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MODE S
Terminal Configuration

OPERATIONAL TEST & EVALUATION (OT&E)
OPERATIONAL and OT&E INTEGRATION TESTS

QUICK LOOK REPORT

FAA WJH Technical Center
00020064

AVAILABLE IN ELECTRONIC FORMAT

FAA TECHNICAL CENTER
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September 10, 1993
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Executive Summary

The Mode S Operational Test and Evaluation (OT&E) was conducted at the FAA Technical Center from June 28 to August 27, 1993. The Mode S system under test was configured to support terminal field configurations. This configuration allows for 60 mile coverage, a target load of 400 aircraft, a data link communications load of 75 % of the full Mode S specification requirements and a collocated radar of either the Airport Surveillance Radar (ASR)-9 radar or an ASR-7/8 radar . The Mode S software version used for the OT&E effort was TR21.2 with a maximum hardware configuration utilized . The attached evaluation provides initial findings and attempts to identify any issues which may be pertinent to Mode S deployment. Complete analysis of collected data will be performed and a final report published by early November.

Testing was conducted using the two Mode S configurations needed to support the two different type radars encountered in the field. The Mode S / ASR-9 configuration was interfaced to both the Automated Radar Terminal System (ARTS) IIIA and the ARTS IIA systems. The Mode S/ASR-9 pair provides radar/beacon merged, correlated radar-only, correlated beacon only and uncorrelated radar/beacon targets to the ARTS systems. The Mode S/ASR-7/8 configuration that was tested, only interfaced to the ARTS IIA since all ARTS IIIA sites have ASR-9 radars. In this configuration, no radar target data is provided to the Mode S or the ARTS IIA other than the radar video sent to the ARTS IIA air traffic controller displays. ARTS IIIA software used to conduct the OT&E testing was A3.04 while the ARTS IIA software used was A2.07 .

A performance baseline was first established of the Mode S system by conducting a series of tests which focus on surveillance performance. This baseline data verified proper system operaton and will be used as a comparison tool with future Mode S upgrades. Incremental NAS integration tests were next conducted for each of the two configurations to verify proper inter-system operation. This was comprised of interface testing with the ASR-9, ASR-7, Data Link Processor (developmental unit), ARTS IIA, ARTS IIIA and the Mode S system control/monitoring devices. Proper operation of the electrical interface, data protocol and data reliability of each of the inter system interfaces was verified prior to conducting any multiple system testing. Numerous automated analysis programs were developed and utilized for this phase of the OT&E effort. Having automated tools allowed the effort to be conducted in the relatively short time allotted to formal OT&E. At the completion of integration tests, National Airspace System (NAS) level operational testing was conducted using equipment configurations to be utilized at field sites. In this phase of testing such issues as surveillance performance, capacity loading operation, NAS throughput timing, degraded operations and operational suitability were addressed. Target simulators, live world operations and flight test aircraft were used to extensively test end-to-end NAS level operations. Field air traffic controller and technicians participated in a majority of the operational tests to provide objective evaluations and to identify any potential problems which may impact normal field operations.

As a result of the formal OT&E effort, three major deficiencies were identified which will impact deployment of the Mode S system :

1) The Mode S/ ASR-9 configuration induces data delays to the ARTS IIIA system which impacts ARTS IIIA target tracking software. The resultant effect is that track coasts occur for those targets which are received late. ARTS IIA operation only experienced minor problems with data extraction because of the data delay . Changes to the ASR-9 are expected to resolve the issue.

2) Mode S system status reporting was found to be incorrect after configuration changes resulting from fault induced recoveries. These status inaccuracies were noted primarily at the remote control panel used by Air Traffic and will impact operational usage of the system. Changes to the Mode S system and the remote control panel are expected to resolve the issue.

3) Mode S/ASR7/8 configuration does not provide analog beacon video to the ARTS IIA during normal operation. Operational evaluation identified that current Air Traffic Control (ATC) procedures require beacon analog video on the display for target separation as a backup for radar analog video. No resolution is currently proposed.

In addition to these three issues , 40 additional issues of moderate and minor deficiency levels which impact system operation were identified. All moderate level deficiencies, with the exception of one, have been agreed to be corrected in a pre-deployment software upgrade which will undergo OT&E regression tests. The one moderate deficiency not resolved deals with ASR-9 modem data loss . The minor deficiencies are to be corrected in either this next software upgrade or the enroute configuration fielded version of software. Attached is a complete list of the noted deficiencies.

Mode S OT&E
Test Execution Deficiencies

	Description	Defic Level
spr#1	INCORRECT SENSOR STATE ON REMOTE TERMINAL WHILE IN IBI	***Major***
spr#2	INTERMITTENT SCIP MODEMS----HDR SUBMITTED #07303047V	**Moderate**
spr#3	RMS CONTROL POINT CHANGE (TRAP-885)	Minor
spr#4	MARDE STOPS DE WHEN ACTIVE CHAN HAS RECOVERY	**Moderate**
spr#5	CALIBRATION CONSECUTIVE UNFILLED CELL CNT EXCEEDED	Minor
spr#6	REMOVE INTERPOLATION_SURROUND_CELL_CNT SAP IN CAILB	Minor
spr#7	SHORT PWR FAIL LESS 1-SEC CAUSES DPS BREAKERS OFF	**Moderate**
spr#8	SHORT PWR FAIL NOTICE_NOT_REC MSG CPME CONFIGURED	Minor
spr#9	SAP DEFAULT CHANGES (RTQC)	Minor
spr#10	COMIOP FAULT CAUSES RMS COMM BREAK	Minor
spr#11	MULTIPLE TARGET LOSS CAUSED BY S/RIOP FAULT	Minor
spr#12	SENSOR DOES NOT OUTPUT ATCRBS TARGET AFTER MASTER/RS	Minor
spr#13	LOCAL TERMINAL LOCKED UP ON EVENTS 3 DEGRADE TEST	**Moderate**
spr#14	TARGET DISSM LOSS ON ASR9 ON POST PROCESSOR FAULT (HDR# 08023048V)	Minor
spr#15	FE RED CODES 113/114 RECEIVED AFTER CHANNEL SWITCH	**Moderate**
spr#16	APG FAILURE TO RETURN TO PRIMARY STATE	**Moderate**
spr#17	DATA DELAY TO SCIP HDR#--07303047V	***Major***
spr#18	HEAVEY FRUIT FAULTS SENSOR	**Moderate**
spr#19	REMOTE TERMINAL SENSOR STATUS INDICATION	***Major***
spr#20	DIAGNOSTICS DOCUMENTATION	Minor
spr#21	DIAGNOSTICS FUNCTIONAL OPERATION/VALIDATION	Minor
spr#22	STAY IN ATCBI MODE AFTER POWER FAILURE-POWER ON	**Moderate**
spr#23	CHANNEL STATUS COMMAND (ONLINE TO OFFLINE NON VALID)	Minor
spr#24	DATA LOSS WITH STANDBY CHANNEL FAULTED	Minor
spr#25	SHUTDOWN PROCEDURE INCORRECT	Minor
spr#26	VSWR MEASUREMENTS INCORRECT	Minor
spr#27	CAN'T DO OVERALL SYS SENSITIVITY IN MODES MODE	Minor
spr#28	CPME AZIMUTH STABILITY	Minor
spr#29	SIMULTANEOUS CPU FAULTS ACTIVE DPS ,RMS COMM BREAK	Minor
spr#30	SIMULTANEOUS CPU PID FAULT ON ACTIVE DPS PREVENT SWITCH	Minor
spr#31	MODES TARGETS ALL-ZERO CODES	Minor
spr#32	MODES TRACKS UNLOCK DURING CPME ACQUISITION	Minor
spr#33	REACQUISITION OF DROPPED CPMES	Minor
spr#34	IMAGE TEST FOR ATCRBS AND POTENTIAL RINGAROUND	Minor
spr#35	REMOTE TERMINAL SENSOR STATUS/CPME STATUS	**Moderate**
spr#36	MODES TRANSPONDER IDENT NOT DISSEMINATED	**Moderate**
spr#37	ATCBI CHAN INIT CAUSES OTHER CHANNEL TO GO RED	Minor
spr#38	CAN'T SWITCH ATCBI CHAN FROM ACTIVE RMS COMM PORT	Minor
spr#39	FE MODULATION UNIT FAULT NOT RECEVIED ON STBY CHAN	Minor
spr#40	STATUS MESSAGE CONFLICT BETWEEN CHAN-A & CHAN-B	Minor
spr#41	LASUR BRDS NOT DETECTED AS FAULTED ON STNBY CHANNEL	Minor
spr#42	FAILURES COMING OUT OF ATCBI	**Moderate**
spr#43	MODE S/ ASR-7 DOES NOT PROVIDE BEACON VIDEO IN NORMAL MODE	***Major***

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1. PURPOSE

In order to identify issues and disseminate initial findings of the formal Mode S OT&E concerning system operations, a quick look report has been prepared . This report will provide preliminary analysis in each area of test along with any information concerning observations and situations encountered during testing which may impact deployment of the terminal configuration of the Mode S system to field sites.

