-call mode. If the sensor has a status of "primary," with respect to that aircraft, it locks out the transponder from responding to further All-Call interrogations. Primary status is assigned by air traffic control (ATC) or is determined by the geographical position of the aircraft and requires the sensor to read downlink messages from an airborne transponder in addition to performing the lockout function.

Each sensor may provide surveillance and communication services to specified ATC facilities. Radar and beacon surveillance data are transmitted from the sensor to a facility on a one-way channel. Other communications between the facility and the sensor or between the facility and the aircraft make use of a two-way interface.

DABS sensors may be netted to each other with two-way communication links when overlapping or adjacent geographical coverage provides the advantages to be realized from creating a multiple-sensor network. Such advantages include redundant coverage in the event of failure of one site and tracking assistance for sensors experiencing transponder fade as a result of antenna shielding or cone-of-silence entry. The sensors are also capable of operating in the so-called "stand-alone" mode, in which they are not netted to each other but must operate in areas of overlapping coverage. Failure of a communications link between two operating sensors will result in a de facto entry into the stand-alone mode.

<u>DABS SENSORS</u>. Each DABS sensor is composed of an interrogator/processor (I&P) front end which contains the transmitter unit (MCU); the reply processors (one each for DABS and ATCRBS); the azimuth system timing unit (AZSTU), which interfaces to the antenna shaft encoder and to a WWVB receiver; and a performance monitor, which samples such I&P performance items as the transmitter power, receiver gain, receiver noise, and monopulse values. The I&P section has been expanded at the Technical Center site to include inputs from either moving target generator (MTD) or radar data acquisition subsystem (RDAS) radar, the choice to be made when the system is initialized.

The I&P hardware is interfaced to a distributed computer system containing 36 minicomputers, most of which are organized into groups (or ensembles) of four computers interfaced to a local data bus. Most ensembles are coupled between two global data buses, which are used to gain access to a common global memory containing program store, data base, and the address space of the I&P.

One of the ensembles is designed especially for handling the required communications between the sensor and ATC facilities and the additional communications required for sensor-to-sensor communications in a DABS network. Another ensemble is dedicated to the processing of ATCRBS replies. A functional block diagram of a DABS sensor is shown in figure 1.

TEST EQUIPMENT. Items of test equipment used in performance evaluation were the system test console (STC) and the Aircraft Reply and Interference Environment Simulator (ARIES).

System Test Console. The STC, located at the Technical Center, is a data entry and display device devoted exclusively to DABS. It consists of an ATC type display and keyboard and a computer subsystem, which monitors in real time all communication and surveillance lines in the DABS network and displays and/or records on magnetic tape those data which have been specified by the operator. Under keyboard command, the STC is capable of displaying surveillance data disseminated from any individual sensor or that disseminated from all sensors simultaneously. Keyboard commands are also used to determine which data shall be selected for recording.

The STC can also be used as a simulated ATC facility, permitting an operator to generate uplink messages to an aircraft, either in real time or by running a prerecorded message scenario. Uplinks sent to the DABS sensor are recorded on the STC tape, as are the responses returned from the sensor to the STC. The message generation and recording capability is useful in exercising the data link between the DABS sensor and a DABS-equipped aircraft.

Additional ATC functions for which the STC has been used include generation of aircraft control state messages used to designate a DABS aircraft as a controlled target (see "Controlled Targets section" of "Descriptions of Equipment") and generation of sensor failure/recovery messages. Sensor failure/recovery messages provide the user with a convenient means of reconfiguring a sensor's coverage by telling it that one or more of its neighbors within the network has failed.

Aircraft Reply and Interference Environment Simulator. The ARIES is an automated device for supplying the DABS sensor with replies to DABS and ATCRBS interrogations. It may be used by itself or superimposed upon real world inputs. The user of the ARIES specifies a scenario in which a mixture of simulated DABS and ATCRBS aircraft exist, each one having a certain initial position and velocity. Depending upon the means used for scenario generation, aircraft trajectories may be specified and the downlink message bit ("B-bit") may be set in the simulated DABS replies, causing the DABS sensor to exercise the downlink message retrieval mechanism. Fruit generators allow simulation of various levels of DABS and ATCRBS fruit. The two ARIES units, one located at the Technical Center and one located at Elwood, may be used either to supplement or to substitute for real world inputs to the DABS.

ARIES scenarios have been used extensively in previous baseline testing, in conflict analysis, and in capacity testing, since loads of up to 400 targets in any DABS/ATCRBS mixture can be provided. The present multisite testing effort has made use of the fruit generation capability of the ARIES. Future multisite tests will involve communication between the two ARIES units to simulate the behavior of DABS transponders in an environment in which they are subject to lockout by the two participating DABS sensors.

DESCRIPTION OF SYSTEM.

SYSTEM CONFIGURATION. The three DABS sensors are connected to each other and to the system test console at the Technical Center by means of dedicated telephone lines. One pair of bidirectional lines is used to connect the Technical Center sensor with Elwood,

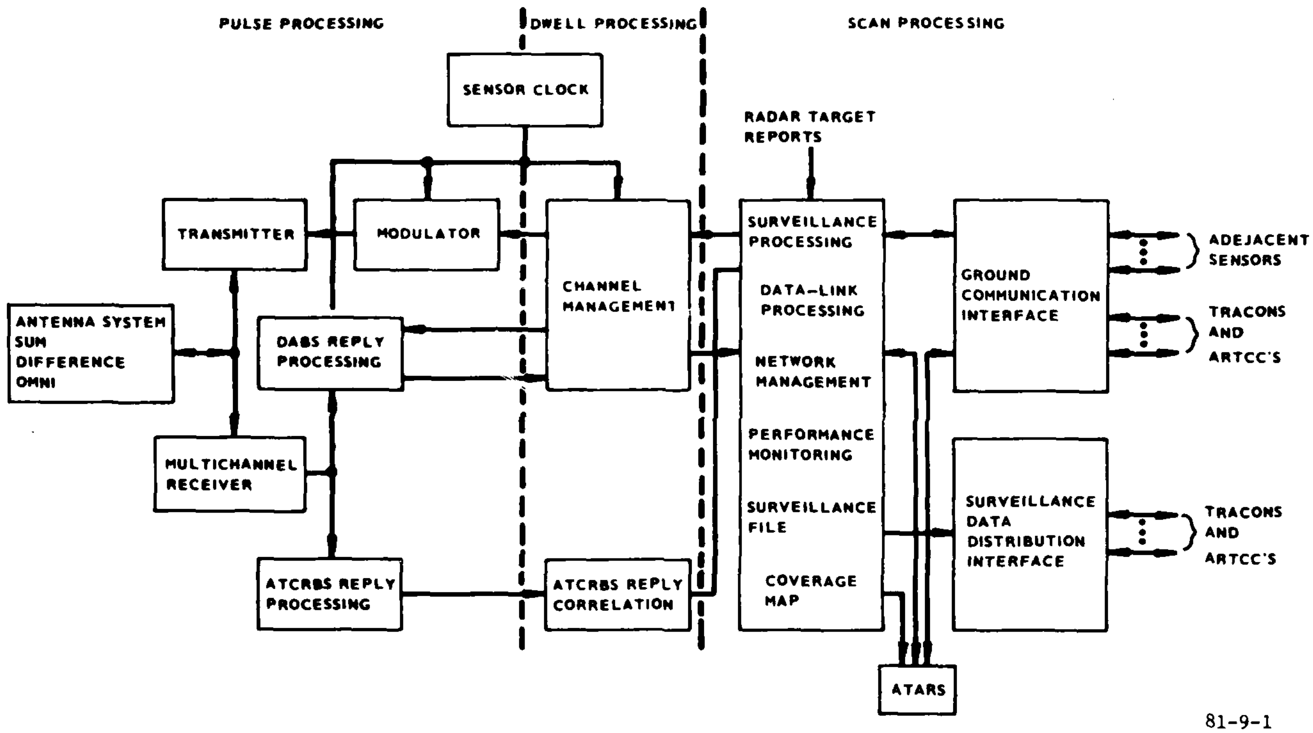

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FIGURE 1. DABS SENSOR FUNCTIONAL BLOCK DIAGRAM

one pair is used to connect Elwood with Clementon, and one pair is used to connect Clementon back to the Technical Center. A single bidirectional line connects Elwood with the STC. A similar line allows communication between Clementon and the STC. Since the STC is collocated with the Technical Center sensor, telephone connections are not required and the communication takes place across direct lines.

Three communication lines exist between each of the sensors and each of two simulated ATC facilities: the System Support Facility (SSF) and the Terminal Automation Test Facility (TATF). Two of the three lines are one-way surveillance lines that carry target reports and radar messages. The third line is bidirectional and is used for message exchange using the Common International Civil Aviation Organization (ICAO) Data Interchange Network (CIDIN) protocol. The SSF is capable of communicating with all three sensors during the same run. However, the TATF has only one port, which restricts it to servicing only one user during a given test.

When located within surveillance range of a given target, multiple DABS sensors provide redundant surveillance coverage to insure continuity of tracking in the event of the failure of a DABS site, during target fade conditions arising from antenna shielding, or operations conducted within the sensor's cone of silence. Essential to the successful maintenance of redundant coverage is the DABS function known as network management. It is one of the four DABS functions which were evaluated in a live, multiple sensor environment as a basis for the present report. The other three functions are surveillance processing, data link processing, and intersensor communications.

NETWORK MANAGEMENT — CONCEPTS AND DEFINITIONS. The purpose of the network management function is to provide coordination between the sensors in regions of redundant surveillance coverage. The exact nature of this coordination depends upon whether or not the sensors are connected to each other by landlines.

Connected Sensors. When redundant surveillance coverage occurs between or among sensors which are connected to each other, network management provides:

1. Acquisition assistance on a target entering another sensor's coverage (handoff).

2. Tracking assistance for a sensor whose target has faded.

3. Coordination between sensors to determine which sensor is "primary" for each uncontrolled DABS target. A primary sensor is responsible for obtaining readout of pilot-initiated downlink (Comm B and Comm D) messages, for locking out DABS transponders to All-Call interrogations, and for issuing synchronized interrogations if required.

Unconnected Sensors. In cases where redundant surveillance coverage is provided by sensors which are not connected to each other by operational landlines, network management reverts to its "stand-alone" mode. In this mode, lacking a communication link, the network management function provides:

1. A scheme of intermittent lock and unlock of the ATCRBS/DABS All-Call state so that unconnected sensors may acquire or reacquire a DABS aircraft without external assistance.

2. An assignment of primary responsibility for an uncontrolled DABS target based solely on its geographical location. In the unconnected mode it is expected that multiple sensors will have primary responsibility in areas where their internal coverage maps dictate that overlapping coverage exist.

Partial Connectivity. In surveillance regions where mixtures of connectivity occur (e.g., two sensors connected and one unconnected), the network management function must provide appropriate behavior with respect to the connectivity state of each neighboring sensor.

Controlled Targets. Regardless of intersensor connectivity, a controlled target depends upon the cognizant ATC facility for its primary or secondary specification. The network management function overrides the current sensor priority status with the value specified by the content of the most recent aircraft control state message received from ATC.

THE SURVEILLANCE PROCESSING FUNCTION. The surveillance processing function is responsible for the tracking of targets within the sensor. This function has undergone a few minor changes between the time of the baseline testing discussed in report FAA-RD-80-36, for which software release 6.3 was used, and the DABS multisite testing contained in this report for which release 7.2 was used. These changes were primarily concerned with ATCRBS performance and were expected to have little, if any, effect on the observed behavior of DABS. These changes are summarized below.

1. A fixed jitter was added to the pulse repetition frequency (PRF) in order to avoid site-to-site interference among the three DABS sensors, which operate at the same basic PRF. If this change was to result in an observable difference, it would be expected to make a slight reduction in the number of interrogations issued and improve the number of replies needed for declaration of a report.

2. The effective receive beam width was increased from 2.4° to 3.5°, primarily to increase the number of replies available for use in declaration of ATCRBS reports. If this increase was to have an effect on DABS surveillance performance, it might be visible as a lower reinterrogation rate because of an increased probability of receiving usable replies at the leading edge of the beam.

3. A new ATCRBS target-to-track associator/correlator was added in order to fix a timing problem involving the dissemination of nondiscrete ATCRBS targets to noncorrelating ATC users. All such targets are now automatically held for four sectors, thus, increasing the percentage of late disseminations. This change has no apparent relationship to DABS.

The most significant change between release 6.3 and release 7.2 was the inclusion of an upgraded network management function (described in the previous section).

THE DATA LINK PROCESSING FUNCTION. The data link processing function manages the communications that take place between a DABS aircraft and the ground-based users of the system, which currently include the Automatic Traffic Advisory and Resolution Service (ATARS) function and ATC en route and terminal facilities. Messages may originate on the ground, in which case they are addressed to a specific DABS aircraft, or they may originate in the air for dissemination to all "appropriate" facilities as determined from a site-adaptable table within the sensor. A tactical downlink message from an aircraft contains 56 bits of message data. A tactical uplink message originated by a ground-based user may contain up to four 56-bit segments to be sent to the aircraft as four "standard length" uplink messages. Some DABS transponders have the capability for sending and receiving extended length messages (ELM's), which may contain as many as sixteen 112-bit segments and are sent on the data link using special transactions, one per segment. This report addresses testing of the standard length messages only.

Messages are handled by two distinct parts of the data link function: the input message processor and the output message processor.

Input Message Processor. The input message processor performs an acceptance check on incoming messages. If the message is addressed to an aircraft which is not in the surveillance file, the message is discarded and a rejection notice is sent to its originator. If the target is in the surveillance file but is not in the roll-call state, the message is placed on the uplink queue and a message delay notice is sent to the originator as a warning that the sensor is temporarily unable to deliver it. For a target that is being tracked in the roll-call state the message is placed on queue for delivery.

Output Message Processor. The output message processor is responsible for informing the originator of an uplink message: (1) that the message was successfully transmitted to the aircraft, or (2) that the expiration time contained within the message was exceeded and the message was discarded. If downlink messages were received in conjunction with the replies from the DABS aircraft, the output message processor is responsible for extracting the data and forwarding it to the appropriate ground-based user(s).

INTERSENSOR COMMUNICATIONS. Additional functions which are used in a multi-sensor environment are responsible for making periodic checks on the status of connected sensors. If status messages are not received each scan from a neighboring connected sensor, a process of inquiry is begun which is designed to help the local sensor "infer" the status of the missing sensor. Other members of the net are asked for what information they may have about the status of the sensor in question, and this information is used in assigning to the missing sensor the status of "inferred failure" (in which case the missing sensor is treated as failed), or "inferred communications failure" (in which case the missing sensor is treated as if it were unconnected). A missing sensor about which no judgment can be made is left in a status known as "loss of message" and treated as if it were operational but unconnected. A "failed" sensor is one which has either reported its own failure by sending a "red" sensor-to-sensor status message or which has been reported as failed by an ATC facility. In order to detect the recovery of a failed sensor (whether it was a reported failure or an inferred failure), the sensor continues to send out periodic inquiries to all the remaining members of the net.

When any adjacent sensor has been judged by one of these means to be in a state of failure, the network management function operates in what is known as the "special mode." This involves reading the coverage map in such a way as to omit the failed sensor from consideration in building the adjacent sensor assignment lists and determining which sensor should have primary responsibility. The special mode is the means used by DABS to cover, insofar as possible, the network management responsibilities of missing sensors.

Each local sensor is also required to make periodic requests for surveillance data on the calibration and performance monitoring equipments (CPME's) of each connected neighbor. Should the known position of one of these fixed targets slip too far out of tolerance, the local sensor is, thus, made aware of the condition and will report it to its cognizant ATC facility. No other operational action concerning adjacent CPME's is currently specified for the local sensor.

TEST CONFIGURATION.

SENSOR NETWORK CONFIGURATIONS. Because there are different reactions of the network management function to the presence of connected or unconnected sensors, various configurations of one, two, and three DABS sensors were used for testing and evaluation. The combinations that were tested were selected to reflect the fact that two of the sensors are configured to operate as terminal sensors, having a nominal 60-nautical mile (nmi) coverage radius, an antenna scan rate of 4.7 seconds, and a single antenna face. The other sensor, located at Elwood, is configured for en route operation having a nominal 200-nmi coverage and two identical beacon antennas in a back-to-back configuration, which provides an effective scan rate of 4.8 seconds. The 200-nmi coverage was reduced, for test purposes, to 60 nmi in order to reduce the data load at the STC. Because the specified size of the STC is 400 targets (total), only 133 targets may be received from each of the three sensors before target reports are discarded.

Tests were also performed on single unconnected sensors as well as on the following multisite configurations. Any sensors not participating in a test configuration were declared to be in a state of failure through generation of the appropriate sensor failure messages at the STC.

Two-Sensor Configurations. The two-sensor configurations tested were as follows:

1. Two terminal sensors (Technical Center and Clementon), both connected and unconnected.

2. En route sensor (Elwood) and one terminal sensor (Technical Center), both connected and unconnected.

Three-Sensor Configurations. Several three-sensor configurations were tested as follows:

1. Three sensors, all connected and all unconnected.

2. Two terminal sensors (Technical Center and Clementon), connected to each other, en route sensor fully unconnected.

3. One terminal sensor and the en route sensor (Technical Center and Elwood) connected and the other terminal sensor (Clementon) fully unconnected.

4. Fully connected except for the terminal/terminal connection (Technical Center-Clementon link broken).

5. Fully connected except for one terminal/en route connection (Clementon-Elwood link broken).

No appreciable difference in test results was expected when substituting the en route sensor for a terminal sensor in any of the test configurations, but that expectation was deemed worthy of some actual testing.

TEST ENVIRONMENT. The tests used as a basis for this report were conducted in the real world environment using a test aircraft in one of two predetermined flightpaths described below. Simulated fruit at levels previously used in the single-site system baseline testing program were injected into the system using the ARIES.

Single Transponder Tests. Testing in the real world was performed against a background of ATCRBS targets of opportunity and a DABS stationary transponder (parrot) affixed to a tower located at Mizpah, New Jersey, approximately 12.5 nmi southwest of the Technical Center sensor. The stationary target has a 24-bit hexadecimal DABS address of "FAADAB" and could be set to respond any desired altitude. Altitudes of 5,000 and 10,000 feet have been used during various phases of the testing. A single real aircraft carried a transponder with an address of 7FFFFF and flew one of two predetermined patterns:

Pattern A. The aircraft passes through the cones of silence over each of the DABS sites for the purpose of creating target fade conditions to test the network management external track data functions.

Pattern B. The aircraft avoids the zenith cones and potential ATARS conflicts with the stationary Mizpah transponder in order to test the uplink message delivery capability without being hindered by target fades and competition from ATARS for use of the data link.

Ideally, the aircraft was to have maintained an altitude of 5,000 feet throughout the testing, but occasional cloud cover and turbulence necessitated deviations from this goal to a maximum altitude of 8,500 feet. From the viewpoint of network management, the most observable feature of the altitude difference is the size of the cones of silence and, hence, the length of time that the aircraft is not tracked on local data as it passes over the sensors. Because the cell structure of the coverage maps is also affected by altitude, some displacement of the points of primary/secondary transitions would be expected.

Dual Transponder Tests. One feature of the stand-alone network management design is the extension (up to a maximum) of the length of the lock cycle in order to avoid simultaneous unlock of two proximate transponders with consequent risk of garbling. Two tests were made with two transponders carried aboard a single test aircraft. These transponders were addressed as 7FFFFF and 555555, respectively, with the 7FFFFF transponder reporting the actual mode C altitude of the aircraft, while the 555555 transponder was set to respond with a fixed altitude of 10,000 feet.