2. SCOPE

The quick look report will address the current findings for all tests conducted during the two month formal Mode S OT&E effort. The information presented in most cases is

only a representative sample of the data acquired during the OT&E testing. Analysis of that data is being provided in a preliminary format using summary level listings from automated software analysis packages and insight the test personnel may have to interpret that data. The complete analysis and evaluation of the Mode S OT&E effort will require, because of the number of tests conducted and enormous amount of data acquired, approximately two months to complete. At the end of that time, a final test report will be prepared which will present a complete analysis of the data collected and the deficiencies identified .

The scope of Mode S OT&E encompassed internal system performance, integration and operational testing of NAS interfaces, surveillance performance, system capacity loading, system accuracy, degraded operations and operational evaluations. These tests were conducted by ACW-100. Reliability and maintainability type testing was not performed during OT&E due to schedule constraints. DT&E tests were conducted in the factory to prove compliance in these areas. OT&E shakedown testing was conducted by AOS-500. The Mode S system was operated at only one set of system parameter settings, a majority of which were optimumized during Developmental Test & Evaluation (DT&E) testing . A few parameters have been modified as a result of initial site installation and problems encountered during preliminary dry run testing at the Technical Center. The resultant set of system parameters used during OT&E is the same as is being proposed for initial field deployment.

3. BACKGROUND

The Mode S OT&E effort was conducted at the FAA Technical Center from June 28 to August 27, 1993. The Mode S system under test was a fully populated, dual channel system, configured to support terminal field configurations. This hardware configuration is currently being delivered to field sites and is used in a reduced capacity as an ATCBI-5 equipment replacement. Prior OT&E testing of this hardware with an earlier version of software was successfully completed in the fall of 1992. The current test effort, with revised software, is intended to verify proper operation of the full functional capabilities of the Mode S equipment terminal configuration. This configuration allows for 60 mile coverage, a target load of 400 aircraft, a data link communications load of 75 % of the full Mode S specification requirements and a collocated radar of either the ASR-9 radar or an ASR-7/8 radar . The Mode S software version used for the OT&E effort was TR21.2 .

The Mode S was integrated to the ASR-9 and subsequently that pair was integrated to the ARTS IIA and the ARTS IIIA. This configuration is the predominant configuration of the Mode S system needed to support terminal operations. The ASR-9 equipment used for the test was a complete system with all current field modification and an additional draft EEM chapter (Chapter 18) which contained required Mode S to ASR-9 interface revisions. The ARTS IIIA system used for test was a dual IOP configuration running software version A3.04. The Mode S/ASR-9 equipment was used as input to one IOP while an ATCBI-5/ASR-8 (via a SRAP) was used as the input to the other IOP. The second IOP was used only for those tests requiring operational comparisons

between the Mode S/ASR-9 configuration and a currently fielded configuration of the ARTS IIIA. Two ARTS IIA systems were used. One system was connected to the Mode S/ASR-9 equipment via the Mode S/ASR-9 Line Adapter (MALA) running software version A2.07. The second ARTS IIA, for operational comparison testing, was connected to the ATCBI-5/ASR-8 equipment, running software version A2.06. Analog video provided to the ARTS systems from the Mode S/ASR-9 was reconstituted video while the ATCBI-5/ASR-8 pair provided actual video to their interfaces.

The Mode S/ASR-7 configuration tested requires interfacing of only synchronization triggers between the Mode S and the radar. The Mode S/ASR-7 (or ASR-8) configuration will be used at only a limited number of ARTS IIA sites. The same two ARTS IIA systems used for the Mode S/ASR-9 configuration were used for this configuration with the exception that the Mode S provides the digital input to the ARTS IIA MALA. Analog video provided to the ARTS IIA systems in this configuration came directly from the associated radar or beacon system.

4. TEST DESCRIPTIONS AND RESULTS

The following tests identified in sections 4.1 and 4.2 were conducted in accordance with the Mode S OT&E Test Plan, DOT/FAA/CT-TN8951 dated August 1990, and the associated Interim Terminal Mode S/NAS OT&E Test Procedures, DOT/FAA/CT-TN91/41 dated January 1993. The tests identified in section 4.3 was conducted in accordance with the Mode S Performance Test Plan, DOT/FAA/CT-TN89/24 dated july 1989 and the Mode S Performance Test Procedures, dated February 1992.

4.1 Interim NAS Configuration No. 1

The configuartion tested in Configuration Number 1 is that of the Mode S/ ASR-9 pair to the ARTS IIA and ARTS IIIA equipment. All surveillance data provided to the ARTS equipment is via the ASR-9. During normal operation the Mode S receives digital radar target reports from the ASR-9 with which it performs radar/beacon correlation. Beacon and radar data is than returned to the ASR-9 for dissemination to the ARTS. Radar and beacon video and triggers are provided to the ARTS by the ASR-9 in the form of reconstituted video from digital data. During Mode S backup operation (IBI mode) the Mode S degrades to a conventional ATCBI-5 system, providing beacon video to the ASR-9 's beacon processor. The ASR-9 then performs the beacon/radar processing and delivers the surveillance data to the ARTS as during normal operation.

4.1.1 Integration Test A. Mode S Transponders

4.1.1.1 Test Description

Category A of the OT&E Test Matrix is designed to verify the requirements defined in the Test Verification Requirements Tracibility Matrix which pertain to the Mode S /Transponder over the air link.

The intent of the test was to show that the Mode S could interface with Mode S and ATCRBS transponders in a live world environment. To accomplish this a test transponder was employed to generate replies in response to the Mode S/ATCRBS interrogations contained in the frame table under test. The frame table pattern was confirmed by comparing it to the interrogation pattern received by an independent reference receiver (ARIES) connected to the sensor. In response to the interrogation pattern, data replies were examined to determine that they corresponded to the appropriate interrogations and that the Mode S could correctly decode the received messages. In the case where it was required to show that the sensor generated Mode B and Mode D, timing measurements were made at the receiver to verify that the pulse widths and spacings corresponded to the required interrogations.

4.1.1.2 Test Results

Considerable investigation into the Mode S performance in the areas discussed in this test were conducted during factory testing. As such, the data analysis takes a more qualitative approach, simply verifying that the Mode S can generate the required interrogation pattern and receive and decode data appropriate for that pattern. The requirements were proven for the following frame tables:

1. Site Addressed Lockout
2. Full Lockout
3. Conventional Lockout
4. Conventional ATCRBS
5. Modes B and D.

The ARIES pattern program verified that the frame table correctly matched the transmitted pattern and did so for both channels for each of the frame tables under test. The reply data showed that the sensor received the correct transponder replies requested by sensor interrogations. Surveillance data was correctly decoded for all reply formats. Unfortunately, the test transponder was not equipped with an altimeter so the data in the altitude field for the Mode C replies did not exist when requested by interrogations from the frame table under test. To show that this field was capable of being decoded by the sensor, the data from one of the CPME's was reduced. It showed that the CPME replied to the Mode C interrogation and reported its altitude which was correctly decoded by the Mode S. Similar analysis was performed on roll call replies in the case of the Mode S frame tables. The results in these cases were successful as well. The results are characterized in Tables 4.1.1-1 and 2.

Mode B and Mode D are not currently used by the FAA, nevertheless, it was required to show that the sensor generated them. To do so, the frame table consisting of the two modes was installed in the sensor and pulse width and pulse spacing measurements were performed at the ARIES unlink receiver board. These measurements were then compared to the Mode S National Standard requirements for these interrogations and shown to be in accordance. The results were successful for both channel A and B.
Table 4.1.1.1-3 summarizes the results.

CONVENTIONAL ATCRBS & FULL LOCKOUT FRAME TABLE
TABLE 4.1.1-1 (Preliminary Data)

	Mode A,C,2 Transmitted & Received	ATCRBS/Mode S All Call Mode A & C Trans/Rec	Mode A & C Roll Call Trans/Rec	Table veriified by ARIES
Channel A	Successful	Successful	Successful	Successful
Channel B	Successful	Successful	Successful	Successful

SITE ADDRESSED LOCKOUT FRAME TABLE
TABLE 4.1.1-2 (Preliminary Data)

	ATCRBS Only Mode A, C All Call Trans/Rec	Mode S Only All Call Trans/Rec	Mode A , C Roll Call Trans/Rec	Table Verified by ARIES
Channel A	Successful	Successful	Successful	Successful
Channel B	Successful	Successful	Successful	Successful

MODES B AND D FRAME TABLE
TABLE 4.1.1-3 (Preliminary Data)

	Mode B Pulse widths & Spacings	Mode D Pulse widths & Spacings
Channel A	Complies with National Standard	Complies with National Standard
Channel B	Complies with National Standard	Complies with National Standard

4.1.2 Integration Test 1B. Mode S/ASR9

4.1.2.1 Test Description

Category B of the OT&E Test Matrix is designed to verify the requirements defined in the Test Verification Requirements Tracibility Matrix which pertain to the Mode S/ASR9 Interface and Mode S surveillance processing functions when configured with an ASR9.