NETWORK COVERAGE MAPS. The network management coverage used by each of the sensors is defined by a site-specific coverage map, which is expressed as a collection of cells in a polar coordinate system having the antenna as its origin. Each cell contains a specification of the multiplicity of coverage desired by the user and an ordered list of the neighboring sensors that are regarded as candidates for the list of "assigned" sensors; i.e., those being used for redundant surveillance. If the user specifies the local sensor to be at the top of the assigned sensor list for a given cell, the local sensor is regarded as primary for uncontrolled targets within that cell. Such a defaulted assignment may be overridden by an aircraft control state message generated by the controlling ATC facility. All primary assignments in this report are as dictated by the coverage maps, except where noted.

For test purposes, the coverage maps were devised with areas of overlapping primary assignment. Multiple primary assignments are to be expected in areas where there is overlapping primary coverage involving unconnected sensors. These multiple assignments are resolved into single assignments when connectivity between the sites is present. For test purposes, overlapping primary coverage was assigned to the Technical Center and Elwood sensors in the vicinity of the Technical Center. Similarly, overlapping primary coverage was assigned to the Clementon and Elwood sensors in the vicinity of Clementon. In the vicinity of Elwood all three sensors were specified to have overlapping primary responsibility.

DATA LINK SCENARIOS. Three separate scenarios were used for testing the performance of the data link between the DABS sensors and the test aircraft with respect to data link capacity and message handling protocal. These are named S1, S2, and S3 and have the characteristics described in the following paragraphs. These scenarios are sent by the STC operating as a simulated ATC facility. Tactical uplink messages are sent at the rate of two messages to each DABS address every 5 seconds. This rate is maintained for 2 minutes, and then a 1-minute gap occurs allowing time for any outstanding message transactions to be completed. The message rate is then increased by one and the above sequence is repeated until a message rate of eight is concluded. Each of the messages is a single segment, normal priority tactical uplink with a "time-to-expiration" of three scans, and each contains a 4-bit internal message number. In each successive message to a given address the message number is incremented by 1 until a maximum of 15 is reached and the cycle starts over.

1. Data link scenario S1. This scenario addresses all messages through the Technical Center sensor to destinations of the Mizpah transponder (FAADAB) and the test aircraft (7FFFFF).

2. Data link scenario S2. Scenario S2 is identical to S1 except that all messages are addressed to FAADAB and 7FFFFF through the Elwood Sensor.

3. Data link scenario S3. Messages in this scenario are sent through all three DABS sensors. For messages sent through the Technical Center and Elwood sensors, the destinations are FAADAB, 7FFFFF, and 55555. Since the Mizpah parrot is mounted too low to be tracked consistently by Clementon, the destinations used for messages sent through the Clementon sensor are 7FFFFF and 555555 only. During the tests that did not involve 555555, the DABS sensor was expected to respond with message rejection notices indicating that the target was not being tracked within the surveillance area.

TEST MATRIX. Tests were conducted according to the specifications set forth in the test matrix shown in table 1. The test matrix is organized such that each test is listed by its respective test number. Test data used in this report were taken from tests 13 through 34 and 48 through 55. For each test the matrix specifies date of test, participating sensor(s), connectivity, fruit, data link scenario, and number of DABS transponders.

DATA COLLECTION.

TEST CONDUCT. At the beginning of each test all participating sensors underwent an initial program load and were released into operation simultaneously by voice command over the telephone. After verification that all participating sites were operational, the nonparticipating sites were declared to be "failed" sensors by means of messages sent from the STC. Data extraction were initiated simultaneously at all the operating sensors, and data link scenarios were started shortly after the beginning of each test. Each test run was concluded with a system dump after completion of the data link activity.

DATA RECORDING TAPES. Data were collected on magnetic tape at each of the participating sensor sites as well as at the STC.

System Test Console. The STC monitors in real time all communication and surveillance lines in the DABS network and records these data on digital tape. The resulting time-ordered merge of the many data streams is well-suited to supporting a system-level analysis of DABS multisite performance in less than a capacity environment. Sensor-to-sensor message exchanges (if any) and sensor-to-ATC message traffic are recorded in the order of their occurrence, allowing for cause-and-effect analysis of message transactions occurring in multiple sensor tests.

Certain information, such as the contents of a DABS surveillance file entry, are needed for data analysis in the areas of surveillance processing and network management. Normally, much of this information is maintained only within the internal data base of a

TABLE 1. MULTISITE NETWORK MANAGEMENT TEST MATRIX

Test 13-34 are zenith cone flights for network management and surveillance testing.

Test No.	Date	Multiplicity	Connectivity	Fruit ATCRBS/DABS	STC Scenario	Comments
13	4/2/80	TC,E,C	TC-C,TC-E,E-C		S1	1 Test Aircraft/1 Transponder
14	4/7/80	TC,E,C	TC-C,TC-E,E-C		S2	1 Test Aircraft/1 Transponder
15	4/7/80	TC,E,C	TC-C,TC-E,E-C		S3	1 Test Aircraft/1 Transponder
16	5/1/80	TC,E,C	TC-C,TC-E,E-C	4K/50	S3	1 Test Aircraft/1 Transponder
17	5/15/80	TC,E,C	TC-C,TC-E,E-C		S3	1 Test Aircraft/2 Transponders
18	4/7/80	TC,E,C			S1	1 Test Aircraft/1 Transponder
19	4/18/80	TC,E,C			S2	1 Test Aircraft/1 Transponder
20	4/18/80	TC,E,C			S3	1 Test Aircraft/1 Transponder
21	5/1/80	TC,E,C		4K/50	S3	1 Test Aircraft/1 Transponder
22	5/15/80	TC,E,C			S3	1 Test Aircraft/1 Transponder
23	4/18/80	TC,E,C	TC-C,TC-E		S3	1 Test Aircraft/2 Transponders
24	4/2/80	TC,E,C	TC-C		S3	1 Test Aircraft/1 Transponder
25	4/30/80	TC,E,C	TC-E		S3	1 Test Aircraft/1 Transponder
26	4/16/80	TC,C	TC-C		S1	1 Test Aircraft/1 Transponder
27	4/16/80	TC,C			S1	1 Test Aircraft/1 Transponder
28	4/22/80	TC,E	TC-E		S2	1 Test Aircraft/1 Transponder
29	4/22/80	TC,E			S2	1 Test Aircraft/1 Transponder
30	4/21/80	TC			S1	1 Test Aircraft/1 Transponder
31	4/22/80	TC		4K/50	S1	1 Test Aircraft/1 Transponder
32	4/22/80	E			S2	1 Test Aircraft/1 Transponder
33	5/1/80	E		4K/50	S2	1 Test Aircraft/1 Transponder
34	4/21/80	TC,E,C	TC-E,E-C		S3	1 Test Aircraft/1 Transponder

Test 48-55 are non-zenith cone flights for data link and surveillance testing.

Test No.	Date	Multiplicity	Connectivity	Fruit ATCRBS/DABS	STC Scenario	Comments
48	6/20/80	TC,E,C	TC-C,TC-E,E-C		S3	1 Test Aircraft/1 Transponder
49	6/20/80	TC,E,C	TC-E		S3	1 Test Aircraft/1 Transponder
50	6/20/80	TC,E,C			S3	1 Test Aircraft/1 Transponder
51	6/30/80	TC,E	TC-E		S3	1 Test Aircraft/1 Transponder
52	6/12/80	TC,C	TC-C		S3	1 Test Aircraft/1 Transponder
53	7/7/80	E			S2	1 Test Aircraft/1 Transponder
54	6/12/80	C			S3	1 Test Aircraft/1 Transponder
55	7/7/80	TC,E,C	TC-C,TC-E,E-C	4K/50	S3	1 Test Aircraft/1 Transponder

sensor and is not shared with other sensors or with ATC facilities. To aid in the analysis of multisite data, special surveillance file "snapshot" messages, which have a message type code of 90 and which are activated through a site-adaptation command, have been added to the system. These messages may be addressed to any external "facility" whose lines are monitored and recorded by the STC. Because of bandwidth and processing limitations, only a limited number of DABS targets may be treated in this manner. Other kinds of internal data, such as DABS raw replies, are never sent between facilities and are, therefore, not available to the STC.

Sensor Data Extraction. As part of the initial program load, the sensor is given a set of data extraction commands specifying which operational data are to be collected and written to magnetic tape. The operator may override this command set by use of cassettes or keyboard entry. The current testing effort required that raw DABS replies be collected to assist in monitoring the behavior of the various DABS transponders used and to observe the formation of DABS reports from their component replies. The data extraction function also collects surveillance file information on both DABS and ATCRBS tracks. Other useful data collected include a recording of all site-adaptation parameters used during the test, and a "memory dump" at the end of the tape to aid in determining the exact state of the global memory and the DABS computers at the instant the test was terminated.

TEST RESULTS AND ANALYSIS

NETWORK MANAGEMENT.

Network management data analysis consisted largely of inspecting system data to show that the functional operating requirements were being met. These characteristics and their verification are described in this section. For convenience, they are broken down into categories of "General Results" that apply to all DABS configurations, "Multisite Netted Results" that apply to netted systems only, and "Multisite Nonnetted Results."

GENERAL RESULTS. The following results were verified for all tests, whether netted or nonnetted:

1. Determination of sensor priority status. The assignment of the local DABS sensor as primary or secondary, with respect to data communications downlinked from an aircraft, was made in the case of an uncontrolled aircraft according to information derived from the network coverage map. In the case of a controlled aircraft, it was made as directed by the most recent ATC control state message. The correct setting of the sensor priority status bit was verified by inspection of the surveillance file for each cell boundary crossing along the flightpath of the test aircraft.

2. Adjacent sensor assignment. Each time an aircraft crossed a surveillance boundary (which is usually, but not always, the boundary of a cell in the network coverage map) the position of the target was used to assign a set of adjacent sensors which, geographically speaking, were capable of providing redundant surveillance coverage. The assignments of these sensors, if any, and their connectivity characteristics (connected or unconnected) were verified by inspection of dumps of surveillance file information from the STC recording tape.

MULTISITE NETTED RESULTS. The following results were obtained from tests involving netted sensors:

1. Track data message protocol. During periods when the aircraft was not

visible to the local sensor, data were supplied upon request from other sensors in the net that had the aircraft under surveillance. The exchange of network management messages required to accomplish the external support involved a track data request, track data messages, cancel request, and data stop message. Dumps of the STC recording tape were inspected in order to verify that the message sequences were correct. Tracks newly acquired by the local sensor were shared with adjacent connected sensors through spontaneous issuance of track data messages. Receiving sensors which were able to track the targets locally turn off the incoming data by sending cancel request messages. This sequence of events was also verified by inspection of STC dumps.

2. INLIST and OUTLIST entries. Whenever a sensor was supplying track data to one or more adjacent sensors, the recipient(s) were identified in a surveillance file entry known as the OUTLIST. A sensor receiving data from one or more sources stored the identity of the supplier(s) in the INLIST, along with a flag showing which stream of incoming data was being retained for local use. Dumps of the STC recording tapes were used to test the management of the INLIST and the OUTLIST during periods of track data message exchange. It was during these tests that a pair of coding errors in the management of the INLIST were identified. One error resulted in the failure to discard track data messages that arrive from any but the "active" INLIST sensor. The other error resulted in a failure to clear the INLIST flag when the incoming track data stream was interrupted. These errors were such that the "sole-source" characteristic of the incoming data stream for a given track could not always be guaranteed.

3. Externally supplied track data. During periods of prolonged fade, particularly in the cone of silence over a sensor's antenna, a connected adjacent sensor was expected to supply sufficient surveillance data to permit the local sensor to maintain tracking until the target emerged from the fade and could once again respond to local interrogations. Tests were performed on networks of two and three sensors in varying states of connectivity. The results showed that tracking was maintained throughout the zenith cone on external data supplied from connected adjacent sensors. One of the tests discussed ("Three Sensors, One Unconnected," in the Network Management Results of Specific Tests section), presents some figures which show tracking across two of the three zenith cones in a test environment of only one connected adjacent sensor. The presence of only one connected sensor provides certainty over the source of the data, showing that tracking through the zenith cone can be maintained on the remote data provided by a single sensor.

4. Sensor priority status in the zenith cone. The current system design allows several scans (the maximum expected could be on the order of 20) to occur between the time an uncontrolled target fades in the local zenith cone and a neighboring sensor has a cell boundary crossing that would trigger a primary handoff transaction. During this time no sensor could exercise primary responsibility for the target, notably, the readout of a pilot-originated downlink message. Creation of a new "primary available" message to trigger an earlier boundary crossing would help in some cases. (See item 3 of "Recommendations" for "Network Management.")

MULTISITE NONNETTED RESULTS. The following results were observed for tests involving nonnetted sensors:

1. Lockout state and lockout counts. In a multisensor environment containing one or more unconnected adjacent sensors providing redundant surveillance

coverage, the state of lockout to All-Calls must be changed periodically to "unlocked" to allow for target acquisition by adjacent sensors. The locked state was maintained for a site-adaptable number of scans and was followed for another number of scans by an unlock period in which the transponder was allowed to time out and begin responding to All-Calls. This mode of operation is known as "intermittent lockout." The length of the lock and unlock sequences, as well as the actual lockout bit configuration, was observed in dumps of the surveillance file and in the output of one of the Honeywell computer programs (item 5 of appendix B). These sequence lengths were seen to correspond to those specified by site adaptation.

2. System-wide periods of transponder unlock. Verification that the lockout state and lockout counts were correctly maintained on an individual sensor basis (item 1) was not sufficient to verify the performance of network management in a multisensor nonnetted environment. The system must function globally in such a way as to ensure that the periods of unlock are synchronized, enabling all sensors to receive All-Call replies.

Tests were conducted with the three sensors in various states of connectivity, from totally connected to totally unconnected. In the case of total connectivity, no periods of unlock were needed or expected. In all other cases, such periods were required during flights in regions of overlap. The verification that transponder unlock periods became synchronized across the system was made using plots of the All-Call reply sequences, like those presented in the Lockout Management portion of the Network Management "Results of Specific Tests" section below.

RESULTS OF SPECIFIC TESTS. Although tests were performed using the DABS sensors in all possible combinations and in all possible states of connectivity, only three cases have been selected for a detailed discussion in this report. These three cases involve all three DABS sensors and the connectivity states fully connected (each sensor communicating with the other two), fully unconnected (no sensor communicating with any other), and the case of two connected to each other with the third not connected to either of the first two. The results that have been omitted provide no new information beyond the cases discussed. Three plots, one showing the live DABS track as seen by each sensor, are presented for each of the three cases. The first plot in each set shows the track as seen by the Technical Center, the second shows the same track as seen by Elwood, and the third plot represents the same track in the Clementon sensor. Special symbols are used to differentiate among the possible track states within a given sensor: a chevron represents a local track when the sensor is primary, a dot represents a local track when the sensor is secondary, a slash is used to show that the track is being maintained on external data, and a box indicates a scan on which the track is being coasted.

Three Sensors, All Connected. These results are the output of test number 13 (run 3) of the test matrix. The flightpath begins southeast of the Technical Center sensor and traverses in succession all three sensor's zenith cones. Figure 2, depicting the track as seen by the Technical Center, shows that the Technical Center sensor is primary for downlink communications (indicated by the chevron symbol on the plot). The other sensors, Elwood (figure 3) and Clementon (figure 4), are secondary (indicated by the dot symbol on their plots) showing that coordination between the sensors has occurred and the network has agreed upon only one primary sensor. (As will be shown in the next section, lack of such coordination results in multiple primary sensors.)

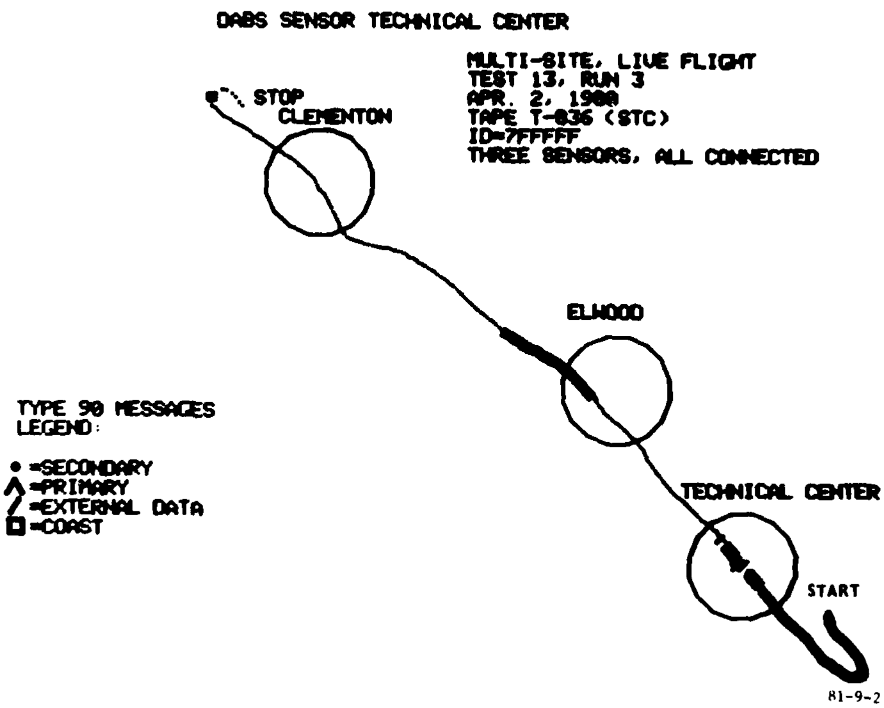

FIGURE 2. TECHNICAL CENTER SURVEILLANCE PLOT, THREE SENSORS, ALL CONNECTED

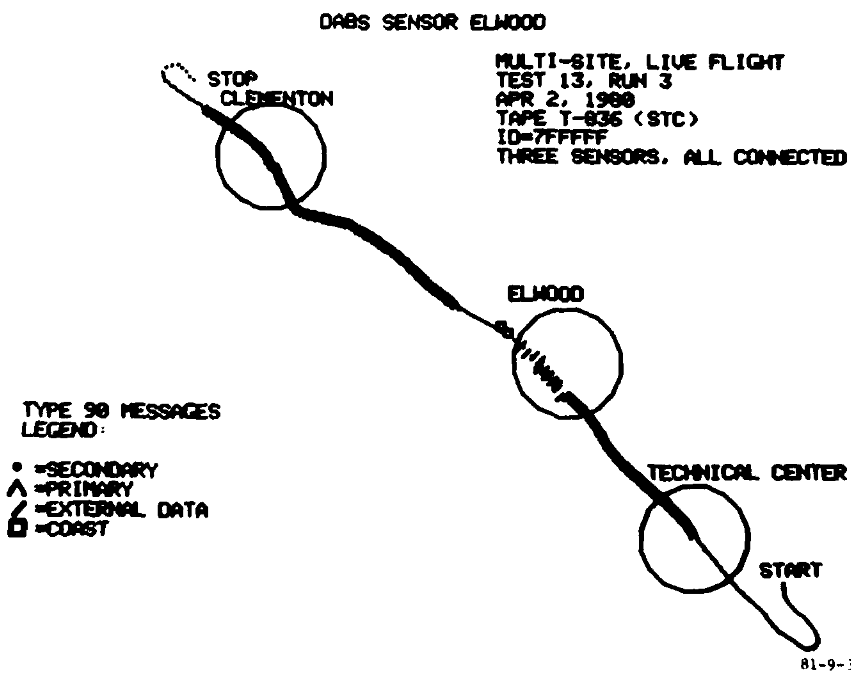

FIGURE 3. ELWOOD SURVEILLANCE PLOT, THREE SENSORS, ALL CONNECTED

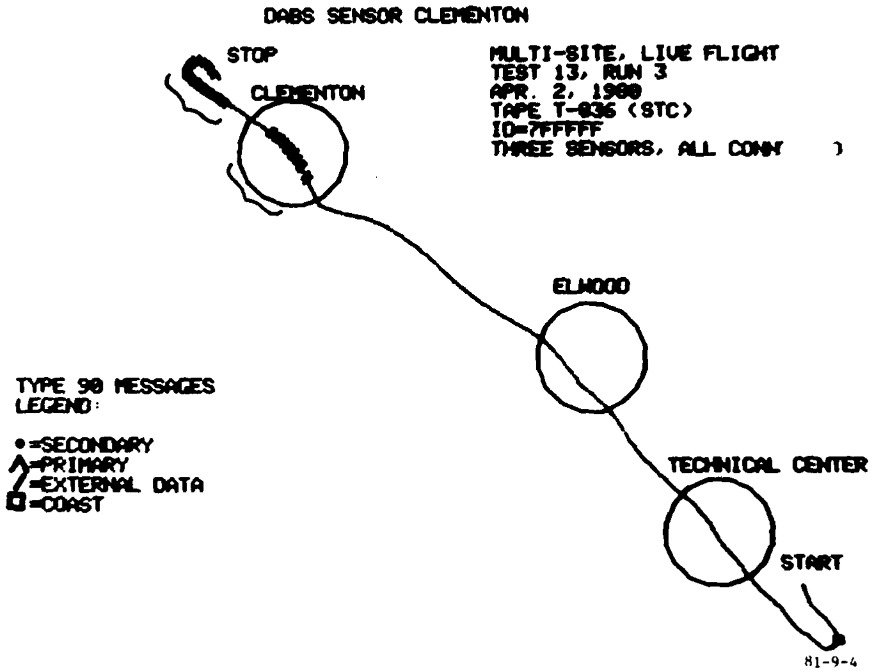

FIGURE 4. CLEMENTON SURVEILLANCE PLOT, THREE SENSORS, ALL CONNECTED

Figure 2 shows that the Technical Center sensor remains primary with the track on local data until it enters the zenith cone, at which time the track is updated using external data (indicated by the slash symbol). An enlarged plot of the Technical Center zenith cone area is given in figure 5. This plot shows an unexpected primary report within the zenith cone. The jitter observed in the external data is attributed to coordinate conversion errors that are generated near the center of the zenith cone (origin of the coordinate system).