The primary intent of the test was twofold. First it had to prove the reliability of the link between the Mode S and the ASR9. Second was to show that the Mode S utilized the radar data to provide reliable and timely correlated surveillance data to ATC. The test was designed to provide a snapshot of the operation of the ASR9/Mode S under a live world target load and it was in this context that the requirements were proven. Data collection was performed at the ASR9 output to the Mode S, Mode S sensor data extraction, and at the ASR9 to ATC output. Message transfer reliability was quantified over 27 scans. To verify sensor surveillance functions, ten clear air targets were chosen, 5 Mode S and 5 ATCRBS, and data was reduced on these targets to verify reinforcement, updating and timeliness of message availability. Data was also collected with the sensor processing only radar data to try and isolate any effects in operation which might be attributable to the radar.

4.1.2.2 Test Results

The data characterizing the message transfer is shown in Tables 4.1.2-1 and 2. Among the messages sent from the ASR9 and received by Mode S there were 8 messages which did not reach the Mode S (seen in the last column in Table 4.1.2-1). These messages were for targets beyond the 60 nmi. limit for terminal radar and are masked by the ASR9. The 23 messages at the Mode S which could not be associated with messages from the ASR9 seen in column two, were status messages. Status messages are not extracted at the point where target extraction was

performed but are still received by the Mode S over the interface. The program therefore cannot associate these messages with messages from the ASR9. Thus there were no unassociated messages which could not be accounted for. Message traffic data on the interface from the Mode S to the output of the ASR9 is shown in Table 4.1.2-2. In this direction messages associated 100% of the time.

Results of the analysis pertaining to radar beacon correlation were examined for six of the 10 targets required. These targets had an average reinforcement ratio of 95%, considerably higher than the average target reinforcement ratio of 83% as calculated from the data in table 4.1.2-1. One would expect this to be the case since the targets chosen are clear air. The 83% average reinforcement ratio is a little low, e.g. ratios computed on dry run data for this test were 86% and in factory testing they were measured at 88%. The radar reinforcement data for both the six selected clear air targets and the average radar reinforcement for the live world data is presented in Table 4.1.2-3. Further analysis is required to determine the causes of the reduced reinforcement. At this point the data seems to indicate that it is a minor deficiency in performance.

To show the timeliness of message availability for correlating users, throughput calculations were performed on six of the ten selected clear air targets. In all cases measured thus far the data is well within the 1/8 of a scan (.575 sec) limit. Typical measured values being .380 sec. The data indicates that the throughput is satisfactory but the target loading for this type of test is minimal.

TABLE 4.1.2-1 (Preliminary Data)
MESSAGE TRAFFIC TOTALS FROM THE ASR9 TO THE MODE S

Message Type	Total Correlated	Uncorrelated at Mode S	Uncorrelates at ASR9
Radar Target	5658	0	8
RTQC	21	0	0
Total	5679	23	8

TABLE 4.1.2-2 (Preliminary Data)
MESSAGE TRAFFIC TOTALS FROM THE MODE S TO THE ASR9

Message Type	Total Correlated	Uncorrelated at Mode S	Uncorrelated at ASR9 Output
Beacon Only	217	0	0
Radar/Bcn. Reinf	1053	0	0
Beacon RTQC	21	0	0
Radar Only	4606	0	0
Radar RTQC	21	0	0
System Status	44	0	0
Total	5962	0	0

TABLE 4.1.2-3 (Preliminary Data)
RADAR REINFORCEMENT DATA

	Target Total	Scans	Total Reports	Total Reinf.	Percent Reinf.
Selected Clear Air Targets	6	27	162	154	95%
Total Live World Data	60 (avg. per scan)	21	1270	1053	83%

4.1.3 Mode S/ARTS Integration Tests C1/C2

4.1.3.1 Test Description

Testing was conducted for the Mode S/ARTS-3A and Mode S/ARTS-2A interfaces. These tests verify the requirements related to the transmission of surveillance and communication data to and from the Mode S/ASR-9 subsystem and the ARTS-3A and ARTS-2A subsystems. Communication data from an ATC facility was simulated by the CID. Surveillance data was both live world data as well as simulated data provided by the ARIES. The Mode S/ASR-9 subsystem provided the appropriate surveillance data (via the ASR-9/Remote SCIP) and communications data (via the Mode S sensor) to the ARTS-3A and ARTS-2A subsystems and the simulated ATC facility, CID.

Data was collected on the ARTS-2A, ARTS-3A, and Mode S systems, as well as the ARIES and CID simulators. Surveillance output data of the ASR-9 was collected by an RTADS. Another RTADS was used to collect data being fed to the ARTS-2A. Finally, a TRACS retro-fitted with a SRAP-to-TRACS I/O board was used to record data on the SRAP input bus of the ARTS-3A.

Each test was run twice on each channel of the Mode S system. Each test run consisted of two parts, in the first section live world data was collected along with data input by an ARIES scenario, in the second section only live world data was collected.

4.1.3.2 Test Results

Data from the ARTS-3A data reduction, DRAM, is summarized in the ARTS-3A DRAM Statistics table, table 4.1.3-1. All data exceeded optimum performance levels with the following exceptions: code validity for runs 1-4 of 6/23, code validity for run 1 of 7/23, blip scan for run 2 of 6/23 and false reflection from run 1 of 7/23. Detailed analysis of these exceptions will be performed as part of the final report .

Data extraction taken at various points in the flow of data were compared to the data extracted at the Mode S to determine if any data loss was occurring. With the exception of the first execution of the test, where a .25 to 2.8% data loss was noted at the ARTS-2A RTADS due to a temporary problem with intermittent surveillance lines , all data looked good. An irregularity was noted in that split status messages were recorded by the ATRAIN in the data output by the SCIP to the ARTS-3A. This is being studied.

During a test case when live world data and ARIES simulated target were simultaneously being input into Mode S, a simulated target had the same ID as a live target. This resulted in one of the live target's ID and code confidence going to zero. This resulted in a lower blip scan value for this test case (CR2,623). Further investigation of the data is required for this problem.

ARTS-3A DRAM Statistics

Test	Radar Reinfrc	Blip Scan	False Reflect	False Split	Alt Error	Alt Validity	Code Validity	Split Az	Split Rg
CR1.623	87.2	97.3	0	0	0	98.2	96	0	0
CR2.623	86.3	93.3	0.7	0.02	0	98.2	95.9	0.02	0
CR3.623	85.8	95.6	0.1	0.12	0	98	96.8	0.12	0
CR4.623	85.8	95	0.2	0.18	0	98	96	0.18	0
CR5.623	83	96.8	0.2	0	0	97.6	98.5	0	0
C1.723	87.2	95.7	2	0.09	0	99.4	93.5	0.09	0
C3.723	89.8	98	0	0.064	0	99.5	96.9	0.064	0
C4.723	89.5	98.5	0.4	0.05	0	99.9	99.2	0.05	0
C5.723	90.6	97.3	0	0	0	99.3	99.1	0	0
Range	83.0-90.6	93.3-98.5	0-2.0	0-.18	0	97.6-99.9	93.5-99.2	0-.18	0
Average	87.24	96.89	0.4	0.058	0	98.68	96.88	0.058	0

Table 4.1.3-1 (Preliminary Data)

4.1.4 Local Terminal Tests

4.1.4.1 Test Description

The Mode S local terminal was tested to verify that command options executed at the local terminal resulted in the expected sensor actions. Command options tested included RMS monitoring, Sensor Control, Data Extraction, and Site Adaptation. Descriptions of the local terminal functions can be found in the Software Users and Diagnostic Manual for the Mode S Beacon System Sensor, TM-PA-0028/311/xx.

4.1.4.2 Test Results

Several comments were generated over the course of the local terminal testing. Deficiencies were corrected by later local terminal software releases and retests were completed. Remaining problems are listed below.

The "Don't Yield Control" command causes control to be immediately returned to the Remote Terminal. Since control can be regained at the local terminal without affecting sensor operation. This is a minor deficiency.

If the user disables the local terminal after disabling the MPS, or after the MPS disabled itself, there is no way to get control back except by resetting the sensor. Once disabled the local terminal and the MPS are unable to get control because they are disabled and unable to enable themselves because they do not have control. The enable local terminal command can never be executed from the local terminal. In order to gain any control over the sensor a hard reset must be performed on the sensor. This is a moderate deficiency.

At several points, after executing a command, the main menu reappeared; however, the command option bar was no longer displayed at the bottom of the terminal. The function keys still operated as expected when used. System functionality is in no way impaired by this problem. This is a minor deficiency.

Nonexistent CPMEs, 3-5, are listed as ACTV NONPR in LU CPME Status. Listing these CPMEs as ACTV NONPR implies that they are available for use. Better terminology should be used to describe their status. An SPR was submitted to address this problem. System functionality is in no way impaired by this problem. This is a minor deficiency.

No mechanisms are in place for flagging invalid inputs which are entered in an altered form. Several examples follow.

1) The delay_sequence_tbl of the CHMGT_TABLE has a range which is incremental by 16. When an attempt is made to enter a valid number within the range but not divisible by 16, the largest multiple of 16 not greater than the input is entered. No indication is given on the LOT that only increments of 16 are acceptable.

2) The k_half SAP of the CHMGT_TABLE rounds numbers (2.99 -> 3.0) if extra digits are added.

3) The DE filter for ATCRBS ID is accepting invalid data. As long as a valid octal digit is present as the first digit the input is accepted and truncated.

Examples:	Input	Recorded data
	1950	0001
	23a0	0023
	5m52	0005
	6a22	0006
	53. *	0053

4) The scan count filter in DE allows a number greater than 65535 to be entered and then wraps around. Invalid data needs to be rejected.

This minor deficiency could result in unexpected data being entered.

When doing a download or SAP install (TEMP/PERM) when the configuration of the Port/Channel are not the same the majority of the times you are not notified of a completion notice (message), but the download and install actually took place. This is verified at the MIOP window; however, the MIOP will not be available in the field. Since a change was made to switch the Port and Channel simultaneously, this problem can only arise if the user specifically requests a different Port and Channel. This is a minor deficiency.

Two methods are available for setting a channel off-line from the configuration commands, Set Element Off-line and Set Channel Off-line in the Sensor Channel Selection commands. When the Set Channel Off-line command is used conflicting status is reported by the MPS, the remote terminal, the local terminal, and the MIOPs. The MPS, remote terminal and the top level menu of the local terminal report a status of off-line. The MIOP and the configuration report of the local terminal list the status as on-line. This status problem is documented by SPR FB93-18101. When faults occur while in this state, multiple channel switches and channel mode changes can occur, see SPR FB93-18003. This is a minor deficiency but because of the interaction with other status issues, it will be considered during regression tests.

When both CPMEs were set to rank 2, the system went into ATCBI. This is a minor deficiency.

4.1.5 Mode S/Non-ATC Communication Link Integration tests.

4.1.5.1 Test Description.

Testing was accomplished employing simulation equipment, the ARIES and the CID, to exercise most of the non-ATC communication exchanges over the interface as defined by the Mode S/Non-ATC Communication Link interface control document (ICD). The ARIES simulated the functions of a Mode S beacon equipped environment with various data link capabilities. The CID simulated the functions of a non-ATC facility. Test specific scenarios were loaded in the simulators to exercise to all of the message types that are defined in the Mode S/Non-ATC Communication Link ICD. This test was conducted through both channels

of the Mode S sensor, with the Data Link and Message Routing SAP append_positional_data set to append positional data on Pilot Downlinks, Ground-Initiated Downlinks, and ELM downlinks, and later set to exclude positional data on the same messages. All necessary data was recorded at the Mode S sensor, the ARIES, and the CID.

4.1.6.2 Test Results.

The test results are presented in table 4.1.5.2-1. This table lists all of the messages defined in the Mode S/Non-ATC Communication Link ICD. Messages not tested are shown with "(NT)" after them. The first column contains all of the messages sent to the Mode S sensor and the third column contains all of the messages generated by the Mode S sensor. Columns 2 and 4 reference requirement numbers form the Test Verification Requirements Traceability Matrix (TVRTM) part of the Mode S Master Test Plan.

All non-ATC communication exchanges between the Mode S sensor and the CID were successful based on comparing the communication data types extracted at the Mode S sensor with those recorded at the CID. All data link exchanges between the Mode S sensor and the ARIES were successful based on comparing the Mode S roll-call replies and interrogation data types extracted at the Mode S sensor with those recorded at the ARIES. The data link functions of the Mode S sensor were also tested. Referring to table 4.1.5.2-1, a message in column 3 that is adjacent to a message in column 1 represents the correct response to that message. Only one condition tested needs to be investigated in more detail, ie. no response was received from the Mode S sensor for one of the Data Link Capability requests generated. The generation of the Sensor Recovery Notice message type was verified under the degraded operations Tests G_3 and N_3.

Non-ATC to Mode S Uplink Messages	TVRTM	Mode S to non-ATC Response Messages	TVRTM
Standard Uplink 29	n/def	Message Rejection/Delay Notice 31 (rejected)	4262
Standard Uplink 29	n/def	Uplink Delivery Notice 32	4248
ELM Uplink 2a	n/def	Uplink Delivery Notice 32	4248
ELM Uplink 2a	n/def	Message Rejection/Delay Notice 31 (delayed)	4262
ELM Uplink 2a	n/def	Uplink Delivery Notice 32 (delayed delivered)	4248
ATCRBS	n/def	ATCRBS ID message 45	n/def
Message Cancellation Request 2d	4260		
		Message Rejection/Delay Notice w/ID 39 (NT)	4234
		Mode S to Non-ATC Downlink Messages	**TVRTM**
Request for Downlink Data 2b	4272	Ground Initiated downlink with Position 4c	n/def
Request for Downlink Data 2b	4272	Ground Initiated downlink 44	n/def
		Pilot Downlink with Position 49	n/def
		Pilot Downlink 41	n/def
		ELM Downlink with Position 4a	n/def
		ELM Downlink 42	n/def
		ATCRBS_ID message 45 (Track Transition s2-s4)	n/def
		Data Link Capability 34 (Track Transition s2->s4)	4230
		Broadcast Downlink 40 (NT)	n/def
		Broadcast Downlink with Position 48 (NT)	n/def
Non-ATC to Mode S Status Request	**TVRTM**	**Mode S to non-ATC Status Messages**	**TVRTM**
Data Link Capability request 0a	4256	Data Link Capability message 34	4230
Data Link Capability request 0a	4256	Message Rejection/Delay Notice 31 (no track file)	4262
Request for Aircraft State 08	4270	Aircraft state 4e	4224
Request for Aircraft Position 09	4268	Aircraft Position 4f	4222
Test Message 61	n/def	Test Response Message 62	n/def
		Track Drop 4b	n/def
		Track Alert Message 9c	n/def
		Sensor Recovery Notice Message 6f (NT)	n/def

Note: n/def = No specific TVRTM number was assigned to this message type.

Table 4.1.5.2-1. Mode S/Non-ATC Communication messages (Preliminary Data)

4.1.6 Integration Tests - System Level

4.1.6.1 Accuracy and Resolution G1

4.1.6.1.1 Test Description

The accuracy of Mode S with ASR9 primary radar was tested using live aircraft being tracked by the NIKE precision tracker. The data collected by the NIKE will be compared to the Mode S data extraction tape, comparing ranges, azimuths, and elevations of the particular aircraft being tracked by the NIKE. The difference between the actual aircraft position measured by the NIKE and the position calculated by the Mode S will determine how accurate the Mode S is. The accuracy flight tests consist of the aircraft flying radial legs and orbital

legs. The 50 mile radials and 90° arcs of a constant 13 mile radius were flown 3 times with the aircraft using its ATCRBS transponder and 3 times with the aircraft using its Mode S transponder at different altitudes to show different elevation angles.

The resolution flight tests were conducted with 2 aircraft, each being tracked by a separate NIKE precision tracker. This test was conducted to determine how well the Mode S resolves 2 aircraft in close proximity to one another. The NIKE data collected is again compared to the Mode S data extraction to see if the Mode S kept track of each aircraft as one passed the other. Each aircraft was equipped with both an ATCRBS and a Mode S transponder to see how well the sensor resolves differently equipped aircraft.

4.1.6.1.2 Test Results (G1)

The data collected has not been analyzed since the transponder delay times have not been measured as of this writing. The accuracy program was run, without the correct transponder delay times incorporated, for one ATCRBS radial, one Mode S radial, one ATCRBS orbital, and one Mode S orbital. The results for disseminated data are summarized below.

	Sample	Range Error (Ft)		Azimuth Err (Deg)	
	Size	Mean	Std-Dev	Mean	Std-Dev
Mode S radial outbound	120	64.2	31.5	-0.111	0.082
Mode S radial inbound	135	98.7	31.9	-0.107	0.080
ATCRBS radial outbound	120	35.6	44.8	-0.093	0.047
ATCRBS radial inbound	140	9.7	41.5	-0.078	0.053
ATCRBS orbital cw 6000'	86	-3.5	36.8	-0.102	0.040
ATCRBS orbital ccw 6000'	81	-16.6	35.2	-0.108	0.040
Mode S orbital cw 6000'	91	47.6	31.0	-0.117	0.044
Mode S orbital ccw 6000'	84	52.0	28.9	-0.094	0.043

Table 4.1.6.1.2-1 (Preliminary Data)

The initial data analyzed indicates areas of possible noncompliance with the Mode S specification. The specification requires range accuraccy to be within ±30 feet bias (mean) and ±25 rms jitter (standard deviation). Azimuth accuraccy is required to be within a bias of ±0.033 ° and jitter less than 0.060°. The higher than expected errors noted in the sampled data are considered at this time to be a minor deficiency and may be due to incorrect transponder delay settings in the accuracy analysis program or effects of antenna pattern changes for various elevation angles. Further analysis is being conducted and will be included in the final report.

4.1.6.2 Target Capacity and Throughput

4.1.6.2.1 Test Description

Target capacity and throughput were tested to ascertain whether the Mode S sensor, functioning as part of an ASR-9/ARTS-3A Interim NAS Configuration No. 1 is capable of handling the NAS specified target numbers and target distributions within the specified time constraints, while running the surveillance, data link, and RMS capacity levels. The ARIES was used to generate a 400 target scenario, provide fruit, and provide 300 "random" radar only targets. ARIES scenarios used included all ATCRBS, mixed targets - 200 ATCRBS and 200 Mode S, and all Mode S. Each scenario was run with various levels of fruit: no fruit; light fruit - 4k ATCRBS, 30% mainbeam and/or 50 Mode S, 30% mainbeam, 25% long replies; and heavy fruit - 40k ATCRBSs, 30% mainbeam and/or 200 Mode S, 30% mainbeam, 25% long replies. The CID was used to generate data link messages.