When the target is once again seen by the Technical Center sensor and is being tracked locally, it is apparent from the symbol (dot) in both figures 2 and 5 that a transition from primary to secondary sensor status occurred while the target was being tracked on remote data. Inspection of the track plot from the Elwood sensor (figure 3) shows that while the track was in the fade condition at the Technical Center, Elwood seized primary status, which it kept until the fade occurred in Elwood's zenith cone and the Technical Center was able to seize back the primary status. When the aircraft departed from the region in which the Technical Center was permitted to be primary (about one-third of the distance between Elwood and Clementon), primary status was handed off to the Elwood sensor (figure 3). This figure also shows that in the Elwood zenith cone the track was maintained on externally supplied data. An enlarged view of the Elwood zenith cone is given in figure 6. The remote data shown in this figure, while adequate to maintain the aircraft in track on all but two scans (the coasts are shown by the box symbols), was not as smooth as that shown in the similar plot for the Technical Center. Coasts which appear in these plots are indicative of poor predictions that take place when the target is close to the origin of coordinates. The "sawtooth" appearance of the remote data in the Elwood zenith cone is attributed to the software coding errors which allowed a mixture of remote data from the other two sensors to be used for track update.

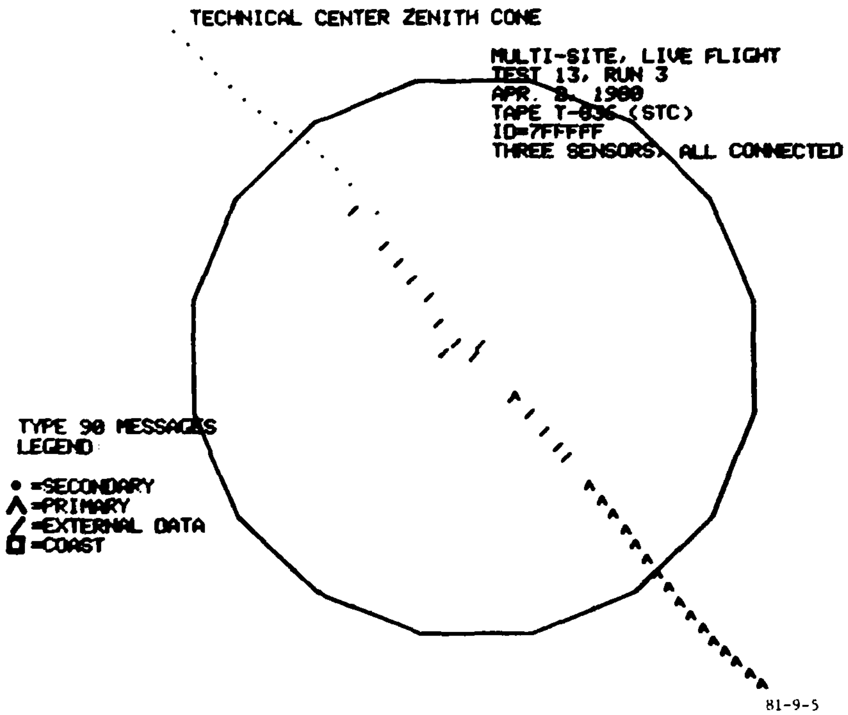

FIGURE 5. TECHNICAL CENTER ZENITH CONE SURVEILLANCE PLOT, THREE SENSORS, ALL CONNECTED

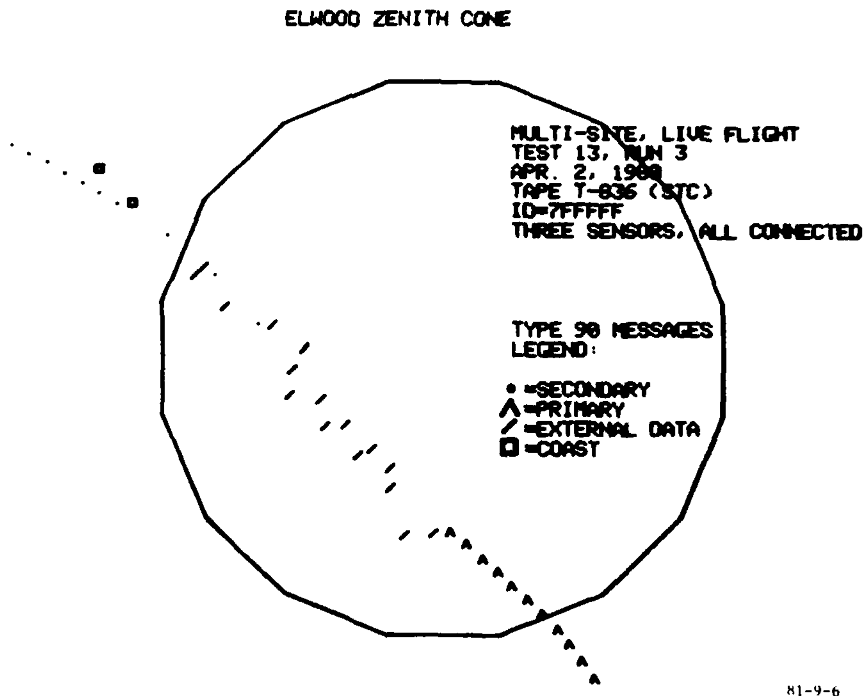

FIGURE 6. ELWOOD ZENITH CONE SURVEILLANCE PLOT, THREE SENSORS, ALL CONNECTED

Figure 4 shows that the Clementon sensor tracked the aircraft solidly up to the point of entry into the Clementon zenith cone (see detail in figure 7), except for one coast near the very beginning of the track, attributed to shielding of the aircraft's antenna during the turn. As was expected, the Clementon sensor remained secondary until the aircraft departed from the Elwood primary coverage area and received a handoff of primary status from Elwood. The Elwood plot (figure 3) shows the transition of Elwood from primary to secondary at the same point as the Clementon plot (figure 4) shows Clementon's transition from secondary to primary.

During some connected tests, notably test 14 (run 1) and test 16 (run 2), a track was maintained on external data for a considerable time following its exit from the Clementon zenith cone. When local tracking was finally resumed it appeared normal. In both these cases, an incorrect time-of-day value was supplied by the Elwood sensor as part of the remote track data. The resulting prediction error caused the Clementon sensor to miss the track with local interrogations. The time-of-day problem resulted from the failure of the clock to lock onto the WWVB signal and is a phenomenon associated with poor signal propagation in certain locales and at certain seasons of the year. A proposal to upgrade the clocks is currently under study.

<u>Three Sensors, All Unconnected</u>. These results were obtained from test 21 (run 2) of the test matrix. The flightpath starts a few miles west of the Technical Center in a coverage map region in which both the Technical Center and Elwood are primary. Since there is no communication between the sensors, assignment of a single primary sensor cannot be resolved and the condition of dual primary exists. (See figure 8 for the Technical Center plot and figure 9 for the Elwood plot.) The Clementon sensor is secondary in this region as is seen from the Clementon plot (figure 10). As the aircraft approaches the 180° radial from the Technical Center, it departs the region in which Elwood has any responsibility for primary coverage (figure 9 shows the transition from primary to secondary) and then, as the aircraft turns inbound, the transition back from secondary to primary occurs.

On the Technical Center plot (figure 8) the track coasts to a drop within the Technical Center's zenith cone as the lack of sensor-to-sensor connectivity precludes any receipt of remote data to be used for external tracking. After emergence from the cone of silence the track is reacquired on All-Call by the Technical Center showing that the transponder is unlocked. Figure 11 shows the enlargement of the zenith cone area for the Technical Center sensor. Figures 12 and 13 show the Elwood and Clementon zenith cones, respectively. Plots of just the All-Call replies received by each of the sensors during this test are discussed in the "Lockout Management" section. Note that the Elwood and Clementon tracks (figures 9 and 10) are, as would be expected, continuous through the Technical Center's zenith cone.

The Elwood track (figure 9) remains primary for the rest of the test and is continuous throughout, except for the expected coasts and drop in the Elwood zenith cone.

Figure 10 shows that the track, as seen by the Clementon sensor, is continuous, except for the expected coast and drop in the Clementon zenith cone. About midway between the Technical Center and Elwood the aircraft enters the region in which Clementon is primary. From this point until the point in figure 8 where the Technical Center transitions from primary to secondary, a condition of triple primary exists in which all three sensors in the unconnected state are entitled to receive pilot initiated downlink communications from the aircraft.