Data was collected on the ARTS-2A, ARTS-3A, and Mode S systems, as well as the ARIES and CID simulators. Surveillance output data of the ASR-9 was collected by an RTADS. Another RTADS was used to collect data being fed to the ARTS-2A. Finally, a TRACS retro-fitted with a SRAP-to-TRACS I/O board was used to record data on the SRAP input bus of the ARTS-3A.

Each test was run twice, once with the Mode S system operating on channel A and once with it operating on channel B.

4.1.6.2.2 Test Results

The ARTS-3A DRAM output is displayed in table 4.1.6.2-1 with all statistics being in an acceptable range. The ARIES/Mode S compare summary statistics are listed in table 4.1.6.2-2. The Mode S PoD is low because of an unexplained condition which resulted in one run having a PoD value of 94.85%. Without this run the PoD is 99.97%. This will be investigated.

Table 4.1.6.2-3 contains data delay statistics for the disseminated data from Mode S to the ARTS IIIA. The time is measured from antenna boresight of the target to the receipt of the target report at the ARTS IIIA. Mode S is required to hold targets reports until 5/64 of a scan and than disseminate before 3/32 of a scan. For this antenna rotation rate the time window would be .363 seconds to .436 seconds. Revisions are in progress to modify the analysis software to present the data output to be aligned with sector boundaries so as to relate to the requirements. Slight amounts of target data appears to be exceeding the limits but further analysis is required before a conclusion can be reached.

Subtests which generated heavy fruit caused the system to switch channels and then enter back up mode. New scenarios with intermediate fruit, 20k ATCRBS and/or 100 Mode S, were generated. Tests run with these new scenarios produced the same results. An SPR was written to address the Mode S system Performance Monitoring's inability to handle high fruit loads and is considered a moderate deficiency.

The ARTS-2A and ARTS-3A are not capable of handling the maximum Mode S target load of 400 targets but did continue to operate with a reduced target set being displayed . Once the target load reduced back to within the capacity of each respective ARTS system, they resumed normal operation.

Data extraction taken at various points in the flow of data were compared to the data extracted at the Mode S to determine if any data loss was occurring. Mode S data compared with the surveillance output data of the ASR-9 showed a 99.996% correlation. Mode S data compared with the data being fed to the ARTS-2A indicated a 99.996% correlation also. Mode S data compared with data being fed to the ARTS-3A indicated 99.9% correlation; however, extra status messages were recorded.

Test	Radar*** Reinfrc	Blip Scan	False Reflect	False Split	Alt Error	Alt Validity	Code Validity	Split Az	Split Rg
ATCRBS, no fruit-A*	80.1	99.5	0	0	0	99.7	82		
ATCRBS, no fruit-B*	79.8	99.5	0	0	0	99.7	82.7		
ATCRBS, light fruit-A*	79.7	99.3	0	0	0	99.7	82.2	0.03	0
ATCRBS, light fruit-B*	79.7	99.4	0	0	0	99.8	81.7	0.03	0
ATCRBS/ModeS, no frt-A*	80.9	99.6	0	0	0	96.1	84.5		
ATCRBS/ModeS, no frt-B*	80.5	99.2	0	0	0	96.1	84.6		
ATCRBS/ModeS, lgt frt-A*	80.2	99.6	0	0	0	97.7	87.9	0.03	0
ATCRBS/ModeS, lgt frt-B*	80	99.6	0	0	0	97.7	87.8	0.03	0
ModeS, no fruit-A*	80.1	99.7	0	0	0	95.4	96.2		
ModeS, no fruit-B**	80.3	99.7	0	0	0	95.2	96.1		
ModeS, light fruit-A**	79	98.6	0	0	0	95.5	96.3		
ModeS, light fruit-B**	79.6	99.6	0	0	0	95.3	96		
Range	79-80.9	98.6-99.7	0	0	0	95.2-99.8	81.7-96.3	0.03	0
Average	79.9	99.4	0	0	0	97.3	88.2	0.03	0

*Tests run 7/26/93
**Tests run 8/13/93
***All ARIES scenarios were run with 80% radar reinforcement.

ARTS-3A DRAM Statistics for Capacity Tests

Table 4.1.6.2-1 (Preliminary Data)

Test	Prob. of Detect	ID Rel	ID Conf	Alt Rel	Alt Conf	Rg Error	Az. Error	ARIES Rply/Rpt	MDS Rply/Rpt
ATCRBS Average	99.82	99.27	99.13	99.26	98.79	0.004	0.041	5.727	5.510
Mode S Average	98.95	100.00		99.99		0.008	0.039	1.946	1.826

ARIES/Mode S Compare Summary Statistics

Table 4.1.6.2-2 (Preliminary Data)

Target Load	.3 - .4 sec delay (% Target @)	.4 - .5 sec delay (% Target @)	.5 - .6 sec delay (% Target @)
100	99.5	0.5	0
150	99.6	0.4	0
200	98.3	1.7	0
250	97.3	2.7	0
300	94.6	5.4	0
350	86.4	13.6	0
400	64.4	35.4	0.1

NAS Throughput Data - Mode S/ ASR-9 to ARTS IIA and ARTS IIIA
Mixed ATCRBS and ModeS Targets (4k Fruit)
Table 4.1.6.2 -3 (Preliminary Data)

4.1.6.3 Degraded Operations

4.1.6.3.1 Test Description

The Degraded Operations test was conducted with the Mode S sensor processing live world targets, connected to an ASR-9 radar, and interfacing with the ARTS-3A and ARTS-2A subsystems. Fault events (e.g. manual channel switches, fault channel switches, fault on standby channel, etc.) and recovery events (e.g. exit ATCBI mode, master reset, etc.) were executed in a predetermined test sequence, so that each Mode S and ASR-9 channel could be tested in a different channel mode (e.g. active, standby, off-line). Air Traffic Controllers commented on the loss of targets (alphanumeric and beacon video) observed on the ARTS displays during each event. Target loss was recorded on an RTADS at the Mode S site and at the ARTS lab. The local terminal and MPS simulator were used to detect and identify each injected fault. A logic analyzer was used to monitor the status control lines on the Mode S to ASR-9 digital interface. The remote terminal was visually monitored to see if it accurately represented Mode S system status for the degraded operating mode.

A primary objective of this test was to quantify the data loss encountered when the Mode S / ASR-9 systems are faulted, and to determine if the interface to the ARTS-3A and ARTS-2A introduces any additional loss. A second objective was to measure how quickly and accurately the Mode S sensor can detect a fault, and how well sensor diagnostics can fault isolate down to the failed component. A third objective of this test was to observe how well Mode S system status was reported via the Remote Terminal during various modes of degraded operation.

4.1.6.3.2 Test Results

Data loss was out of tolerance (greater than 1 sec.) for 3 out of the 14 types of fault /recovery events. See Table 4.1.6.3 for details. For faults that caused a Mode S channel switch, disseminated surveillance reports were lost for up to 2 sec. Faults which degraded the sensor into ATCBI mode caused disseminated surveillance report loss ranging from 1 to 10 sec.

depending on the type of fault inserted. When the active ASR-9 Post Processor was faulted, targets were lost for 3 to 4 sec. These cases of excessive data loss represent **minor deficiencies** in the Mode S and ASR-9 systems. Mode S System Problem Reports and an ASR-9 Hardware Discrepancy Report have been generated to address these problems.

The Air Traffic Controllers, for the most part, observed alphanumeric and video losses on their displays commensurate to the losses observed on the RTADS and analyzed in recorded RTADS data. There was an instance where ARTS-3A controllers observed 4 more seconds of data loss than ARTS-2A controllers. However, overall there was consistency among controller observations on each system. No significant data loss appears to be introduced by the Mode S / ASR-9 to ARTS-3A, ARTS-2A interface during Degraded Operations. More data analysis will be performed to fully substantiate this.

Fault detection during Degraded Operations represents a **minor deficiency** in Mode S system operation. Faults were not reported (identified) if the fault caused a Remote Monitoring Subsystem (RMS) communications break in the sensor. Faults injected during test dry runs were detected differently than the same faults injected during this formal test, depending on which tasks were running in system software at the time. System Problem Reports were generated during the dry runs and formal test for specific faults which had unexpected results. For example, certain faults were not detected on the standby channel. Interrogator faults were ignored when the interrogator was in ATCBI. Interrogator diagnostics would pass a failed hardware element, even when the fault was still installed. Notification of the failure of any element is required to be available at the RMS output within 1.0 seconds from the time the error is detected. During this test it took a minimum of 13 seconds for a fault to be received at the MPS simulator from the time it was induced.

The Mode S Remote Terminal exhibited a **moderate deficiency** in reporting correct system status during degraded modes of operation. The remote terminal showed the Mode S mode operative, when the sensor was really in ATCBI. It also failed to show any channel being on-line when the system was still outputting targets in backup mode. Changes are being made to remote terminal software to correct these problems.

TABLE 4.1.6.3 (Preliminary Data)
DEGRADED OPERATIONS FAILURE MODES

Fault Event / Recovery Event	Time Amount of Data Loss (sec.)	# of Scans Data Loss	Deficiency
Manual Channel Switch	0.5 - 1	1/8 - 1/4	none
Fault Channel Switch	1 - 2	1/4 - 1/2	**minor**
In-channel Recovery	1	1/4	none
Fault on Standby Channel	0 (unless fault causes MIOP switch- 1 sec.)	0 (unless fault causes MIOP switch- 1/4 scan)	none
Fault into ATCBI mode	1 - 10	1/4 - 2 1/2	**minor**
Fault on Off-line Channel	0	0	none
Fault ATCBI Channel	permanent	permanent	none
ASR-9 Manual Channel Switch	0	0	none
ASR-9 Fault Post Processor Switch	3 - 4	3/4 - 1	**minor**
ASR-9 Standby Post Processor Fault	0	0	none
Diagnostics passes on Off-line Channel	0	0	none
Off-line Channel Initialized	0	0	none
Master Reset	ATCBI targets return immediately & maintained for 45 sec. All targets lost for next 24 sec. Full operation restored.	10 scans with just ATCBI targets. 5 scans all targets lost.	none
Exit ATCBI	24	5	none

4.1.6.4 Mode S/ASR-9 Full-Up Operation.

4.1.6.4.1 Test Description.

This Full-Up Operational test was conducted with the Mode S/ASR-9 subsystem feeding digital surveillance information through the Remote-SCIP to the ARTS-3A and the ARTS-2A systems. The Remote-SCIP also produced reconstituted beacon and search videos, based on the surveillance data, for presentation on the ARTS displays. The Mode S/ASR-9 subsystem processed live world targets and two FAA Technical Center project-controlled aircraft equipped with Mode S and ATCRBS transponders. Field experienced air traffic controllers monitored the displays (the DEDS for the ARTS-3A and the RADS for the ARTS-2A) while flight patterns were conducted, and filled out evaluation questionnaire packages. Data was collected at the Mode S sensor, the ARTS systems, and at the inputs to the ARTS systems using TRACS units to quantify the observations noted by the controllers.

4.1.6.4.2 Test Results.

The general consensus of the test-support air traffic controllers, indicated that the performance of the Mode S/ASR-9 subsystem was equivalent to the performance of the ATCBI-5/ASR-8/SRAP subsystem. Some improvements were noted in surveillance quality of aircraft. When comparing surveillance quality of aircraft equipped with ATCRBS transponders, a slight improvement was observed on the DEDS and RADS displays presenting target data that originated from the Mode S/ASR-9 subsystem over that of the ATCBI-5/ASR-8/SRAP subsystem. Both presentations were satisfactory. When comparing surveillance quality of aircraft equipped with Mode S transponders, an improvement was observed on the DEDS and RADS displays that presented the Mode S/ASR-9 surveillance data. An improvement in target range resolution and altitude reliability was noted. This resulted in an improved data block stability on close proximity targets, especially Mode S equipped targets.

Over the full course of the test, an unusually high number of coasts were observed on the project controlled aircraft over most of the flight patterns exercised. This was observed on the displays for both the Mode S/ASR-9 subsystem and the ATCBI-5/ASR-8/SRAP subsystem which was used as a comparison. Further investigation on the data collected during the test will done to clarify the reason for the unexpected number of target coasts observed. In setting up for this test, a small percentage of surveillance messages, less than 2 percent, were being lost between the Mode S/ASR-9 subsystem and the output of the Remote-SCIP. No indication of a problem was detected at either side. Investigation into the data loss revealed that one of the surveillance modems on the ASR-9 side was intermittent. The non-detection of the intermittent ASR-9 data loss is considered a **moderate deficiency**. A HDR was generated addressing the problem.

While the Mode S/ASR-9 subsystem ran in the full-up operational mode there was detected impact due to Mode S dissemination delay on ATC operations. To properly run with the ARTS-3A system, the ARTS_SRAP_Azimuth_Sync_Delay parameter in the SCIP was changed to 192 ACPs (this parameter is presently set at 64 ACPs in the field). This is

considered a **major deficiency** in the Mode S/ASR-9 subsystem configuration. If the Mode S sensor should switch to the IBI mode and the ASR-9 then processes the beacon video, target reports could occur before the delayed sector marks. This data is essentially is lost by the ARTS-3A resulting in a high number of track drops and track re-initializations as observed on the DEDS displays. The added delay due to Mode S track processing did not appear to have any effect on the operations of the ARTS-2A system except on the data extraction function. The ARTS-2A operating software was modified to accept data 5 sectors old (original setting was 2 sectors). For these tests no attempt was made to optimize this setting.

These was no impact noted by the controllers that has the potential of effecting ATC procedures resulting from the used of reconstituted beacon and radar video generated by the SCIP either at the ARTS-3A DEDS or the ARTS-2A RADS. The reconstituted video was generally preferred because its signal strength and stability was much better than current systems.

No false target problem was observed on either the Mode S/ASR-9 subsystem nor the ATCBI-5/ASR-8/SRAP subsystem. Consensus indicated that the track swaps, splits and coasts were reduced with the Mode S/ASR-9 subsystem.

4.2 Interim NAS Configuration No. 2

The configuration tested with Configuration Number 2 is the Mode S with a non-digitizing radar, primarily the ASR-7 or the ASR-8, providing beacon surveillance data to an ARTS IIA system. The interface between Mode S and the radar is comprised of only trigger signals which are used during backup operations. The Mode S disseminates digital surveillance data directly to the ARTS IIA via the ARTS IIA MALA interface. During backup operations the Mode S provides beacon video and triggers to the ARTS IIA DDAS which allows the ARTS to perform the beacon processing. The radar, in both type of operation, provides radar video and triggers to the ARTS IIA.

4.2.1 Mode S/ASR7/ARTS 2A Integration Test J

4.2.1.1 Test Description

This test was conducted in two phases - live world and simulated. For the live world tests, data was collected for four 10 minute runs (two 10 minute runs with Mode S on channel A and two 10 minute runs with Mode S on channel B). Data was collected by Mode S extraction, RTADS data extraction at the Mode S site, RTADS data collection at the ARTS 2A before input to the MALA board, and data extraction on the ARTS 2A tape drive. This part of the test assures the ARTS 2A can receive live target information direct from the Mode S without going through the ASR9/SCIP. It also verifies what the Mode S sent to the ARTS 2A was received correctly.

The second test phase used the ARIES and CID to generate a 6 minute, 5 target scenario. The scenario generated one of each type of comm. message, to verify the Mode S can handle them. Data for this phase was collected by Mode S extraction, RTADS data extraction at the Mode S site, and both ARIES and CID data extraction. The scenario was run with data collection four times (two times with Mode S on channel A and two times with Mode S on channel B).

4.2.1.2 Test Results

The live world results show 100% correlation between disseminated data on the Mode S extraction and the RTADS extraction at the ARTS 2A from all 4 live world tests. The scenario results show 100% probability of detection, 100% identity reliability, and 100% altitude reliability for reports, surveillance files, and disseminated data.

Towards the end of the scenario the CID sent an ATC_FAILURE message and 10 seconds later sent an ATC_RECOVERY message. If the Mode S receives an ATC_FAILURE message, it stops sending disseminated data. This was noted by all targets disappearing from the RTADS screen and then reappearing after the ATC_RECOVERY message was received by the Mode S sensor. This message was tested, but will never be used in this configuration as the ARTS 2A cannot send communications messages and the DLP (non-ATC) cannot send this type of comm. message either.

4.2.2 Integration Test - System Level Tests

4.2.2.1 Accuracy and Resolution N1

4.2.2.1.1 Test Description

The accuracy of Mode S with ASR7 primary radar was tested using the same test cases aas were used for the Mode S/ASR-9 configuration. Some flights have not been completed for this configuration due to aircraft equipment failures or conflicts with other projects. Rescheduling has been attempted.

4.2.2.1.2 Test Results (N1)

The data collected has not been fully analyzed since the transponder delay times have not been measured as of this writing. The accuracy program was run, without the correct transponder delay times incorporated, for one ATCRBS radial, one Mode S radial, one ATCRBS orbital, and one Mode S orbital. The results for this sample of disseminated data are summarized below(Table 4.2.2.1.3-1).

	Sample Size	Range Error (Ft) Mean	Range Error (Ft) Std-Dev	Azimuth Err (Deg) Mean	Azimuth Err (Deg) Std-Dev
Mode S radial outbound	151	65.5	30.4	-0.107	0.094
Mode S radial inbound	130	103.5	31.7	-0.116	0.077
ATCRBS radial outbound	141	93.5	38.2	-0.092	0.047
ATCRBS radial inbound	124	78.4	30.5	-0.087	0.049
ATCRBS orbital cw 6000'	46	51.1	34.5	-0.118	0.055
ATCRBS orbital ccw 6000'	51	47.7	30.5	-0.105	0.042
Mode S orbital cw 6000'	50	51.1	29.7	-0.125	0.054
Mode S orbital ccw 6000'	53	61.0	27.0	-0.090	0.059

Table 4.2.2.1.2.-1 (Preliminary Data)

The data presented does not meet the Mode S specifications in some cases. Range is required to be within ±30 feet bias (mean) and ±25 rms jitter (standard deviation). Azimuth is required to be within a bias of ±0.033° for elevation angles less than 2.0° (to be performed on tests conducted on the CPME) and jitter less than 0.060°, (1 standard deviation) for elevation angles less than 20° for both Mode S and ATCRBS transponders. These higher than expected errors are considered to be a minor deficiency at the present time since the transponder delays have not yet been measured. A complete analysis will be presented in the final report.