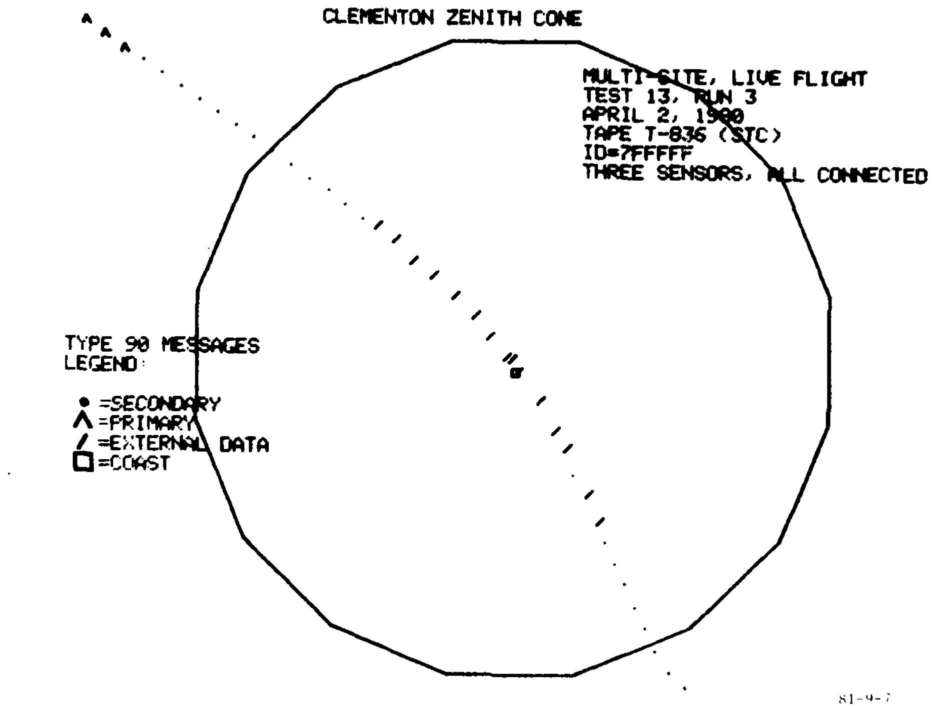

FIGURE 7. CLEMENTON ZENITH CONE SURVEILLANCE PLOT, THREE SENSORS, ALL CONNECTED

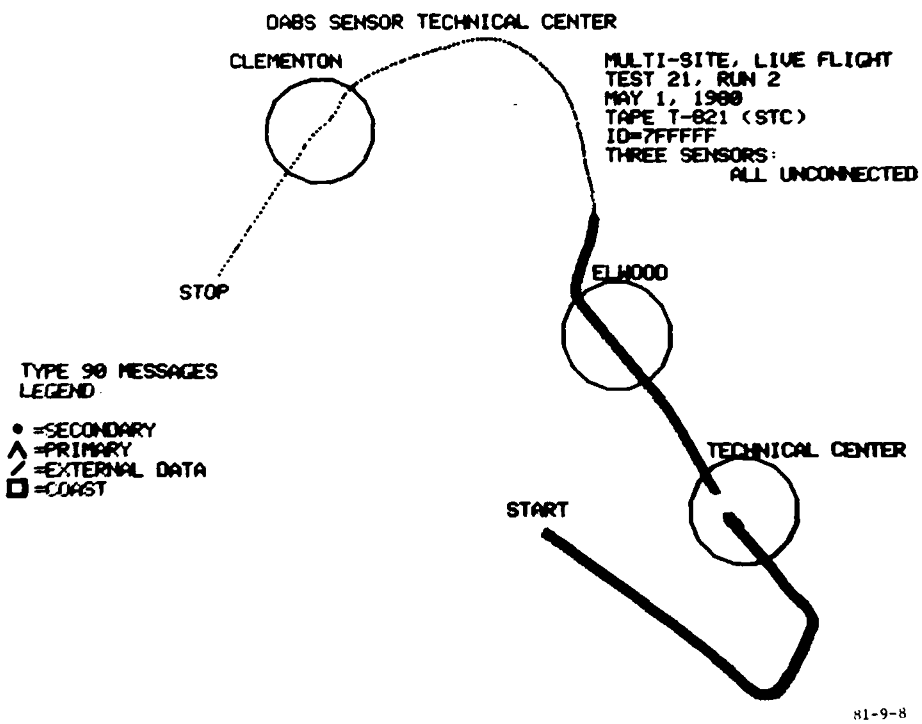

FIGURE 8. TECHNICAL CENTER SURVEILLANCE PLOT, THREE SENSORS, ALL UNCONNECTED

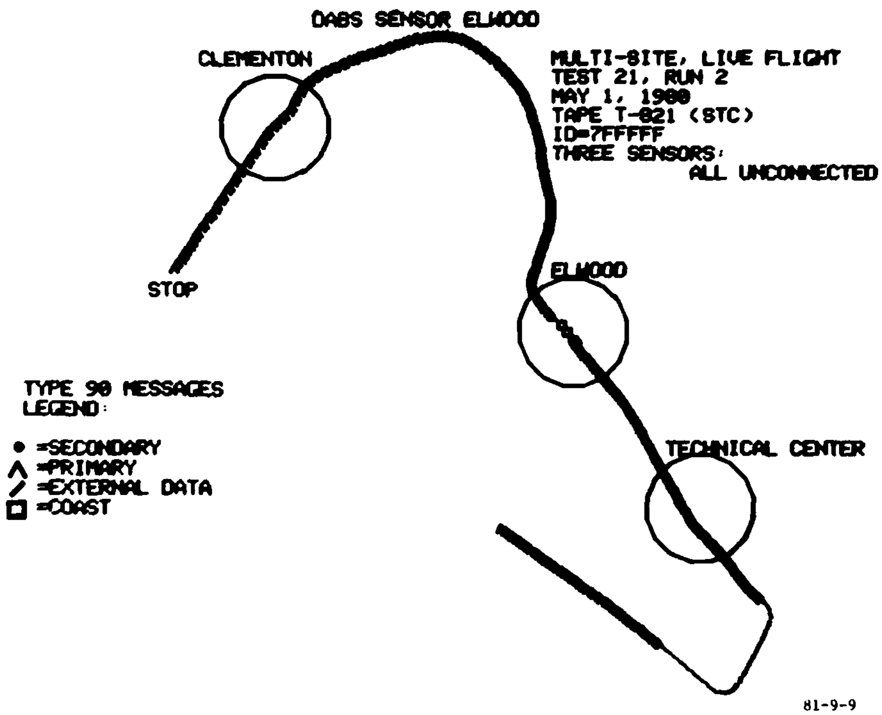

FIGURE 9. ELWOOD SURVEILLANCE PLOT, THREE SENSORS, ALL UNCONNECTED

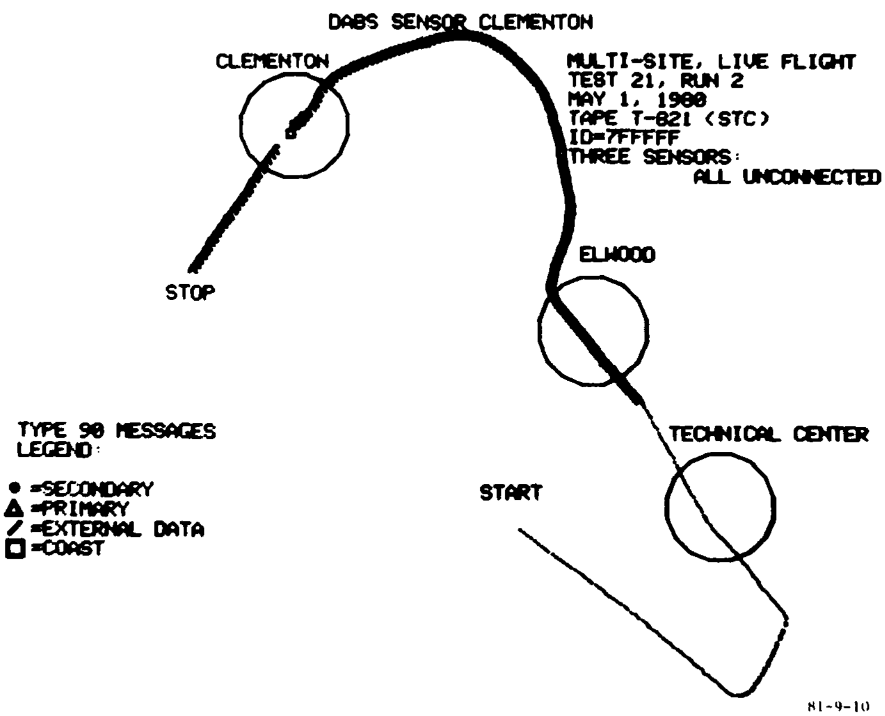

FIGURE 10. CLEMENTON SURVEILLANCE PLOT, THREE SENSORS, ALL UNCONNECTED

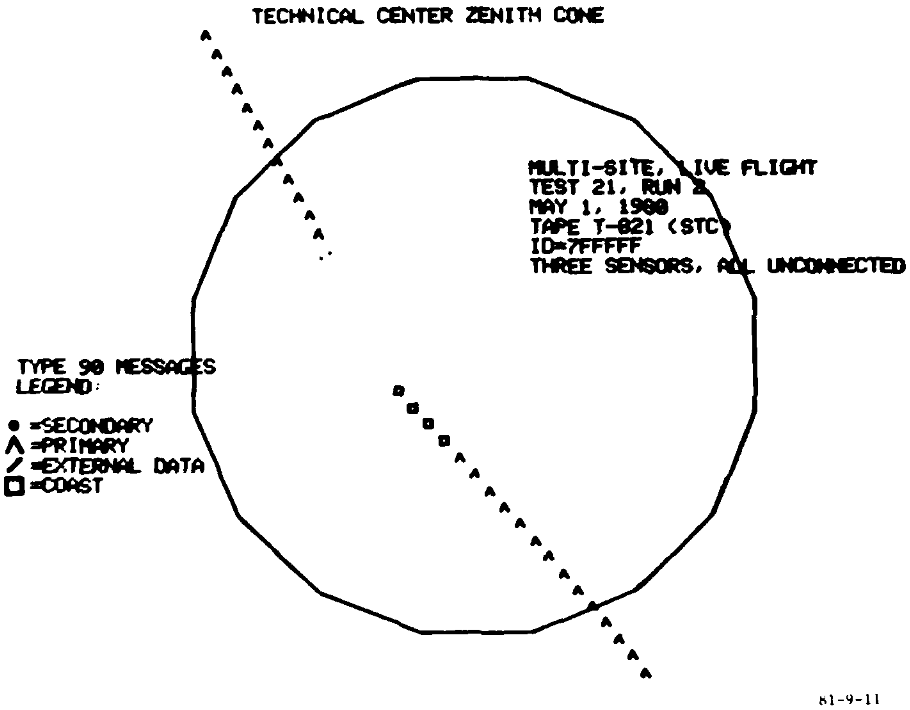

FIGURE 11. TECHNICAL CENTER ZENITH CONE SURVEILLANCE PLOT, THREE SENSORS, ALL UNCONNECTED

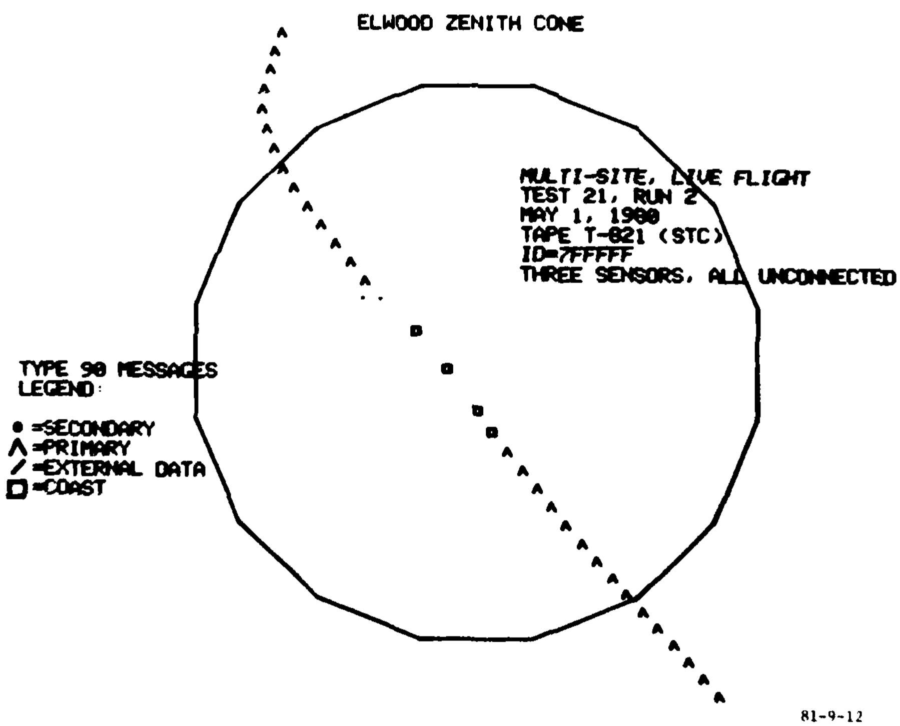

FIGURE 12. ELWOOD ZENITH CONE SURVEILLANCE PLOT, THREE SENSORS, ALL UNCONNECTED

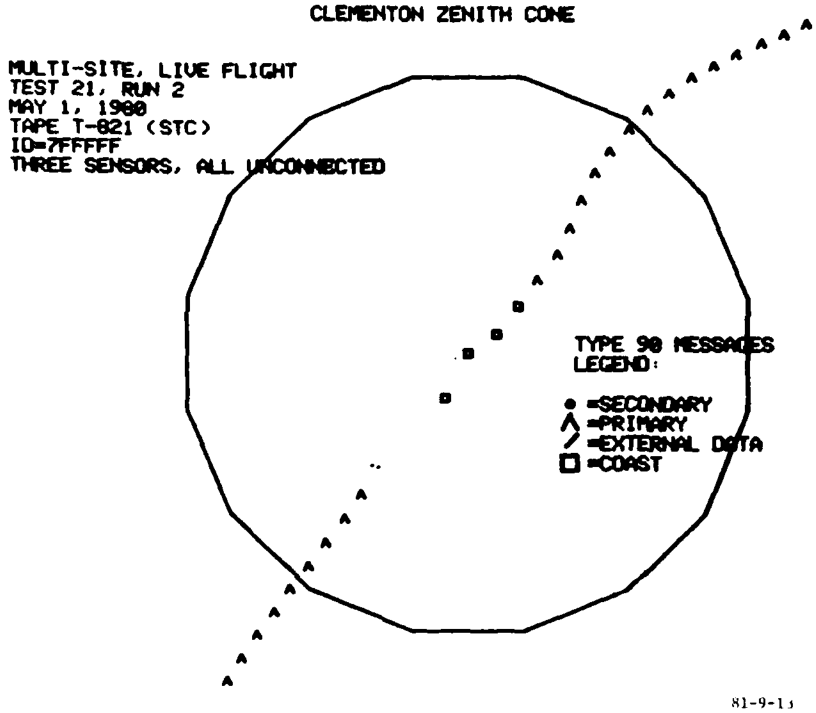

FIGURE 13. CLEMENTON ZENITH CONE SURVEILLANCE PLOT, THREE SENSORS, ALL UNCONNECTED

Three Sensors, One Unconnected. Test 25 (run 2) from the test matrix is discussed here to show the behavior of the DABS system when two sensors are connected to each other and one sensor (in this case, Clementon) is not connected to either of the others. In such a configuration, the behavior of the unconnected sensor should appear exactly as it did in the previous case in which all sensors were unconnected. The pair that are connected (Technical Center and Elwood) should behave exactly as they did in the case for all sensors connected, with the exception that whichever sensor of the pair has primary responsibility will engage in intermittent lockout rather than full lockout. The configuration in which Elwood (the en route sensor) was the unconnected sensor was also tested with no appreciable difference in the results.

Figure 14 shows the track as seen at the Technical Center. It starts southeast of the Technical Center with primary status and, as in previous cases, moves into the zenith cone where it is tracked on external data from Elwood. The enlargement of the Technical Center zenith cone shown in figure 15 shows that the external track was well behaved except for two coasts that are attributed to prediction errors close to the origin of coordinates. When local tracking was resumed, the sensor priority status was secondary, indicating that a primary coordination transaction had taken place during the fade. A glance at the corresponding Elwood plot (figure 16) will verify that Elwood, as expected, assumed primary status when the track was within the Technical Center's zenith cone and retained that status until the fade within its own zenith cone. Figure 17 is an enlargement of the Elwood zenith cone. The four coasts are also attributed to prediction errors close to the origin of coordinates.

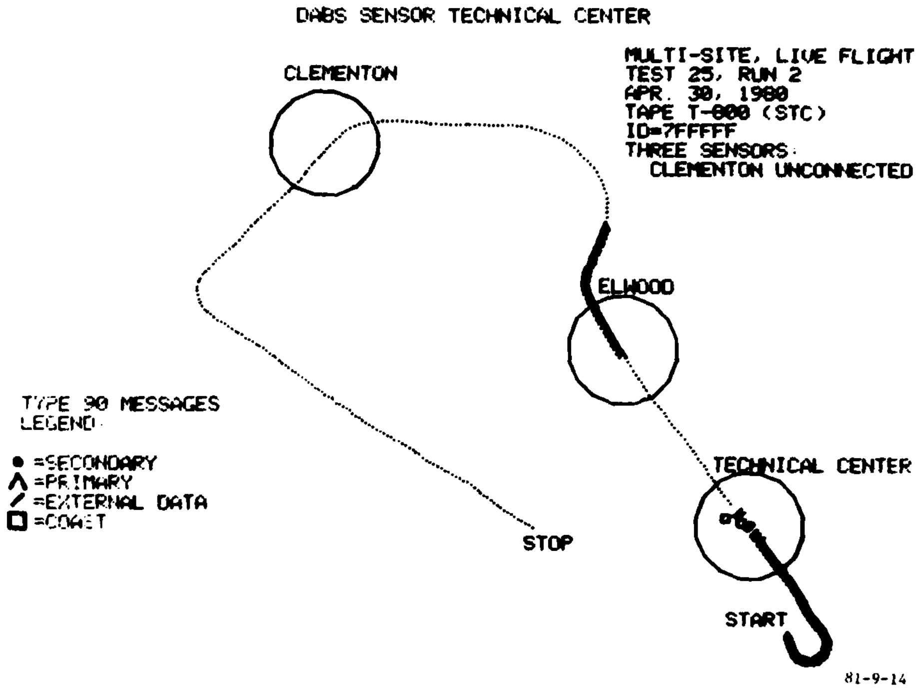

FIGURE 14. TECHNICAL CENTER SURVEILLANCE PLOT, THREE SENSORS, CLEMENTON UNCONNECTED

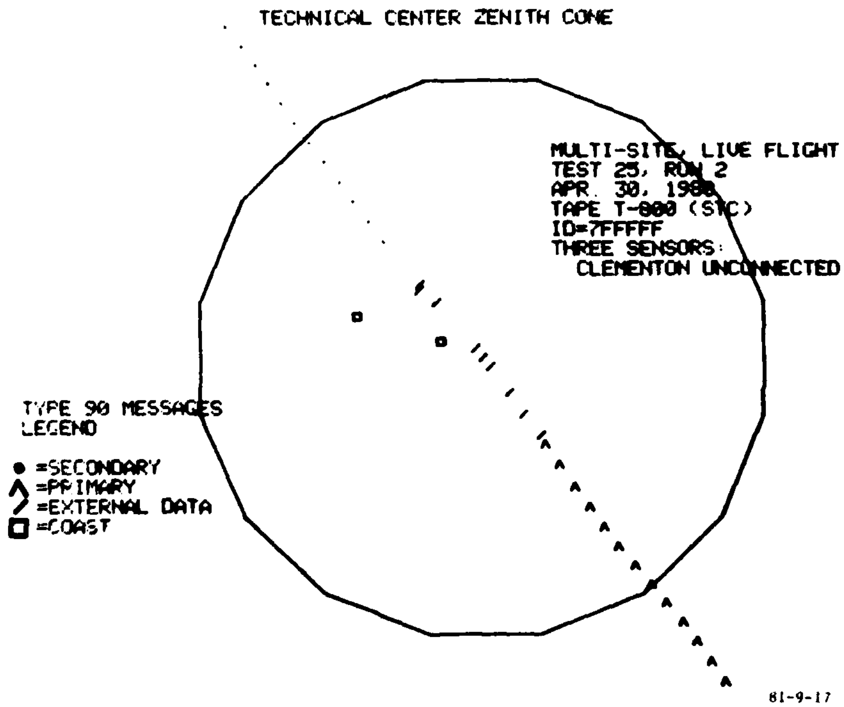

FIGURE 15. TECHNICAL CENTER ZENITH CONE SURVEILLANCE PLOT, THREE SENSORS, CLEMENTON UNCONNECTED

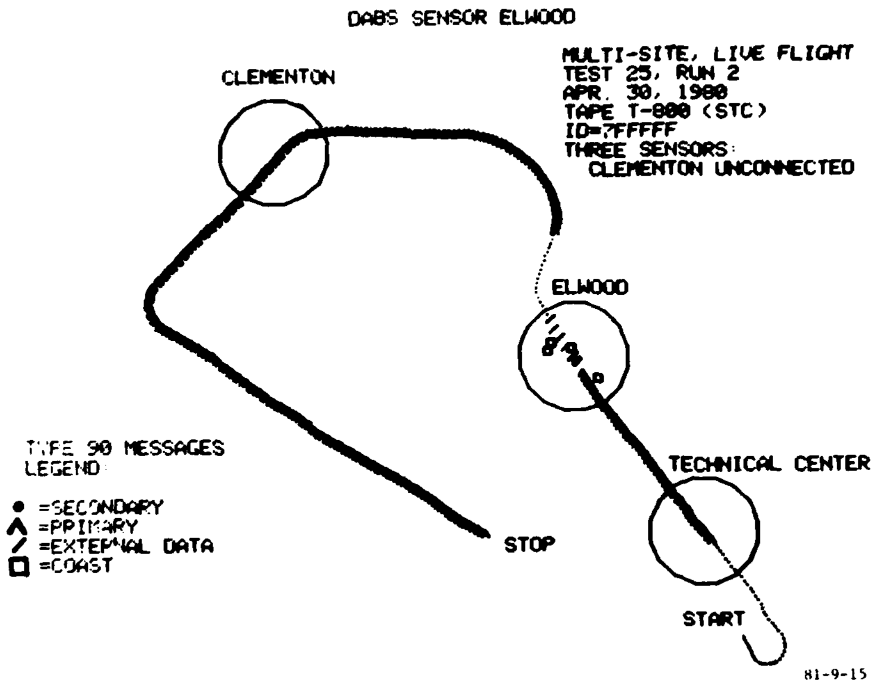

FIGURE 16. ELWOOD SURVEILLANCE PLOT, THREE SENSORS, CLEMENTON UNCONNECTED

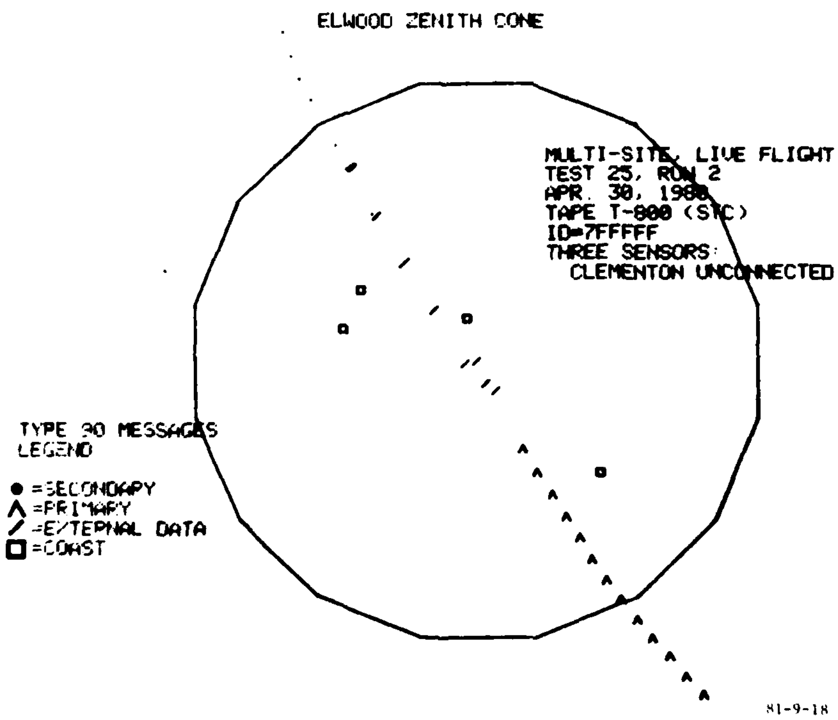

FIGURE 17. ELWOOD ZENITH CONE SURVEILLANCE PLOT, THREE SENSORS, CLEMENTON UNCONNECTED

When the aircraft departed from the Technical Center's primary area northwest of Elwood a coordination took place that left the Technical Center secondary and Elwood primary for the remainder of the test.

The Clementon sensor (figure 18) was unconnected during the entire run so that its determination of status was made with reference only to its own network coverage map. It became primary at a point between the Technical Center and Elwood (where it shared dual primary with Elwood) and remained primary for the remainder of the test, with the exception of a short sequence on the southeast bound leg. This sequence will be discussed in the next section (see "Control State Message").

The enlargement of the Clementon zenith cone (figure 19) shows clearly that the track coasted to a drop since it could not be supported by remote data. It was reinitiated with a new track number after receipt of two local reports, and remained secondary (dot symbols) until it was established on roll-call.

Control State Message. Figure 18, discussed in the previous section, contains an illustration of the effect of sending a control state message. The message was sent to the Clementon sensor from the STC in its role as a simulated ATC facility, and instructed the sensor to make the track controlled and set the sensor priority status to secondary. After the status transition was observed, another message was sent restoring the track to its original uncontrolled state. The Clementon sensor then made the determination of primary status based on the contents of the network coverage map.

Lockout Management. In surveillance areas covered by multiple sensors that are not connected to each other, the DABS system invokes a technique called "intermittent lockout" in which DABS transponders are allowed to be unlocked to All-Calls for a specified number of scans. The presence of the All-Call replies allows an unconnected sensor that may have dropped a track (as happens in its own zenith cone) to reacquire it. The fact that the tracks were reacquired by each unconnected sensor upon departure from the cone of silence is an indication that the transponder is undergoing synchronized intermittent unlock. A more extensive data analysis was performed by inspecting the surveillance file entries at each sensor and verifying that the lock counts, the unlock counts, and the lockout bits were being set correctly. A visual indication of the synchronous unlock are available in figures 20 through 22, which show All-Call replies received at the Technical Center, Elwood, and Clementon sensors, respectively. The very fact that All-Call replies were received is proof that periods of transponder unlock occured. The center of the plot in figure 22 shows an unexpectedly large sprinkling of All-Call reflections. The Clementon sensor does not have a reflector file. This phenomenon should be investigated after a reflector file has been installed.

Lock/Unlock Extension. To prevent garbling of All-Call replies returned from targets that are physically close to each other, the engineering requirement (FAA-ER-240-26) requires the network management function to perform a proximity test on aircraft in the vicinity of a transponder that is about to be unlocked. If a nearby transponder is also about to be unlocked, the lock period for one of the transponders is extended (up to a site-adaptable maximum number of track updates) in an attempt to avoid the garble that might result from a synchronous unlock. Waiting the extra time gives the targets time to move away from each other or to allow the unlocking transponder to complete its unlock cycle and begin a new lock cycle before the other unit actually becomes unlocked. In addition, the software is implemented such that the unlock period will be extended instead of the lock period if the synchronous unlock cycle occurs first.