4.2.2.2 Target Capacity and Throughput Mode S/ARTS 2A Test N2

4.2.2.2.1 Test Description

This test was designed to measure data delays to the ARTS 2A from the Mode S for a large number of targets and tracks. The tests used the ARIES and CID to run 400 target capacity scenarios, with various levels of fruit, with ATCRBS only targets, or Mode S only targets, or mixed (200 ATCRBS and 200 Mode S) targets. The scenario starts out with no targets and gradually starts adding targets until the capacity of 400 is reached. The scenario stays at this capacity level for several minutes and then gradually starts dropping track until the scenario ends with 0 targets. The scenario runs for approximately 12 minutes. Data was collected for each of the 12 tests by Mode S, ARTS 2A, ARIES, and CID data extraction, as well as by RTADS data extraction of disseminated data at the Mode S site and at the ARTS 2A before the MALA board.

4.2.2.2.2 Test Results N2

Data reduction and analysis has not been completed for all the N2 runs prior to this writing. The results for completed analysis is summarized below.

			ARIES	Compare		TRACS at	Compare ASR-7	TRACS at	Compare ARTS2
Test	Chanl	Date	Total	Reprt POD%	Disem POD%	Total	Uncor	Total	Uncor
ATCRB	A	8/04	39484	99.82	99.75	49798	0	49726	0
ATCRB	B	8/27	39709	99.82	99.74	50023	0	50025	0
A/fru	A	8/04	39488	99.75	99.65	49980	0	49980	0
A/fru	B	8/09	39714	99.77	99.69	49734	0	49735	0
Mixed	A	8/04	39778	99.89	99.88	49743	0	49816	0
Mixed	B	8/09	39566	99.83	99.82	50021	0	50021	0
Mx/Fr	A	8/04	39813	99.87	99.86	49995	0	49995	0
Mx/Fr	B	8/09	39778	99.86	99.83	50676	0	50248	0

Table 4.2.2.2-1 (Preliminary Data)

THROUGHPUT - ARIES to TRACS at ASR7 for 400 ATCRBS targets with no fruit

Target Load	.3 - .4 sec delay (% target @)	.4 - .5 sec delay (% target @)	.5 - .6 sec delay (% target @)
100	82.7	17.3	0.0
150	80.8	19.2	0.0
200	72.8	27.2	0.0
250	66.4	33.6	0.0
300	56.9	43.1	0.0
350	47.1	52.9	0.0
400	32.5	67.3	0.2

Table 4.2.2.2-a (Preliminary Data)

The Mode S specification requires that dissemination occurs between 2.5 and 3 sectors. This equates to times of 0.362 to 0.435 seconds. The targets that fall past those times reflect a minor deficiency and will be discussed further in the final report. The throughput analysis program output will also be modified so that time headings will be separated by sector times instead of round numbers.

4.2.2.3 Degraded Operations

4.2.2.3.1 Test Description

The Degraded Operations test was conducted with the Mode S sensor processing live world targets and disseminating surveillance information to the ARTS-2A subsystem. Fault events (e.g. manual channel switches, fault channel switches, fault on standby channel, etc.) and recovery events (e.g. exit ATCBI mode, master reset, etc.) were executed on the Mode S in a predetermined test sequence, so that each channel could be tested in a different channel mode (e.g. active, standby, off-line). Air Traffic Controllers commented on the loss of targets (alphanumeric) observed on the ARTS displays during each event. Target data was recorded on

an RTADS at the Mode S site and at the ARTS lab. The local terminal and MPS simulator were used to detect and identify each injected fault. The remote terminal was visually monitored to see if it accurately represented Mode S system status for the degraded operating mode.

A primary objective of this test was to quantify the data loss encountered when the Mode S system is faulted, and to determine if the interface to the ARTS-2A introduces any additional loss. A second objective was to examine how well the ARTS-2A can handle the switch from full-up Mode S to back-up mode. Another objective was to measure how quickly and accurately the Mode S sensor can detect a fault, and how well sensor diagnostics can fault isolate down to the failed component. A final objective of this test was to observe how well Mode S system status was reported via the Remote Terminal during various modes of degraded operation.

4.2.2.3.2 Test Results

Data loss was out of tolerance (greater than 1 sec.) for 3 out of the 11 types of fault /recovery events. See Table for details. Manually switching Mode S channels caused 1.25 to 1.5 sec. of data loss on the RTADS. For faults that caused a Mode S channel switch, disseminated surveillance reports were lost for up to 2.5 sec. Faults which degraded the sensor into ATCBI mode caused disseminated surveillance report loss ranging from 1 to 10 sec. depending on the type of fault inserted. These cases of excessive data loss represent **minor deficiencies** in the Mode S system. Mode S System Problem Reports have been generated to address these problems.

The Air Traffic Controllers, for the most part, observed target losses on their displays similar to the losses observed on the RTADS and analyzed in recorded RTADS data. No significant data loss appears to be introduced by the Mode S / ASR-7 to ARTS-2A interface during Degraded Operations. More data analysis will be performed to fully substantiate this.

Fault detection during Degraded Operations represents a **minor deficiency** in Mode S system operation. Faults were not reported (identified) if the fault caused a Remote Monitoring Subsystem (RMS) communications break in the sensor. Faults injected during test dry runs were detected differently than the same faults injected during this formal test, depending on which tasks were running in system software at the time. A fault was injected on a board in one interrogator, and interrogator diagnostics fault isolated to the wrong board. System Problem Reports were generated during the dry runs and formal test for specific faults which had unexpected results. For example, certain faults were not detected on the standby channel. Interrogator faults were ignored when the interrogator was in ATCBI. Interrogator diagnostics would pass a failed hardware element, even when the fault was still installed. Notification of the failure of any element is required to be available at the RMS output within 1.0 seconds from the time the error is detected. During this test it took a minimum of 13 seconds for a fault to be received at the MPS simulator from the time it was induced.

The Mode S system exhibited a **moderate deficiency** in reporting correct system status during degraded modes of operation. In one out of four cases, the remote terminal showed the

Mode S mode operative with the sensor really in ATCBI. It also failed to show any channel being on-line when the system was still outputting targets in backup mode. It appears that the remote terminal does not display system status correctly when RMS communication with the sensor is lost. Changes are being made to remote terminal software and Mode S system software to correct these problems.

TABLE 4.2.2.3 (Preliminary Data)
DEGRADED OPERATIONS FAILURE MODES

Fault Event / Recovery Event	Time Amount of Data Loss (sec.)	# of Scans Data Loss	Deficiency
Manual Channel Switch	1.25 - 1.5	1/4 - 1/3	**minor**
Fault Channel Switch	1.5 - 2.5	1/4 - 1/2	**minor**
In-channel Recovery	1	1/4	none
Fault on Standby Channel	0 (unless fault causes MIOP switch- 1 sec.)	0 (unless fault causes MIOP switch- 1/4 scan)	none
Fault into ATCBI mode	1 - 10	1/4 - 2 1/2	**minor**
Fault on Off-line Channel	0	0	none
Fault ATCBI Channel	permanent	permanent	none
Diagnostics passes on Off-line Channel	0	0	none
Off-line Channel Initialized	0	0	none
Master Reset	ATCBI targets return immediately & maintained for 45 sec. All targets lost for next 24 sec. Full operation restored.	10 scans with just ATCBI targets. 5 scans all targets lost.	none
Exit ATCBI	24	5	none

4.2.2.4 Mode S/ASR-7 Full-Up Operation.

4.2.2.4.1 Test Description.

This Full-Up Operational test was conducted with the Mode S/ASR-7 subsystem feeding digital beacon report information through a MALA to the ARTS-2A system. The ASR-7 radar provided search videos for presentation on the ARTS-2A RADS display. The Mode S/ASR-7 subsystem processed live world targets and two FAA Technical Center project-controlled aircraft equipped with Mode S and ATCRBS transponders. A second ARTS-2A system was set up and used as a reference for comparison. It received beacon video form an ATCBI-5 for reply-to-reply processing. The ASR-8 radar provided search videos and the ATCBI-5 provided beacon video for presentation on another ARTS-2A RADS display. Field experienced air traffic controllers monitored the RADS displays while flight patterns were conducted, and filled out evaluation questionnaire packages. Data was collected at the Mode S sensor, the ARTS-2A system, and at the input to the ARTS system using a TRACS unit to quantify the observations made by the controllers.

4.2.2.4.2 Test Results.

The general consensus of the test-support air traffic controllers indicated that the performance of the Mode S/ASR-7 subsystem was not equivalent to the performance of the ATCBI-5/ASR-8 subsystem. General consensus was that current separation standards could not be applied using the ASR-7 video and the ARTS-2A position symbols (ARTS tags) alone. The lack of an analog beacon slash was viewed as a major configuration change to what is currently in the field and would adversely affect current ATC procedures. If a beacon control slashes could be generated, current separation standards could be used. The lack of beacon video during normal operation is considered to be a major deficiency.