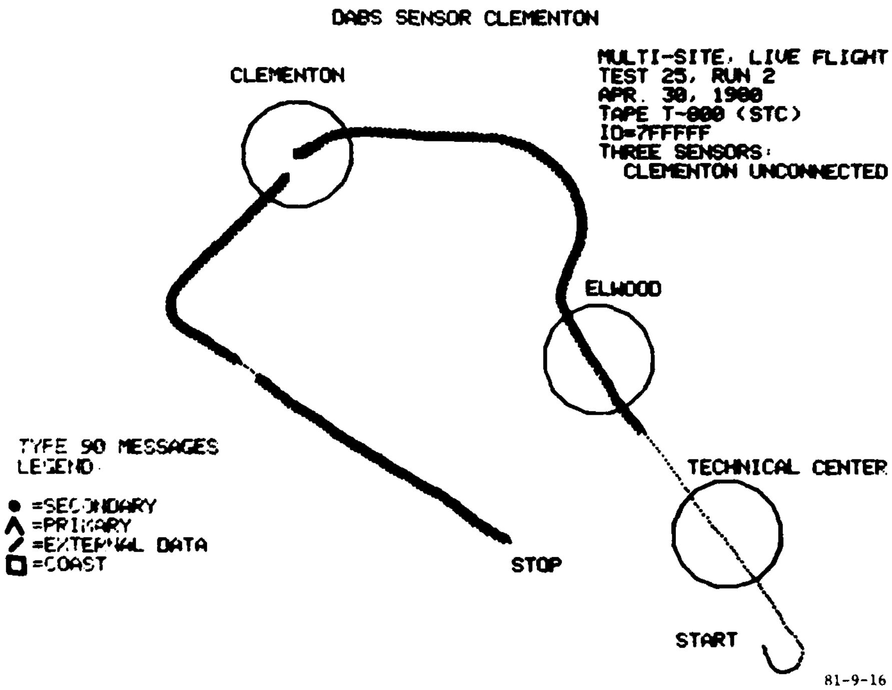

FIGURE 18. CLEMENTON SURVEILLANCE PLOT, THREE SENSORS, CLEMENTON UNCONNECTED

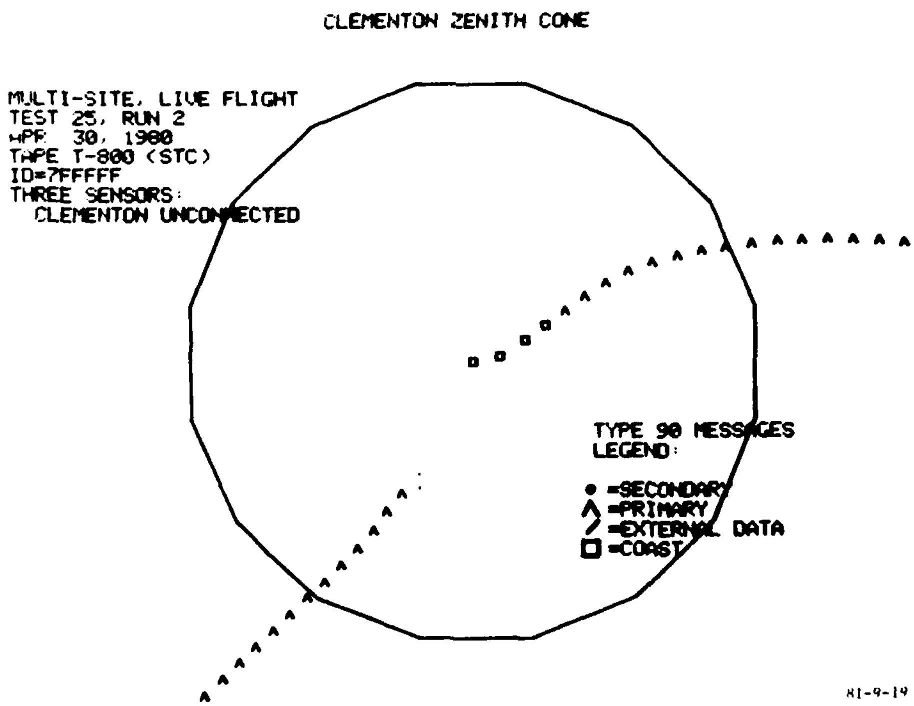

FIGURE 19. CLEMENTON ZENITH CONE SURVEILLANCE PLOT, THREE SENSORS, CLEMENTON UNCONNECTED

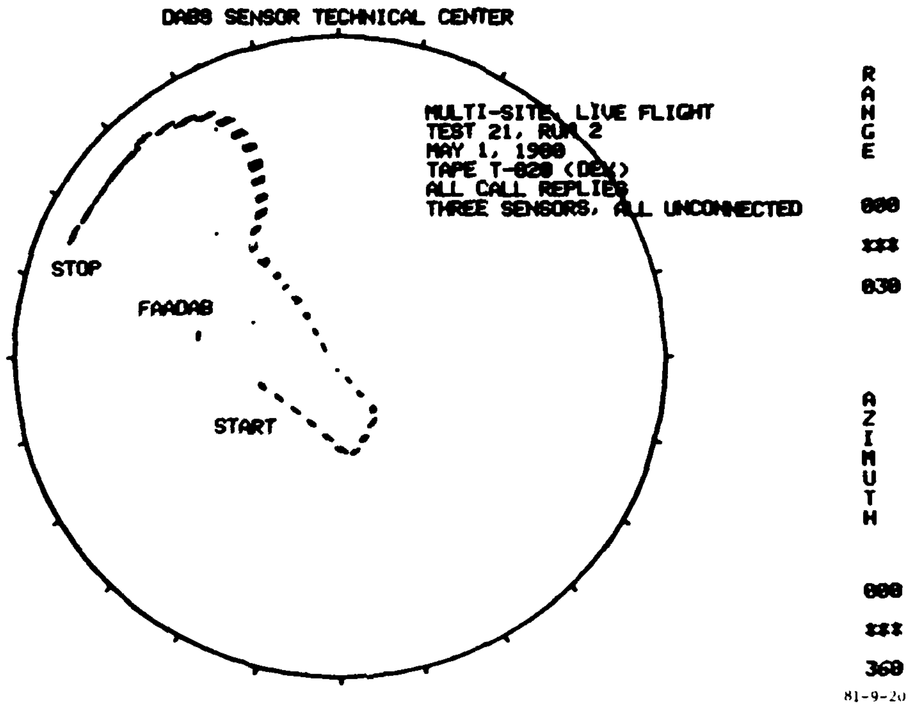

FIGURE 20. TECHNICAL CENTER ALL-CALL REPLY PLOT, THREE SENSORS, ALL UNCONNECTED

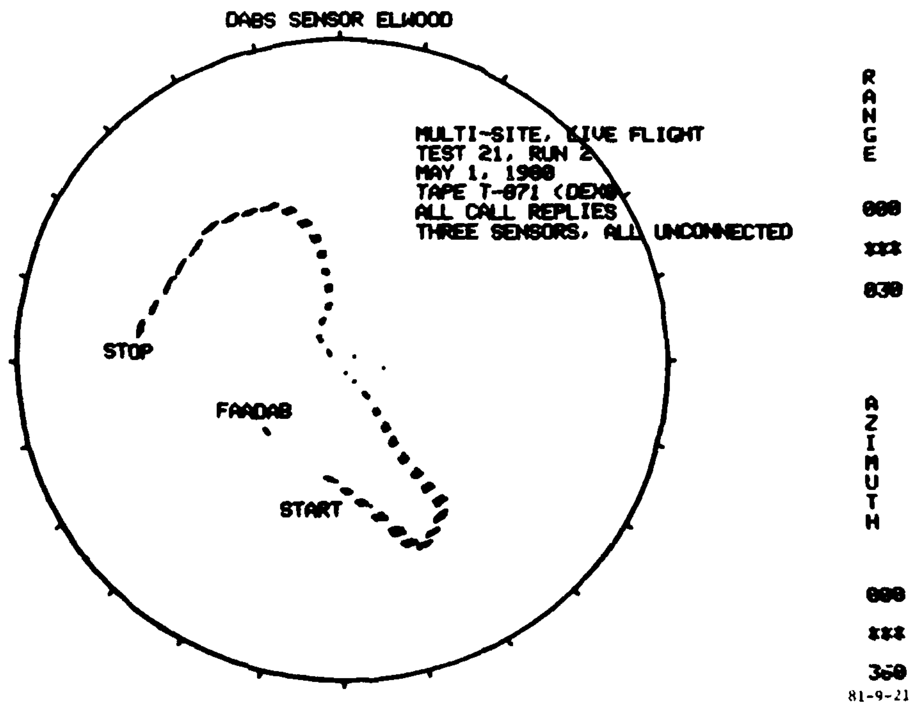

FIGURE 21. ELWOOD ALL-CALL REPLY PLOT, THREE SENSORS, ALL UNCONNECTED

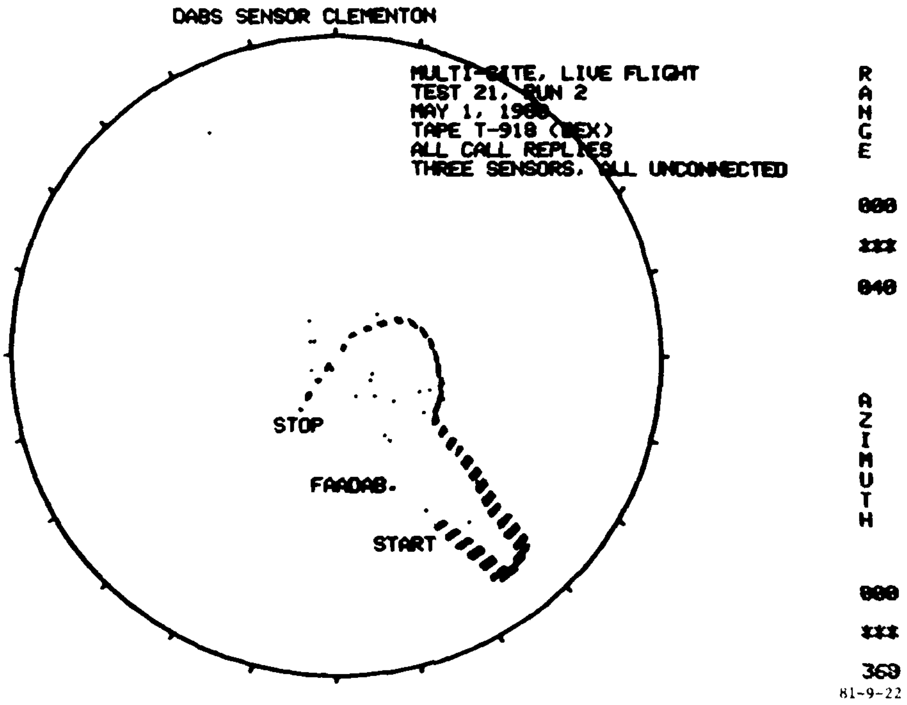

FIGURE 22. CLEMENTON ALL-CALL REPLY PLOT, THREE SENSORS, ALL UNCONNECTED

The extended lock/unlock feature was tested by mounting two DABS transponders in the same aircraft, one (DABS address 7FFFFF) connected to the lower antenna system, and one (DABS address 555555) connected to the upper antenna system. The aircraft was then flown in a two-sensor unconnected configuration in test 46 (run 1) of the test matrix. The test was conducted in the following way: with the aircraft in a surveillance area in which the Technical Center was primary and Elwood was secondary, the 7FFFFF transponder was turned on first and acquired on roll-call before the 555555 transponder was activated. Both of the transponders were being roll-called by both sensors, but the stagger introduced in turning them on for acquisition was then propagated into the lock and unlock sequences. Lock/unlock extension does not occur unless the transponders are synchronized in their lock/unlock cycles. The condition of simultaneous unlock occurred at Elwood as soon as the aircraft crossed the boundary into Elwood's primary zone. When the time came for the lock cycle to begin (unlock count of eight), the Elwood sensor locked the 7FFFFF transponder and set the lock count to one, while the 555555 transponder remained unlocked for an additional two scans before starting its lock cycle. The stagger introduced in this manner remained throughout the region in which Elwood was required to perform the intermittent unlock operation.

Duplicate DABS Addresses. Although the DABS system is based on the concept that duplicate addresses for aircraft are not supposed to exist in the real world, there is a provision for handling such an event. It consists of removing both aircraft track records and reports from the mainstream of the system, placing them in a holding area (the duplicate address alert table), and sending messages to other sensors and to ATC facilities alerting them to the existence of the condition. These messages contain position data which permit ATC to maintain surveillance.

The handling of duplicate addresses has been observed on several occasions. In one case the aircraft was instructed to change the code of its transponder to be the same as the stationary target at Mizpah. Both targets disappeared from the display screen and track alert messages were sent to all connected sensors indicating the presence of an entry in the duplicate address alert table. Any sensor receiving such a track alert message is required to remove the track from its surveillance file if it has not already perceived the duplicate address condition through its own interrogation/response processing. Correct response to the receipt of track alert messages was observed during the test. When the aircraft changed its code back to the original value, both tracks (the aircraft and the parrot) were reacquired. Duplicate address processing also was observed in cases where no concerted effort was made to force it. These cases were always observed during testing configurations in which Clementon was an unconnected sensor and arose from the fact that All-Call reflections were being experienced by a sensor with an empty reflector file. The sensor was unable to discriminate between a reflection and a duplicate address and correctly treated the situation as if a duplicate address existed. Once the aircraft had passed beyond the influence of the reflector, its track was reacquired normally. One such test was test 18 for which the Clementon track is shown in figure 23. The gap in the track just east of the Clementon zenith cone represents the period during which tracking was suspended and alert messages were sent. This event also resulted, understandably, in a reduced blip/scan ratio (BSR) for the aircraft during this test, as discussed in the "Surveillance Processing" section of this report.

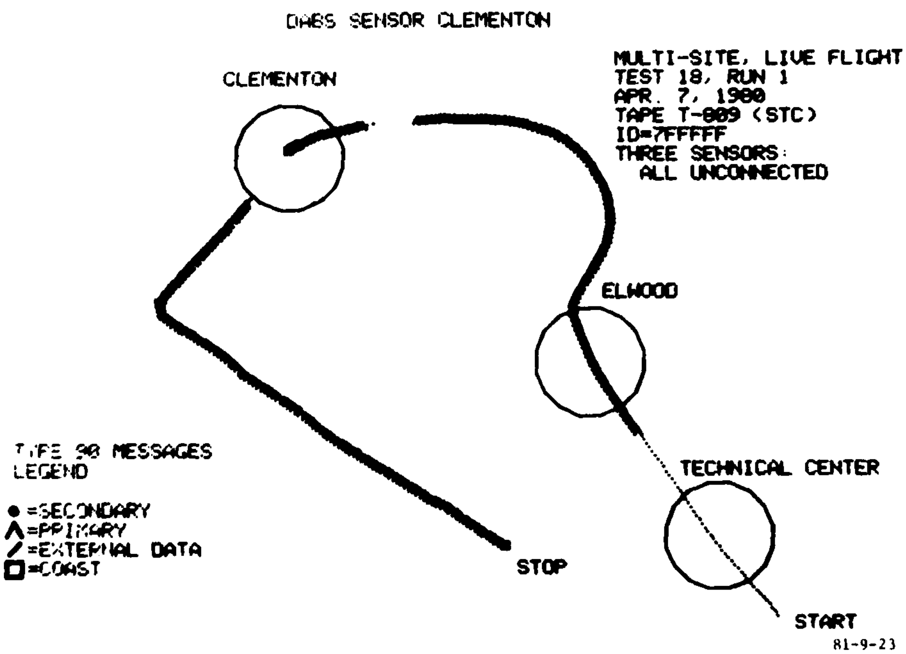

FIGURE 23. CLEMENTON SURVEILLANCE PLOT, DUPLICATE ADDRESS ALERT ARISING FROM ALL-CALL REFLECTION

Special Mode. When fewer than three sensors were used in a multisite test, sensor failure messages were sent to the remaining sensor(s) from the STC declaring all nonoperating sensors to be in the "failed" state. The resulting configuration forced the operating sensors into the "special mode" of reading the network coverage map, namely, to omit the failed sensor(s) when building the list of adjacent assigned sensors, and to rebuild that list immediately upon detection of the failure state. The intent of the one-bit target special mode flag in specification FAA-ER-240-26 seems to have been to flag the fact that the special mode was in effect at the time network management made its determination of the assigned sensor list. Unfortunately, there are many special modes: one in which sensor A has failed, one in which sensor B has failed, and one in which both have failed. A single bit target special mode flag is incapable of discriminating between these failure states in order to determine whether one failure state has been replaced by another. (Consider, for example, the case in which operation begins with two adjacent sensors failed and one subsequently recovers. The target special mode flag is set in both cases.) Because of this ambiguity, the additional processing required for the onset of special mode is undertaken on every scan during the existence of any failure state. While not serious in conditions of light track loads, there is concern that this situation may interfere with capacity testing. Another concern exists with regard to the current implementation's use of the special mode flag to indicate failure not only of a sensor, but also of a communications link to a sensor. It would be desirable to separate the logic used to process sensor failure from that used to process communications failure by defining a new flag, like the special mode flag, that would refer to communications failures only.

SURVEILLANCE PROCESSING.

The surveillance performance of the DABS equipped test aircraft is presented in table 2 which lists the BSR for each of the sensors and the sample size used to obtain it. The assumptions used in calculating the BSR are discussed in the "Surveillance Processing Data Reduction" section of appendix C. In addition, an "ATC BSR" is given which is defined as the number of scans the ATC facility received a report from at least one site, divided by the number of scans over which the measurement was made, with the result expressed as a percentage. It is a measure of the continuity of the surveillance information received by an ATC facility when the output of multiple sensors can be used to "fill-in" for reports missing from any given sensor. As can be seen from the table, the average BSR for each of the sites is above 99 percent, as is the ATC BSR value. The BSR for an individual site excluded that portion of the track that was within the zenith cone. Had the zenith cone data been included, the BSR value would have been lower since most of the flights did penetrate the cone of silence. The lowest BSR in the table was 95.2 percent for test 18 at Clementon, which resulted from an All-Call reflection that caused the sensor to drop the track for several scans as a consequence of duplicate DABS address processing. (See "Network Management" portion of this section.) As can be determined from tables 1 and 2, the connectivity of the sensors (or lack of it) has no observable effect on the BSR values. The results from these multisite tests compared favorably with the results presented in the "DABS Baseline Test and Evaluation" report (FAA-RD-80-36) for which the sensor was operated in a single-site mode with release 6.3 of the DABS mission software. In the ARIES simulation verification section of that report, two flight tests were discussed in which a similar measurement involving

TABLE 2. MULTISITE SURVEILLANCE RESULTS

Data Filter: Range 4-59 nmi; Azimuth All AZ Except 120-145
At Tech Center (Hangar Reflections)

Elevation: All Elevation Angles; Test Aircraft Only (7FFFFF)

		Sample Size			Blip/Scan Ratio			
Test No.	Date	Tech Center	Elwood	Clementon	Tech Center	Elwood	Clementon	ATC
13	4/2/80	208	261	217	99.5	100.	99.5	100.
24	4/2/80	259	249	177	100.	100.	98.9	100.
15	4/7/80	258	184	123	100.	100.	99.2	100.
18	4/7/80	279	275	168[1]	100.	100.	95.2	100.
14	4/7/80	216	224	189	100.	100.	100.	100.
26	4/16/80	244		277	99.6		99.3	99.6
27	4/16/80	258		262	100.		98.5	100.
19	4/18/80	265	190	193	100.	100.	99.5	100.
20	4/18/80	269	185	197	100.	100.	100.	100.
23	4/18/80	262	N.A.	200	98.5	N.A.	100.	100.
30	4/21/80	236			100.			100.
34	4/21/80	249	208	216	98.8	100.	98.6	98.8
28	4/22/80	287	240		100.	100.		100.
29	4/22/80	258	213		100.	100.		100.
32	4/22/80		126[2]			100.		100.
31	4/22/80	266			99.6			99.6
25	4/30/80	263	129[1]	264	100.	100.	100.	100.
16	5/1/80	225	252	242	100.	100.	100.	100.
21	5/1/80	261	176	285	100.	100.	100.	100.
33	5/1/80		N.A.			N.A.		N.A.
41	5/5/80	272		301	100.		100.	100.
42	5/5/80	267		296	100.		100.	100.
46	5/15/80	266	116[1]		100.	100.		100.
17	5/15/80	257	142	232	100.	100.	99.6	100.
52	6/12/80	234		N.A.	100.		N.A.	100.
54	6/12/80			225			100.	100.
48	6/20/80	288	112[1]	283	100.	100.	100.	100.
49	6/20/80	280	N.A.	286	100.	N.A.	100.	100.
50	6/20/80	270	271	301	100.	100.	100.	100.
51	6/30/80	280	284		100.	100.		100.
53	7/7/80		280			100.		100.
55	7/7/80	206	240	297	100.	99.6	100.	100.
Total:		7188	4357	5231				
Avg:					99.8	99.9	99.5	99.9

Grand Total: 16776
Grand Avg: 99.7

N.A. = Read error at beginning of tape
1 = Read error in the middle of tape
2 = Data extraction problem

a live DABS transponder yielded a value of 100 percent. Comparison of the single site results with those obtained in the multisite environment show that the surveillance performance of a network of DABS engineering model sensors is excellent.

In all tests, both baseline and multisite, the reliability figures for the DABS identifier (ID) and the altitude reliability for DABS roll-call reports were 100 percent.

The number of DABS interrogations per scan was calculated manually for five of the multisite tests (test numbers 15, 20, 28, 29, and 34). The data were collected when the test aircraft ranged from 15 to 25 nmi from the DABS sensor. Under these conditions the number of interrogations per scan was calculated to be 1.04. The corresponding measurement in the "DABS Baseline Test and Evaluation" report had a value of 1.17. The difference between these values resulted because of including in the baseline calculation aircraft closer than 15 nmi from the site. A recomputation of the baseline 1.17 value, excluding the close-in reports, yielded a value of 1.06, which is in very close agreement.

DATA LINK MESSAGE PROCESSING.

The results of data link testing are shown as plots. Thirteen different plots are used in presenting the data. The variables defined are totals for each message rate (see "Data Link Scenarios" section, page 9).

L = Number of tactical uplinks delivered where delivered refers to a message delivery notice specifying successful delivery.

E = Number of tactical uplinks expired where expired refers to a message delivery notice specifying expiration.

R = Number of tactical uplinks rejected where rejected refers to a message rejection/delay notice specifying rejection.

D = Number of tactical uplinks delayed where delayed refers to a message rejection/delay notice specifying delay.

N = Number of tactical uplinks received at the sensor from the ATC.

M(i) = Number of tactical uplinks delivered in i time units,

where $i = 0,1,2...,7$

and one time unit is five seconds.

Note: M(i) is a discrete distribution and groups the messages delivered into 5-second intervals. The exact time difference could not be measured, only the 5-second interval in which the delivery notice occured (referenced to the time of receipt of the message at the sensor from the ATC).

The plots represent the following statistical data:

1. Messages delayed (percent) as a function of incoming message rate:

$$P_d = 100 \times \frac{D}{N}$$

2. Completed transactions (percent) as a function of incoming message rate:

$$P_c = 100 \times \frac{(L+E+R)}{N}$$

3. Expired messages (percent) as a function of incoming message rate:

$$P_e = 100 \times \frac{E}{N}$$

4. Successfully delivered messages (percent) as a function of incoming message rate:

$$P_s = 100 \times \frac{L}{N}$$

5. Undetained successful deliveries (percent) as a function of incoming message rate:

$$P_u = 100 \times \frac{M(0)}{N}$$

6. Average message delivery time as a function of incoming message rate:

$$T_a = \frac{\Sigma(i \times M(i))}{\Sigma(M(i))}$$

7. Distribution of delivery times for each incoming message rate:

$$T_d = 100 \times \frac{M(i)}{\Sigma(M(i))}$$

GENERAL PLOT CHARACTERISTICS. Eight tests were run in order to test the data link function. Unlike that used in the network management tests, the flightpath (pattern B) avoided the zenith cones over the sensors in order to prevent interruptions in the accessibility of the data link.

In the plots that follow, the value obtained for each sensor is assigned a unique symbol: a plus sign for the Technical Center, a box for Elwood, and a cross for Clementon. In the S3 scenario all uplinks addressed to the nonexistent DABS address 555555 were correctly rejected and have been omitted from the data in order to avoid distortion of the results.

The plots were examined relative to the conditions present during the eight tests; no pattern relating to multisite configuration could be discerned. Separate plots made for 7FFFFF and FAADAB showed no significant difference in the data link behavior of the two test transponders. In line with these findings, the data from both transponders and the eight separate tests have been combined.

ANALYSIS OF DELAYED MESSAGES. Figure 24 shows that there were no messages that generated delay notices. The output of the track summary data reduction program indicated that the tracks were in roll-call state during the entire test, which means that no sensor ever missed more than N (site adaptable = 2) consecutive reports for either of the test transponders. Since delays should not occur when tracks are maintained on roll-call, the data link function is working correctly in this respect.

ANALYSIS OF COMPLETED MESSAGES. Figure 25 shows that at incident message rates of two through five (messages per 5-second time unit), all three sensors complete the transactions for all incoming messages, which is to say that all messages are delivered, expired, or rejected and none is lost. At an incoming message rate of six, the probability of completion at the Elwood sensor drops to 99 percent, while remaining at 100 percent at the other two sensors. At message rates of seven and eight, a decided degradation can be observed. At a message rate of seven, the Technical Center's percentage of completion is 99 percent, Elwood's is 97 percent and Clementon's is 92 percent. At a message rate of eight, the value at the Technical Center dropped to 92 percent, at Elwood to 91 percent, and at Clementon to 84 percent.

This degradation at higher message rates result from factors in the channel management and data link functions. In the version of channel management used for these tests, the maximum number of interrogations that could be scheduled was six per scan. The value six comes about because the effective beam width for DABS (90 azimuth units, as determined by the value of a site-adaptable

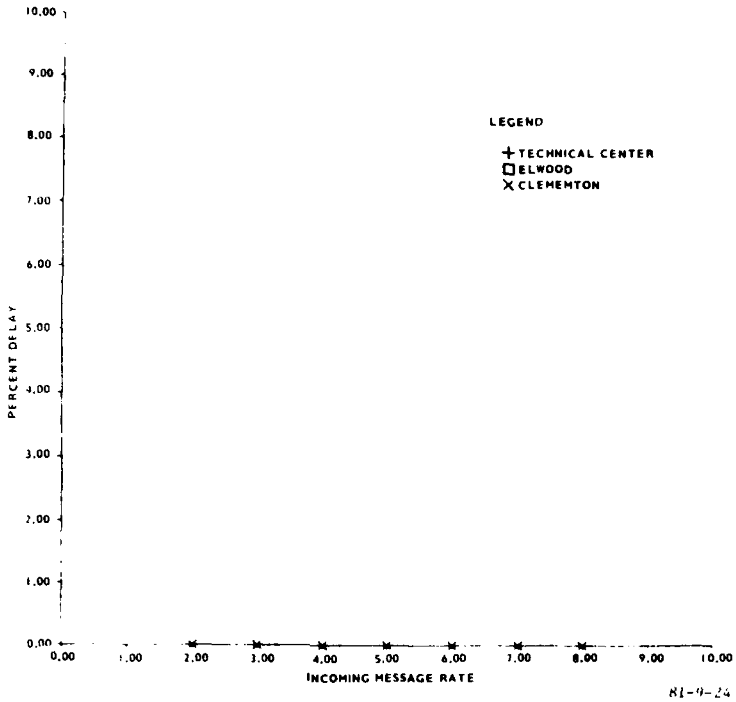

FIGURE 24. ANALYSIS OF DELAYED MESSAGES

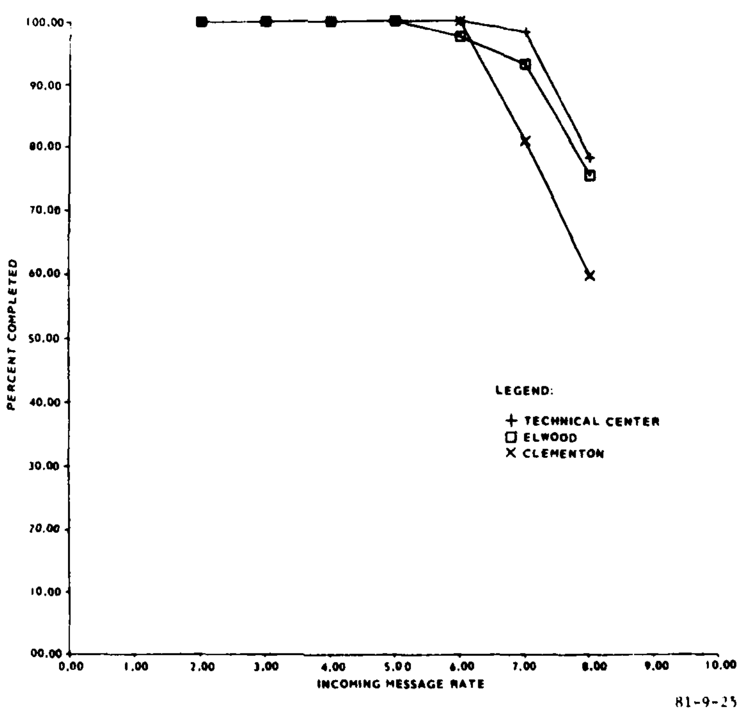

FIGURE 25. ANALYSIS OF COMPLETED MESSAGES

parameter known as THETAH) theoretically allows channel management to schedule 3.15 DABS periods per aircraft during the beam dwell. With only one or two DABS aircraft in the beam, channel management will generally be able to accomplish two schedules per period for a total of six interrogations. Since channel management cannot keep up with the scan-after-scan arrival of seven or eight tactical uplink messages, the number of messages in the queue keeps increasing. It can only increase to 15 for each target because of the 4-bit sizing of an index, known as the entry indicator, that is used by data link processing to manage the waiting entries. Additional messages arriving when the list is full are discarded. Since no provision exists to notify ATC of this "buffer full" condition, the message transaction is never completed (no rejection, delivery, or expiration notice is ever sent) and the message is "lost." The performance monitor, however, will maintain counts of this situation. It should be emphasized that the sensor was being loaded with message rates in excess of ER requirements in order to determine what functions would cause the resulting degradation.

The completion rates shown in figure 25 are similar for the Technical Center and Elwood sensors, but they are considerably worse for Clementon. The degraded data link performance resulted from the fact that during these eight tests the Clementon sensor showed a significantly greater number of "no detect" replies to interrogations, both in and out of the beam. This phenomenon is not understood and should be investigated.

ANALYSIS OF EXPIRED MESSAGES. Figure 26 shows that at lower message rates there are no expirations, a consequence of the fact that at these rates all messages are successfully delivered. At message rates of six, seven, and eight, however, the number of waiting messages increase in the manner discussed in the previous section. The number of expirations would be expected to rise as the messages are forced to wait longer in the queue. The figure shows that the percentage of expired messages never rises above one percent, and even decreases when the rate is increased from seven to eight. This decrease is deceptive for it does not mean that the messages are being delivered at a greater rate. It does reflect the fact that fewer messages get the chance to expire because they are discarded as a result of the entry indicator sizing constraint discussed in the previous section.

ANALYSIS OF SUCCESSFUL DELIVERIES. The data shown in figure 27 are similar to that presented for the analysis of completed messages. The difference is that this statistic does not contain message rejections (of which there were none in this sample) or message expirations. Since there were only a few expirations for reasons discussed earlier, the plots of completions and of successful deliveries are almost identical.

ANALYSIS OF UNDETAINED MESSAGES. Figure 28 shows the plot of the statistic which measures the percentage of messages that are delivered within one time unit (5 seconds) of transmission from the STC.

This statistic is measured in time units rather than scans due to the characteristics of the Elwood sensor. The data link function operates on a half-scan basis at Elwood, but scan markers are recorded only once a scan (every 9.7 seconds). The data at the other sensors refer to a 4.7-second scan, about half that at Elwood. Therefore, time units were used to measure the data at all sites. For rates of two through five, the percent undetained is in the 90's for the Technical Center and Clementon and is in the 80's for Elwood. The explanation of the difference lies in the respective antenna scan rates. The Elwood sensor is an en route sensor, having a back-to-back antenna

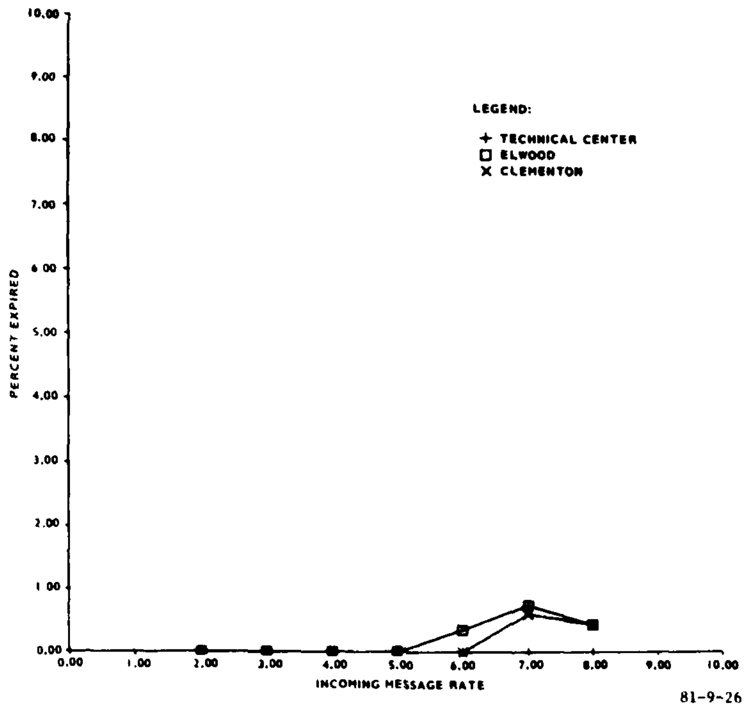

FIGURE 26. ANALYSIS OF EXPIRED MESSAGES

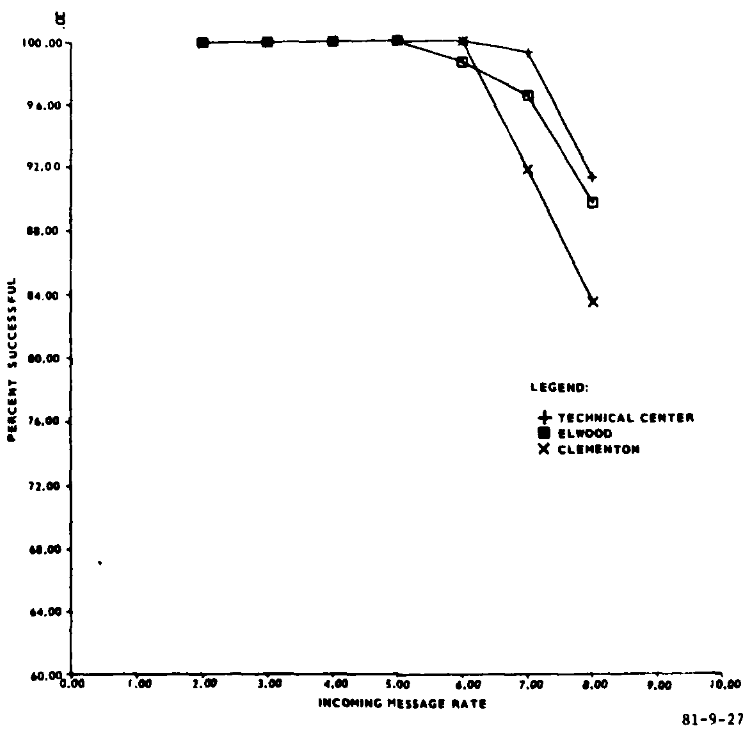

FIGURE 27. ANALYSIS OF SUCCESSFULLY DELIVERED MESSAGES

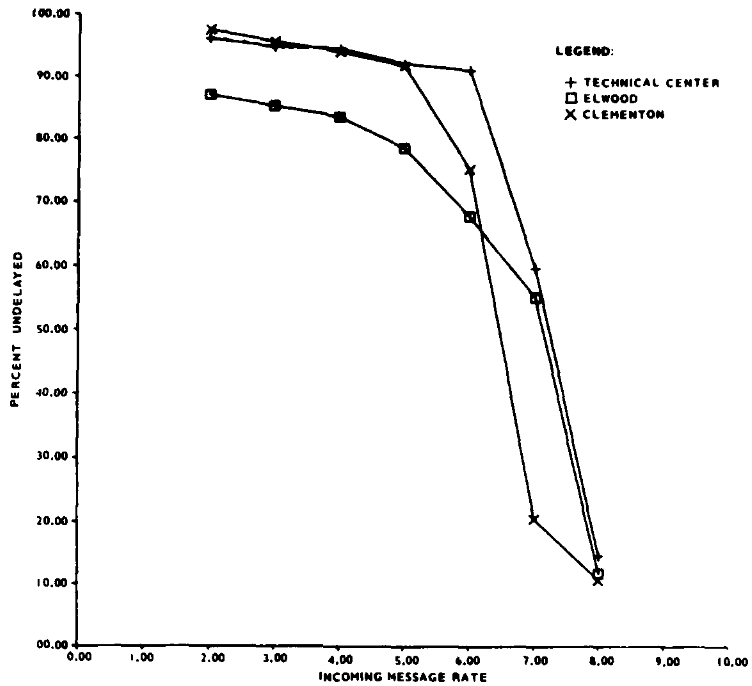

FIGURE 28. ANALYSIS OF UNDETAINED MESSAGES

and a scan rate of 9.7 seconds; whereas, the others are terminal sensors having scan rates of 4.7 seconds. In one time unit the terminal sensor antennas travel

$$\frac{5}{4.7} = 1.06 \text{ scans.}$$

The en route antenna travels

$$\frac{5}{9.7/2} = 1.03 \text{ scans}$$

between antenna faces in one time unit. Data link message processing is handled on a scan basis, and since the terminal sensors have more scans between message blocks, they appear to deliver their messages in fewer time units. The result is a higher percentage of undetained messages for the Technical Center and Clementon than for Elwood.

At a message rate of six, the percentage of undetained messages at Elwood and Clementon both drop off. However, at a rate of seven for Clementon and a rate of eight for the Technical Center and Elwood, there is a large decrease. The drop occurs sooner at Clementon than at the other two sensors because of the greater frequency of "no-detects," as mentioned previously. At a message rate of eight, the statistic for undetained messages is about 10 percent for each of the three sensors. This value reflects the fact that at this rate none of the sensors can keep up with the incoming messages. Initially, when the first few blocks of a message arrive, some of the messages are delivered within one time unit. As more and more blocks arrive, however, the sensors all reach a state in which almost all (if not all) messages are detained.

<u>ANALYSIS OF AVERAGE DELIVERY TIME.</u> Figure 29 shows the statistic that measures, on an average, how many time units are required for message delivery. For the same reasons, discussed earlier in conjunction with the "Analysis of Undetained Messages" (figure 28), the average delivery times for the Technical

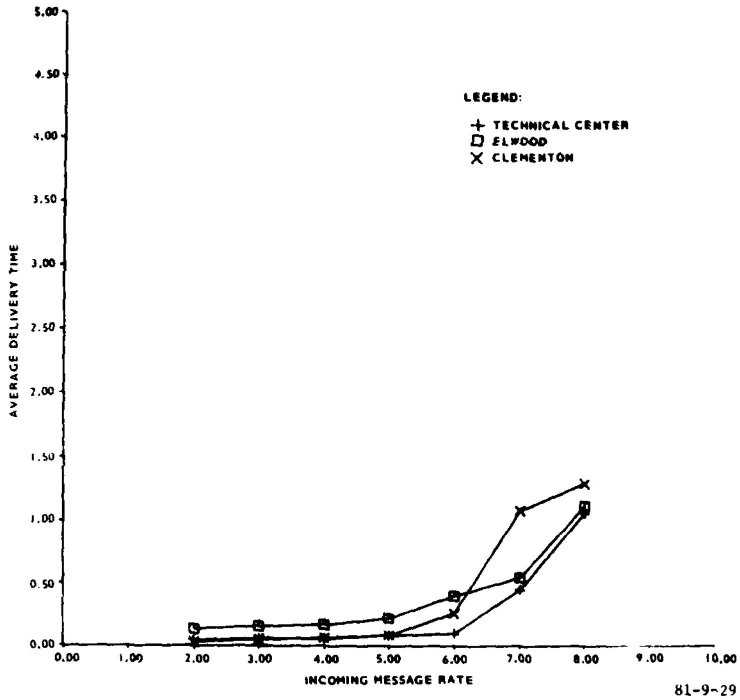

FIGURE 29. ANALYSIS OF AVERAGE DELIVERY TIME

Center and Clementon sensors are similar at incoming message rates of two through five, and Elwood's average is higher across the same interval. The same reasoning used to explain the differences at rates of six, seven, and eight also applies. Through an incoming message rate of seven, the Technical Center and Elwood sensors maintain a value of the average delivery time, T_a, which is less than half a time unit. At a rate of seven, Clementon has $T_a = 1.1$ time units. At a message rate of eight, T_a is less than 1.5 time units for all three sensors. Since T_a is measured in time units and the average value for an interval is its midpoint, seconds equals time units multiplied by 5 plus 2.5. For example: $T_a = 0.5$ time units corresponds to 5 seconds.

ANALYSIS OF DELIVERY TIME DISTRIBUTION. Figures 30 through 36 show the delivery time distribution for message rates of two through eight, respectively. This statistic measures the ratio of messages delivered within i time units (where i = 0,1,2...,7) to the total number of messages delivered.

At message rates of two through five, the terminal sensors deliver within one time unit at least 90 percent of the total number of messages delivered; the Elwood sensor delivers at least 80 percent. The difference between the en route and terminal sensors, in this respect, has already been discussed previously in the "Analysis of Undelayed Messages" section. During the next time unit the sensors deliver all their remaining messages.

At a message rate of six, 90 percent of the messages delivered by the Technical Center are delivered within the first time unit and 10 percent are delivered during the next. Elwood delivers 70 percent within the first time unit, 25 percent during the second, and 5 percent during the third.Clementon's figures are 75 percent and 25 percent for the first and second time units, respectively.

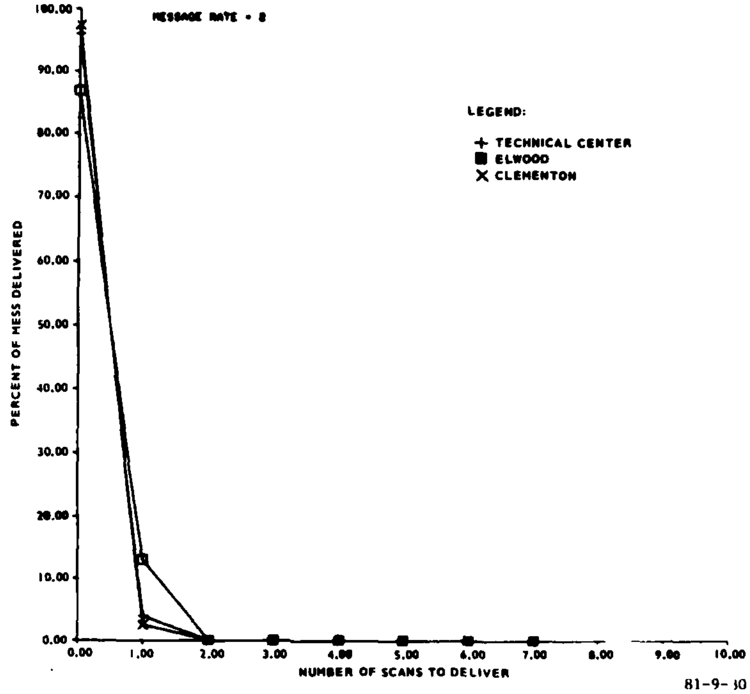

FIGURE 30. MESSAGE DELIVERY TIME FOR MESSAGE RATE OF TWO PER SCAN

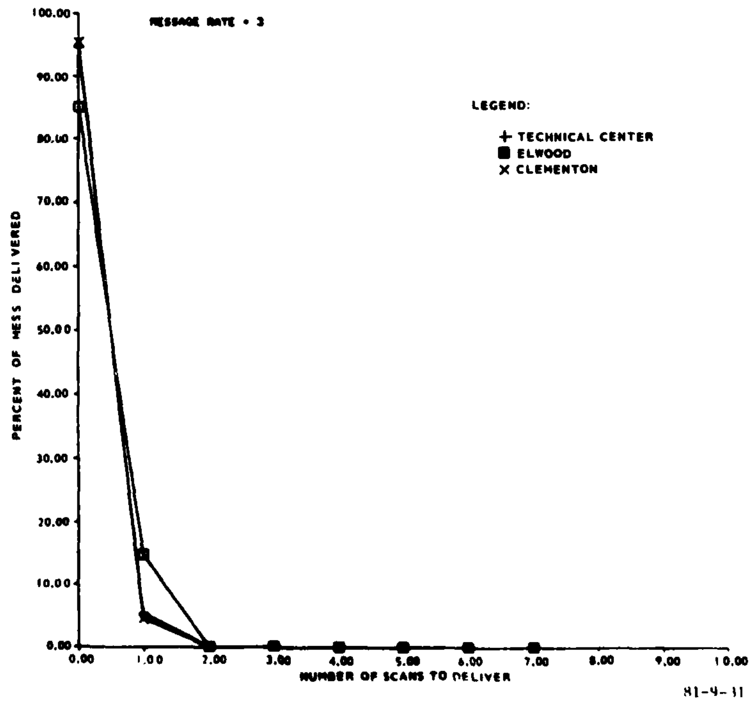

FIGURE 31. MESSAGE DELIVERY TIME FOR MESSAGE RATE OF THREE PER SCAN

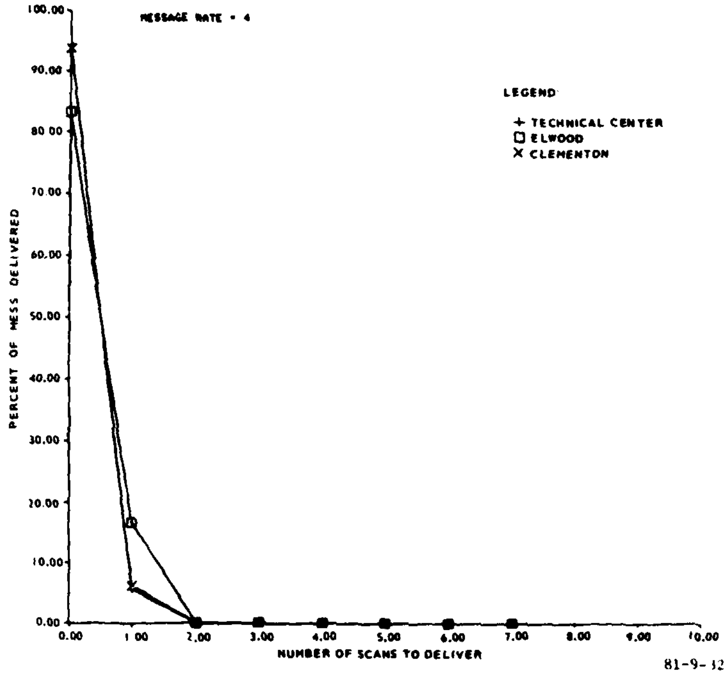

FIGURE 32. MESSAGE DELIVERY TIME FOR MESSAGE RATE OF FOUR PER SCAN

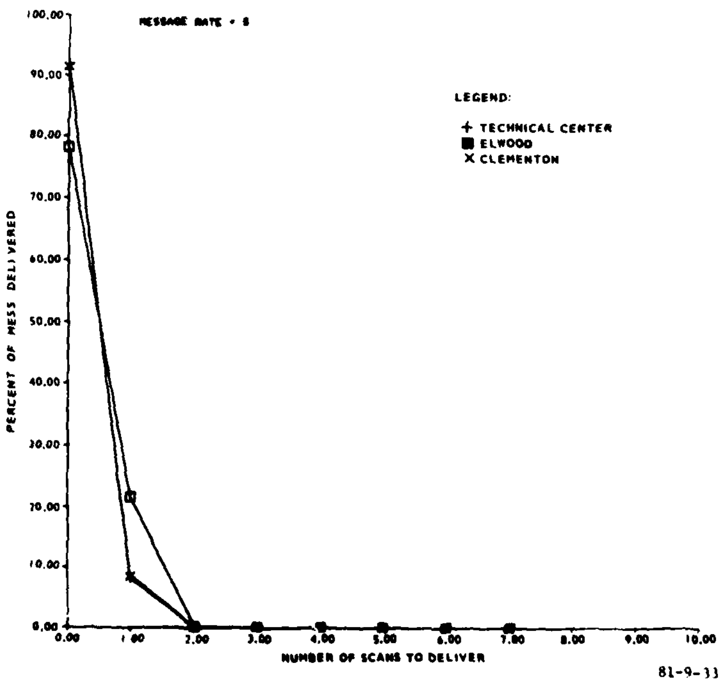

FIGURE 33. MESSAGE DELIVERY TIME FOR MESSAGE RATE OF FIVE PER SCAN

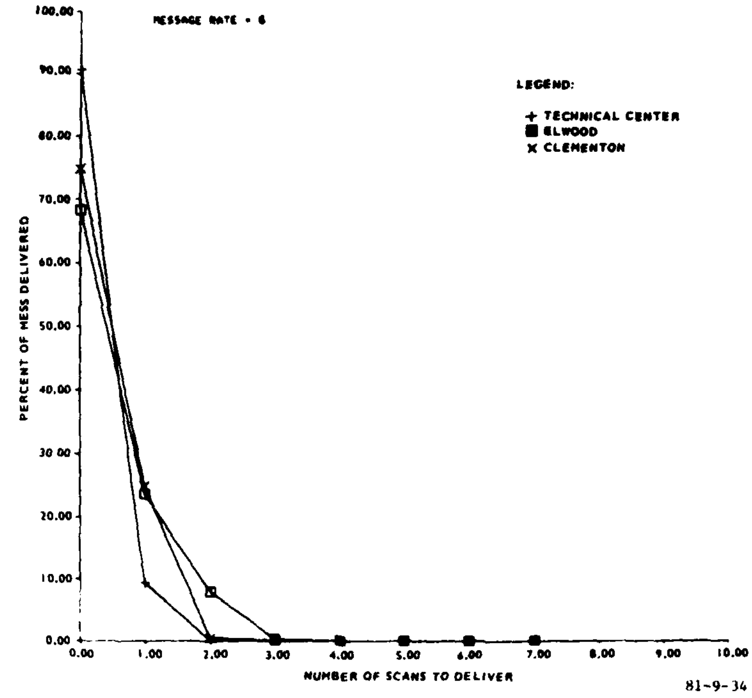

FIGURE 34. MESSAGE DELIVERY TIME FOR MESSAGE RATE OF SIX PER SCAN

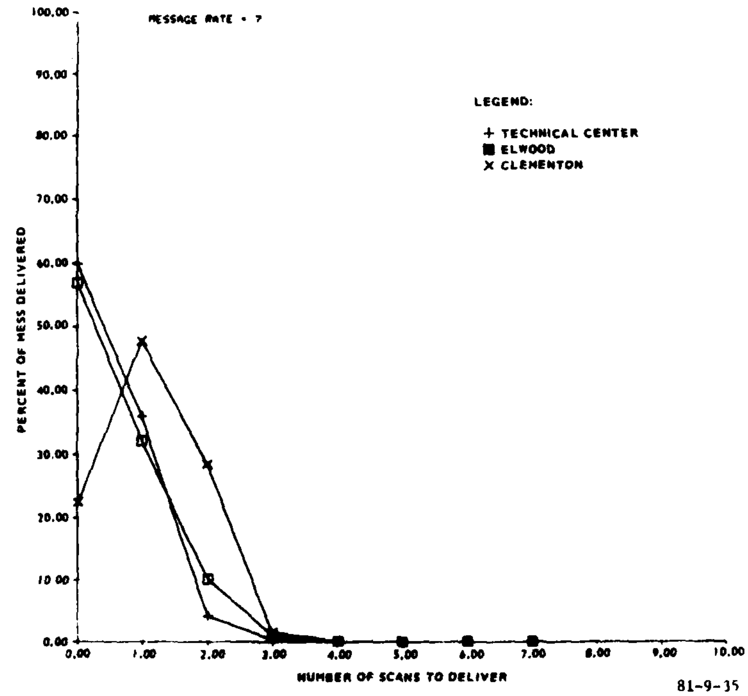

FIGURE 35. MESSAGE DELIVERY TIME FOR MESSAGE RATE OF SEVEN PER SCAN

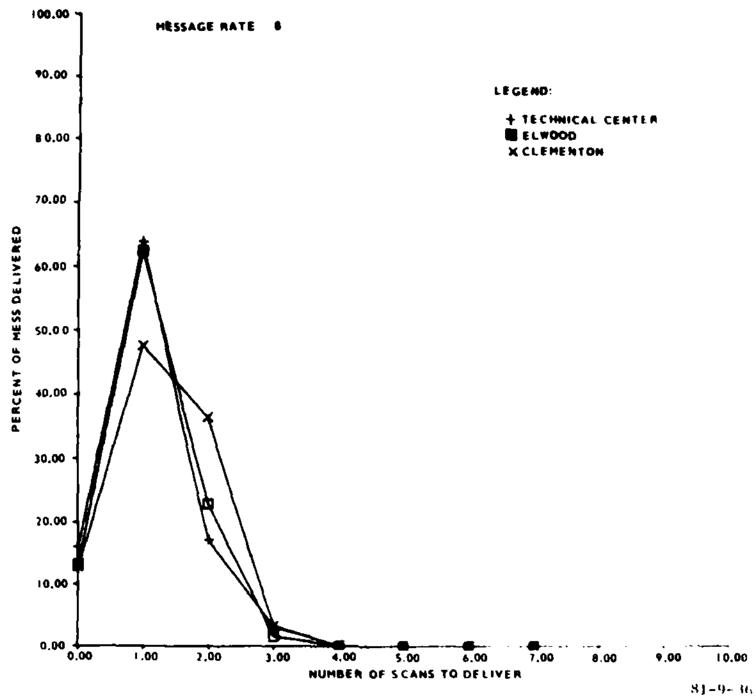

FIGURE 36. MESSAGE DELIVERY TIME FOR MESSAGE RATE OF EIGHT PER SCAN

At a message rate of seven, 60 percent of all messages delivered by the Technical Center are delivered within the first time unit, 35 percent in the second, and 5 percent in the third. Elwood has similar figures. Clementon, on the other hand, has quite a different distribution. Because of the greater number of "no detects" at Clementon, that sensor reaches a state sooner in which almost all messages are being detained. Thus, only 22 percent of the messages delivered are delivered within the first time unit. This value increases to 48 percent during the second time unit, 28 percent in the third, and 2 percent in the fourth.

At a message rate of eight, all three sensors deliver 10 to 15 percent of their delivered messages within the first time unit. The Technical Center and Elwood deliver 65 percent during the second, and Clementon 47 percent. During the third, the Technical Center and Elwood fall to 15 percent and 22 percent, respectively, and Clementon drops to 35 percent. During the fourth time unit, all three sensors deliver about one to three percent of the total messages that they deliver.

The significance of this distribution is that at message rates of two through five, all messages were delivered within two time units (12.5 seconds) and most were delivered within one time unit (7.5 seconds). At higher incoming message rates this distribution becomes skewed toward longer delivery times.

INTERSENSOR COMMUNICATIONS.

ADJACENT SENSOR STATUS CHECKS. On a periodic basis, each sensor that has a connection to a neighboring sensor will attempt to ascertain the condition of any other netted sensor whose scan-by-scan status reports are not being received. Examination of dumps obtained from a data reduction program known as "quick look STC extraction"

(QSTCE) showed that status requests about a third sensor's condition were being sent on schedule, and responses about that third sensor's condition were being returned with the correct content.

ADJACENT SENSOR CPME CHECKS. Each sensor is required to obtain track data on its connected neighbors' CPME's on a periodic basis and report detection of any positional discrepancies by means of a code in the sensor-to-ATC status message once per scan. Correct performance has been verified in conjunction with day-to-day testing.

STC MESSAGE SUMMARY. Table 3 shows a sample message summary obtained from the QSTCE analysis program after a two-sensor (Technical Center/Clementon) connected run. The CIDIN messages are listed first and are broken into categories of message type, source, and destination. Certain message types (such as type 01 northmark messages, type 71 status messages to other sensors, and type 64 status messages to ATC facilities) are sent once per scan, so the counts of these messages should be within one unit of being equal to each other and being equal to the number of scans represented by the test. Any discrepancy would indicate a communications interruption or other malfunction.

The number of type 72 status inquiries about a third sensor (Elwood is missing in this example) sent to a neighboring sensor should be equal to the number of type 73 status responses received from that neighbor. The same logic applies to type 9E requests about a neighbor's CPME and type 9F responses about that CPME. Table 3 shows the outgoing and incoming values to be equal in all appropriate cases.

In this example, the number (2,520) of incoming type 21 tactical uplink messages to be data-linked to the aircraft is in excess of the combined count of possible responses 22 type 31 message rejection/delay notices and 2,463 type 32 message delivered/expired notices, giving a total of 2,485. These missing messages result from an index sizing problem already discussed in the "Analysis of Completed Messages" of the "Data Link Message Processing" section.

Type 45 ATCRBS ID messages do not appear at all as these were deliberately suppressed during testing. There is also a large number (497) of type 9D DABS coordination messages sent by each of the sensors as a result of operating in the special mode (with the Elwood sensor failed).

An unexpectedly high count (28) of type 93 track data requests were sent from Clementon to the Technical Center, a large number (385) of external DABS track data messages were sent to Clementon in response, and a rather high incidence (32) of type 44 data link capability messages went from Clementon to ATC. The number of type 44 messages is an indirect measure of the number of times a DABS track *transitioned* into roll-call state from some other track state. All of these higher than expected counts arise from the observed phenomenon that Clementon is unable to track the mizpah parrot solidly. Most of the time the parrot is being maintained on external data of Clementon, but random local hits will cause Clementon to transition the track to roll-call for a scan or two before the parrot fades and external data are once again requested.

No hard and fast conclusions may be drawn from the other numbers, which are inspected for reasonableness and which give some idea of the average CIDIN message loading encountered during the test.

The surveillance portion of the table shows that 1,043 DABS reports (test aircraft, parrot, and CPME) were disseminated to the ATC facility from the Technical Center and 606 targets

TABLE 3. STC MESSAGE SUMMARY

Message Type Code	Message Type	SEN3 To SEN1	SEN1 To SSF	SEN1 To SEN3	SEN3 To SSF	STC To SEN1	SEN1 To STC
01	Northmark	339	0	339	0	0	0
21	Tactical Uplink	0	0	0	0	2,520	0
31	Message Rejection/Delay	0	0	0	0	0	22
32	Message Delivery/Expiration	0	0	0	0	0	2,463
44	Data Link Capability	0	2	0	32	0	0
64	Sensor to ATC Status	0	339	0	339	0	0
71	Sensor to Sensor Status	339	0	339	0	0	0
72	Status Request (Third)	16	0	16	0	0	0
73	Status Response (Third)	16	0	16	0	0	0
83	Controller Alert	0	7	0	10	0	0
91	DABS Track Data Start	33	0	29	0	0	0
92	DABS Track Data Stop	33	0	30	0	0	0
93	DABS Track Data Request	28	0	1	0	0	0
94	DABS Track Data Message	13	0	385	0	0	0
95	DABS Cancel Request	30	0	33	0	0	0
9D	DABS Coordination	497	0	497	0	0	0
9E	External CPME Request	22	0	22	0	0	0
9F	External CPME Response	22	0	22	0	0	0
D1	ATCRBS Track Data Start	187	0	31	0	0	0
D2	ATCRBS Track Data Stop	98	0	63	0	0	0
D3	ATCRBS Track Data Request	133	0	371	0	0	0
D4	ATCRBS Track Data Message	2,945	0	225	0	0	0
D5	ATCRBS Cancel Request	57	0	210	0	0	0
F1	Surveillance Reports	0	1,043	0	606	0	0

Surveillance Messages - SEN1 to SSF

	DABS	ATCRBS	Radar
Beacon Only	1,043	0	
Radar Substituted	0	0	
Radar Reinforced	0	0	
Radar Only			0
Alerts	0		
Code in Transition		0	
False Target Reports		0	
Radar Status Reports			0
Search RATQC Reports			0
Radar Strobe Reports			0
Radar Map Reports			0

Surveillance Messages - SEN3 to SSF

	DABS	ATCRBS	Radar
Beacon Only	606	0	
Radar Substituted	0	0	

The remainder of the table is the same as above and is omitted.

(test aircraft, CPME, and occasional reports from the parrot) were sent from Clementon. Radar targets were not used during this round of testing and ATCRBS targets, although disseminated to the ATC facilities, were not selected for STC recording.

SUMMARY OF RESULTS

NETWORK MANAGEMENT.

1. DABS sensors which were connected to each other exchanged remote track data, allowing tracking through the cones of silence.

2. Connected sensors satisfactorily accomplished primary/secondary coordination procedures, as dictated by the network coverage maps and the controlled/uncontrolled status of the DABS track.

3. Where at least one unconnected sensor's surveillance coverage overlapped that of other sensors, the intermittent lockout scheme was properly invoked and successfully executed by all primary sensors.

4. In the case of proximate transponders, the unlock sequence was shown to be adequately extended in order to stagger the beginning of the lock/unlock periods.

5. Control state messages sent to the sensor from the STC serving as a simulated ATC facility correctly modified the handling of tracks by the network management function.

6. The presence of a duplicate DABS address within the surveillance area of a sensor correctly causes removal of the track from the surveillance file to the duplicate address alert table and the subsequent issuance of track alert messages.

7. The DABS engineering requirement (FAA-ER-260-26) specifies a one-bit word for the special mode flag associated with each target. The length of this field is insufficient to specify the failure of more than one adjacent sensor. The result is additional processing required on each scan for each target during conditions of adjacent sensor failure.

8. The target special mode flag was intended to signify the existence of an adjacent sensor failure condition at the time of track update. In the current implementation it is also used to indicate the failure of intersensor communications, resulting in an additional processing load on each scan for each target during conditions of communications failure or tests involving unconnected sensors.

9. Guidelines for the building of network management coverage maps specify that the geographical area for which the sensor is primary is that closest to the sensor site. Such a region necessarily includes the cone of silence over the sensor in which the local sensor is unable to communicate with the aircraft. Delays of as many as 20 scans have been observed between the time that the aircraft transitioned to remote data and the time that handoff of primary status to an adjacent sensor occurred. A downlink message originated during this time would have been delayed until the primary handoff occurred.

10. In some of the tests involving Clementon as an unconnected sensor, the live DABS track was dropped for several scans because of duplicate address processing arising from receipt of All-Call reflections having the same DABS address as that of the roll-call track. The sensor's response to the condition was correct; however, such situations could have been avoided if the presence of the reflector had been anticipated and included in the Clementon reflector file.

11. When multiple sensors are supplying remote track data, one data stream is flagged to be retained for use in track update and the other is to be discarded. One of the tests showed that if the incoming data stream is halted as a result of communications failure, the flag is not cleared. This problem has been fixed.

12. A sensor receiving remote track data from more than one adjacent sensor is unable to determine, in some cases, which adjacent sensor supplied the data used to update the track. The problem did not interfere with the current test effort, but it has been fixed in order to facilitate future testing.

SURVEILLANCE PROCESSING.

1. The surveillance BSR for the DABS-equipped aircraft was never less than 99.5 percent at each of the three sensors, exclusive of the sensor's own zenith cone.

2. The multisite surveillance BSR ratio overall for the DABS test aircraft was 99.7 percent.

3. The DABS ID reliability for the test aircraft was always 100 percent.

4. The DABS altitude reliability for roll-call reports from the test aircraft was always 100 percent.

5. The number of DABS interrogations per scan for the test aircraft was 1.04, which is well within acceptable limits.

DATA LINK PROCESSING.

1. At message rates of two through five (incident messages per 5-second time unit), all messages were successfully delivered.

2. For two through five messages per aircraft for each scan, more than 90 percent of the messages for the terminal sensors were successfully delivered without delay. The corresponding values for the en route sensor exceeded 80 percent. The difference between the terminal and en route antenna scan rates is responsible for the difference in percentage.

3. At message rates of seven and eight, the data link performance deteriorates. Messages are lost because the data link buffer structure cannot accommodate more than 15 messages at a time. Consequently, buffers are being filled faster than they can be emptied, and some of the incoming messages are discarded. However, even in the worst case, the percentage of messages successfully delivered was 84 percent.

4. The sensor handled message rejection and message delay conditions perfectly.

5. Until the message rate exceeds the number of times the sensor can interrogate while the target is in the beam, the average delivery time is less than 0.5 time units, or 5 seconds.

6. The size of the data link entry indicator is currently implemented as a 4-bit field, containing a maximum value of 15 and, therefore, allowing only 15 messages per individual aircraft to be in the queue awaiting uplink delivery. This caused queue overflow with resultant message loss.

7. Because of the limitations on the size of the individual data link message queues, most messages that would have expired were discarded before they had a chance to expire.

8. No provision has been made for positive notification to the sender of a data link message that the message has been discarded for lack of an available data link entry indicator or lack of space in the queue.

9. The Clementon sensor showed a significantly greater number of "no detect" replies to interrogations both in and out of the beacon.

INTERSENSOR COMMUNICATIONS.

1. Sensors in a DABS network make periodic requests for status of adjacent connected sensors from which no scan-by-scan messages are being received. The replies to these requests are successfully used to infer conditions of failure, either of a sensor or its communication lines.

2. Sensors in a DABS network also make periodic requests for track data information concerning the CPME at adjacent sensors. The track data messages received in reply are checked for range, azimuth, and altitude. Out-of-tolerance conditions are correctly reported in the sensor-to-ATC status message.

3. Communications intergrity has been verified by observing that equivalent numbers of messages pass across the sensor-to-sensor lines in both directions, and the counts of sensor-to-National Air Space messages are as expected.

CONCLUSIONS

NETWORK MANAGEMENT.

The Discrete Address Beacon System (DABS) network management concept has proven itself to be workable and supports multisensor operation in all configurations from fully netted to fully nonnetted.

Testing of the network management function revealed some minor coding errors which are in the process of being corrected. Some performance deficiencies were noted and recommendations were developed that may improve the performance of future systems.

SURVEILLANCE PROCESSING.

The multisite surveillance processing tested indicated excellent performance from the sensors with respect to the DABS equipped aircraft.

DATA LINK PROCESSING.

The data link function, tested in a multisite configuration with one DABS test aircraft in the beam, met or exceeded the requirements specified in the Federal Aviation Administration (FAA) DABS engineering requirement (FAA-ER-240-26). The limitations noted resulted from the limits in the capability of channel management to schedule interrogations. In the real world environment, so long as messages are not sent at rates that exceed the capabilities of channel management, the number of incomplete message transactions should be insignificant.

INTERSENSOR COMMUNICATIONS.

Tests involving adjacent sensors in the DABS network are performed correctly and evidence was obtained that sensor-to-sensor communications and sensor-to-air traffic control (ATC) communications perform as expected, considering the available real world target load (approximately 100 Air Traffic Control Radar Beacon System (ATCRBS) targets per sensor and one DABS test aircraft). No loss of data was experienced.

RECOMMENDATIONS

NETWORK MANAGEMENT.

The following recommendations are made:

1. The target special mode flag should be increased to a nominal 16 bits to match the system special mode flag and contain information concerning the state of each adjacent sensor at the time of target update.

2. In addition to the target special mode flag, records of sensor-to-sensor communications failure should be kept

distinct from records of adjacent sensor failure and saved.

3. Whenever an aircraft which is in the zenith cone, transitions from roll-call tracking to external data and the local sensor is primary, the local sensor should send a message to all adjacent assigned sensors. The recipients of this message should set a flag in the surveillance file that will trigger a surveillance boundary crossing on the next scan. This flag should be cleared as a part of the routine boundary crossing procedure. The result of these actions should decrease the time required for an adjacent sensor to become primary and initiate readout of pilot-originated downlink messages.

4. The reflectors in the vicinity of Clementon should be identified and included in the Clementon reflector file. The Clementon sensor should then be retested with respect to All-Call reflections.

DATA LINK PROCESSING.

1. Additional testing should be conducted following the installation of the upgraded channel management function. If message loading continues to be a problem, a study should be made to determine the optimum size to which the data link entry indicator should be increased.

2. Message expiration statistics should be reexamined after the recommendation of No. 1 above are implemented.

3. If a message is discarded by the data link function the originator of the message should be notified.

4. Further tests should be conducted at the Clementon sensor in an attempt to reproduce and explain the large number of no detect replies.

APPENDIX A

LOAD TAPES AND SITE ADAPTATION CASSETTES

TECHNICAL CENTER SENSOR.

Sensor load tape: 316N11 Release 7.2

Multisite test tape with "stand alone" network management, upgraded Data Interchange Network (CIDIN), and site 1 coverage map.

Data extraction cassette: DX-8 (collects Discrete Address Beacon System (DABS) replies)

Site adaptation cassettes: N-120, A-110, and A-103

N-120 Special adaptation for Technical Center sensor (site 1 identifies (ID), calibration and performance monitoring equipment (CPME) data, and adjacent sensor list), and

A-110 Standard multisite activation and communication parameters for loopback mode, or

A-103 Standard single site parameters for loopback mode.

ELWOOD SENSOR.

Sensor load tape: 316E16 Release 7.2

Multisite test tape with "stand alone" network management, upgraded CIDIN, and site 2 coverage map.

Data extraction cassette: DX-8 (collects DABS replies)

Site adaptation cassettes: E-123, A-110, A-103

E-123 (Special adaptation for Elwood sensor (back-to-back antenna, site 2 ID, CPME data, and adjacent sensor list), and

A-110 Standard multisite activation and communication parameters for loopback mode, or

A-103 Standard single site parameters for loopback mode.

CLEMENTON SENSOR.

Sensor load tape: 316C11 Release 7.2

Multisite test tape with "stand alone" network management, upgraded CIDIN, and site 3 coverage map.

Data extraction cassette: DX-8 (collects DABS replies)

Site adaptation cassettes: C-118, A-110

C-118 Special adaptation for Clementon sensor (site 3 ID, CPME data, and adjacent sensor list), and

A-110 Standard multisite activation and communication parameters for loopback mode.

APPENDIX B

NETWORK MANAGEMENT DATA REDUCTION

Automated data reduction were used as much as practicable in obtaining the results described in this report. Computer programs capable of processing the data extraction and STC tapes described previously are available on the Honeywell 66/60, the Digital Equipment Corporation (DEC) PDP-11, and the Texas Instruments (TI) 990 computer systems. The remaining analysis was accomplished manually by inspection of data dumped from the tapes.

HONEYWELL 66/60 PROGRAM.

A program for processing STC tapes on the Honeywell 66/60 computer was one of the principal data reduction tools used in developing data for this report. It has the following user-specified options:

1. Hexadecimal dump. The user may request that each record dumped from the tape be followed by its hexadecimal equivalent.

2. Formatted dump. Each record is divided into individual data fields and labelled accordingly. Conversion to more customary systems of units are made (i.e., range is expressed in nautical miles instead of the Discrete Address Beacon System (DABS) "range units;" azimuth is expressed in degrees).

3. Filtered copy. User-specified record types can be copied to tape or disc in the same format as on the input tape. The unwanted record types are discarded.

4. Multisite time profile. The user may request a formatted dump, which is listed in columnar fashion, one column per sensor, with the vertical dimension representing a time line. DABS and Air Traffic Control Radar Beacon System (ATCRBS) surveillance file entries are listed in an abbreviated form.

5. Network management status and lockout analysis. This program produces a formatted scan-by-scan listing of the essential network management parameters such as lockout state, lock/unlock count, sensor priority status, assigned sensors, INLIST, and OUTLIST (see item 2 of "Multisite Netter Results" in the Network Management Data Analysis section). The program flags changes in state for convenient reference.

6. Plot of selected tracks. The desired track(s) are specified by aircraft identification (ID).

7. Track summary. The following items are listed for each DABS ID and site: number of scans, number of points, all surveillance file numbers, number of updates to each track state (coast, All-Call, roll-call, and external), number of scans in zenith cone, and blip/scan ratio (BSR) (overall and corrected for the zenith cone.)

8. Flagging for formatted dump. Each change in track status deemed "interesting" is listed along with the scan number on which it occurred. When the formatted dump is used, the flagging is listed immediately after the surveillance file entry which caused it.

PDP-11 PROGRAMS.

For the sake of convenience and rapid data analysis, plot programs showing the track(s) of selected aircraft were made available on the DEC PDP-11 computer, which is physically located in the same building as the Technical Center sensor and the system test console (STC). Immediate turnaround of plot data between live tests were available when necessary. The following plot capabilities were used:

1. Using the STC tape, the user may obtain plots of aircraft position as given by surveillance file data recorded in the special type 90 track snapshot messages. Plots show both locally and externally supplied data and may be obtained using an option in which special symbols are used to differentiate among possible track states such as: coast, external, local (both primary and secondary), and radar reinforced.

2. From the data extraction tape, plots of All-Call replies may be obtained which show the sequences during which the DABS transponder was unlocked to All-Call.

3. The data extraction tape can be used to produce plots of surveillance reports disseminated to any (or to all) facilities. The reports may be filtered by report type such as: radar only, radar reinforced, and beacon.

TI 990 PROGRAM.

The TI 990 program development system was used for running the quick look STC extraction program (QSTCE). This program allowed filtering of messages by message type, aircraft ID (if appropriate), and surveillance position within a specified range of a given target. Rapid turnaround of Data Interchange Network (CIDIN) message dumps could be obtained as well as a summary of message types sent between various sources and destinations.

APPENDIX C

SURVEILLANCE PROCESSING DATA REDUCTION

Among the data reduction and analysis programs developed by the Federal Aviation Administration (FAA) Technical Center personnel is a real world analysis program which was used to obtain the surveillance performance statistics contained in this report. The real world analysis program runs on the Honeywell 66/60 computer and uses as input the Discrete Address Beacon System (DABS) target reports contained on a sensor data extraction tape. If a target report appears on two consecutive scans, the analysis program initiates a track on the target and maintains a count of the number of scans during which a target report appeared and a count of the number of scans on which that target report correlated the track. The blip/scan ratio (BSR) for an individual aircraft is computed by dividing the latter count by the former one and multiplying by 100. The summation of the BSR values for all aircraft over a specified time interval is used to compute an average BSR value for the sensor. The filtering parameters used to obtain these results consisted of range values between 4 to 69 nautical miles, all azimuths except for those of known reflectors, and all elevation angles.

APPENDIX D

DATA LINK DATA REDUCTION

Automated data reduction programs were created for use on the Honeywell 66/60 computer. These programs make use of the system test console (STC) recording tape or a sensor data extraction tape, as discussed below.

DATA LINK ANALYSIS ROUTINE.

This routine examines the transactions used to handle each tactical uplink message. A message transaction is complete when a rejection, delivery, or expiration notice is returned to the sender of the message. A delayed message may terminate in delivery if the track becomes established on roll-call in time, otherwise it expires. Any message which is not handled in one of these transactions is regarded as "lost." The following counts are maintained by the program:

1. Number of uplinks delivered by each sensor

2. Number of uplinks expired at each sensor

3. Number of uplinks rejected by each sensor

4. Number of uplinks delayed at each sensor

5. Number of uplinks delivered within i time units, where a time unit is defined as the time between successive blocks of messages, namely 5 seconds.

TRACK SUMMARY PROGRAM.

The track summary program divides the data into functional subsets by message rate. For each message rate and for each target as seen by a given sensor, the following quantities are measured:

1. Number of scans in the sample

2. Number of roll-call scans in the sample

3. Number of scans in the zenith cone

4. Blip/scan ratio

DABS EXTRACTION TAPE FILTER PROGRAM.

The sensor data extraction tape is used as an input to this routine. The particular output used in data link analysis is a scan-by-scan count (by target) of the number of roll-call replies assigned to each of the possible failure codes (valid, no monopulse received, no reply detected, and no reply decoded). The no detect and no decode categories of reply are used to determine the number of interrogations that tried (but failed) to deliver an uplink message to the aircraft. The other counts are used to determine the number of uplinks that were actually delivered.

APPENDIX E

INTERSENSOR COMMUNICATIONS DATA REDUCTION

Dumps of sensor-to-sensor message traffic recorded at the system test console (STC) were made using the quick look STC extraction (QSTCE) data reduction program on the Texas Instruments 990 computer system. These dumps showed that multisite performance monitor functions were being carried out correctly, and the STC message summary at the end of each QSTCE run allowed a rapid visual check of the integrity of the intersensor message exchanges that occurred during the testing.

DAT
FILM