The added delay due to Mode S track processing did not appear to have any effect on the operations of the ARTS-2A system except on the data extraction function. The ARTS-2A operating software was modified to accept data up to 5 sectors old (original setting was 2 sectors). For these tests no attempt was make to optimize this setting.

The anticipated improvements surveillance quality of aircraft was not seen through most of the test. When comparing surveillance quality of aircraft equipped with ATCRBS transponders, the target data displayed from the Mode S/ASR-7 subsystem was equivalent to that of the ATCBI-5/ASR-8 subsystem. Both presentations were satisfactory. When comparing surveillance quality of aircraft equipped with Mode S transponders, a degradation was observed on the RADS displays that presented the Mode S/ASR-7 surveillance data. Over the full course of the test, an unusually high number of coasts, altitude drop, and code garble were observed on the project-controlled aircraft. This was observed on both displays but the Mode S/ASR-7 subsystem seemed to be not as good in comparison. In some cases the Mode S/ASR-7 subsystem was unsatisfactory. Further investigation on the data collected during the test will be performed to clarify the reason for the unexpected results observed.

During the flights, beacon identification (Ident), the setting of the special position indicator pulse at the Mode S transponders was not being seen on the displays that receiving beacon data from the Mode S sensor. Later investigation of the Mode S operational software revealed that the Idents were being received by the Mode S sensor but that the surveillance dissemination code did not past this information along in the type 9 surveillance formatted messages. An SPR was generated to correct this problem which is classified as a moderate deficiency.

4.3 Performance Test

All testing was executed in accordance with the Mode S Performance Test Procedure. As of September 7, 1993, all of the procedures have been executed and are considered substantially complete.

All tests were executed using Sensor #1 (Sensor #137 was also used for one test) located in Building 269 of the FAA Technical Center. The software used was the TR21.2 release, version 1.1.21. In each case, the current baseline of surveillance or radar SAPs was loaded into the sensor as the procedure specified.

4.3.1 IBI/ATCBI-5 Comparison

4.3.1.1 Test Description

This test measured the surveillance performance of the Mode S sensor in the IBI mode, against the performance of the ATCBI-5. These comparisons were made with each system in the SLS and ISLS modes. Using the Real Time Aircraft Display System (RTADS) extractions on each system were created and analyzed. Targets of opportunity were used to create each extraction.

4.3.1.2 Test Results

This test measured the surveillance performance of the Mode S sensor in the IBI mode, against the performance of the ATCBI-5. Forty subtests were executed, consisting of over 10 hours of live data collection.

With respect to most surveillance parameters, the ATCBI-5 performed slightly better than the Mode S in the IBI mode. Figures 4.3.1.2-1 and 4.3.1.2-2 illustrate the average results measured using the ATCBI-5 and the IBI (SLS mode).

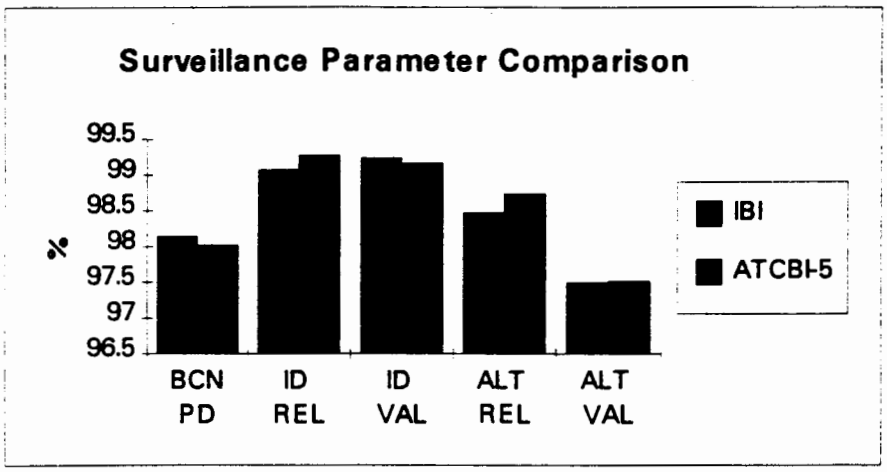

Figure 4.3.1.2-1 - IBI / ATCBI-5 Comparison, (Preliminary Data)

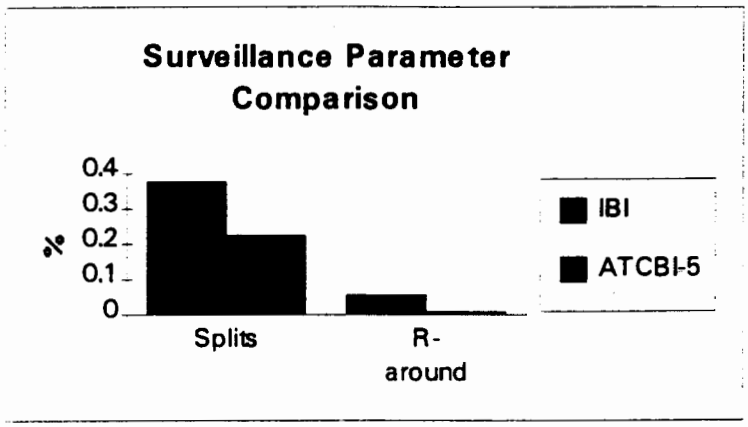

Figure 4.3.1.2-2 - Splits and Ringaround Comparison, (Preliminary Data)

Beacon splits and ringaround rates were higher using the IBI. The main contributing factor is probably the pulse stretching associated with using log beacon video in the IBI instead of linear video used in the ATCBI-5. As a result, when transponders out of specification with respect to the pulse width or frequency are encountered by the IBI, beacon splits and ringaround result. The ringaround values although higher with the IBI are still negligible.

The objectives require that the performance of the IBI surpass that of the ATCBI-5 in the following areas:

- Beacon Probability of Detection
- Mode 3/A code validity and reliability
- Altitude code validity and reliability
- Beacon split rate
- Beacon ringaround rate

- Mode 3/A code 0000 rate.

In IBI mode the Mode S sensor and the ATCBI-5 are essentially the same in most areas. A complete analysis will be provided in the Final Test Report.

4.3.2 IBI Performance Monitoring

4.3.2.1 Test Description

This test measured the accuracy of the forward power monitoring circuits and the accuracy of the VSWR monitoring circuits. This procedure also tested the monitoring alarm points of four key performance parameters of the IBI; Directional Forward Power, Directional VSWR, Omni Forward Power, and Omni VSWR. This test was accomplished by using a peak power levels in the sensor.

4.3.2.2 Test Results

This test measured the accuracy of the forward power monitoring circuits and the accuracy of the VSWR monitoring circuits. Also tested were the monitoring alarm points of four key performance parameters of the IBI including:

- Directional Forward Power
- Directional VSWR
- Omni Forward Power
- Omni VSWR.

All four alarm points were tested on each channel. Each alarm was sent to the remote terminal at the correct levels.

Per the procedure an attempt was made to change the SAP "ap_rvr_sum_pwr_dtct_off" until the VSWR measured on the local terminal matched the VSWR measured using the Peak Power Meter. The SAP was lowered until it reached 0, but the VSWR on the local terminal never reached the measured 1.20, instead it reached 1.25. This problem requires further investigation but does not hinder system operation in any way. This problem is considered a minor deficiency.

4.3.3 Surveillance baseline - Pd/Pfa

4.3.3.1 Test Description

These tests measured the Mode S probability of detection (Pd) and the probability of false alarm (Pfa), as a function of RF signal and fruit levels. ARIES was used to simulate the test

targets at each level and the fruit. Using data reduction tools and formulas, the actual values for Pd and Pfa are calculated.

4.3.3.2 Test Results

The sensor easily met the probability of detection and probability of false alarm requirements for both ATCRBS and Mode S targets for all subtests executed. However, the sensor was unable to execute moderately heavy mixed fruit scenarios. Executing this fruit scenario caused a "CW Interference" red code on the sensor. The sensor was forced into IBI mode shortly thereafter, but also went red in the IBI mode. These subtests were not completed. Figures 4.3.3.2-1 and 4.3.3.2-2 below illustrate the probability of detection and the probability of false alarm for Mode S and ATCRBS targets.

The values of Pd and Pfa measured over the range of RF signal levels and fruit levels in the subtests executed were sufficient to provide a surveillance baseline. The first four sets of data on the left correspond to runs using no fruit. The second four sets of data on the right correspond to run using moderate fruit levels.

It is worth noting that the Pd and Pfa remained relatively constant for Mode S targets for all subtests.

For ATCRBS targets there was a general decrease in Pd with decreasing signal level, see Figure 4.3.3.2-1, subtests 2 to 4a inclusive. This decline was even more rapid at the moderate fruit level, see Figure 4.3.3.2-1, subtests 6 to 8 inclusive. The corresponding inverse variation of Pfa is shown in Figure 4.3.3.2-2.

In Figure 4.3.3.2-2, the high Pd in subtest 8 is due to the combined effect of low signal and moderate fruit levels.

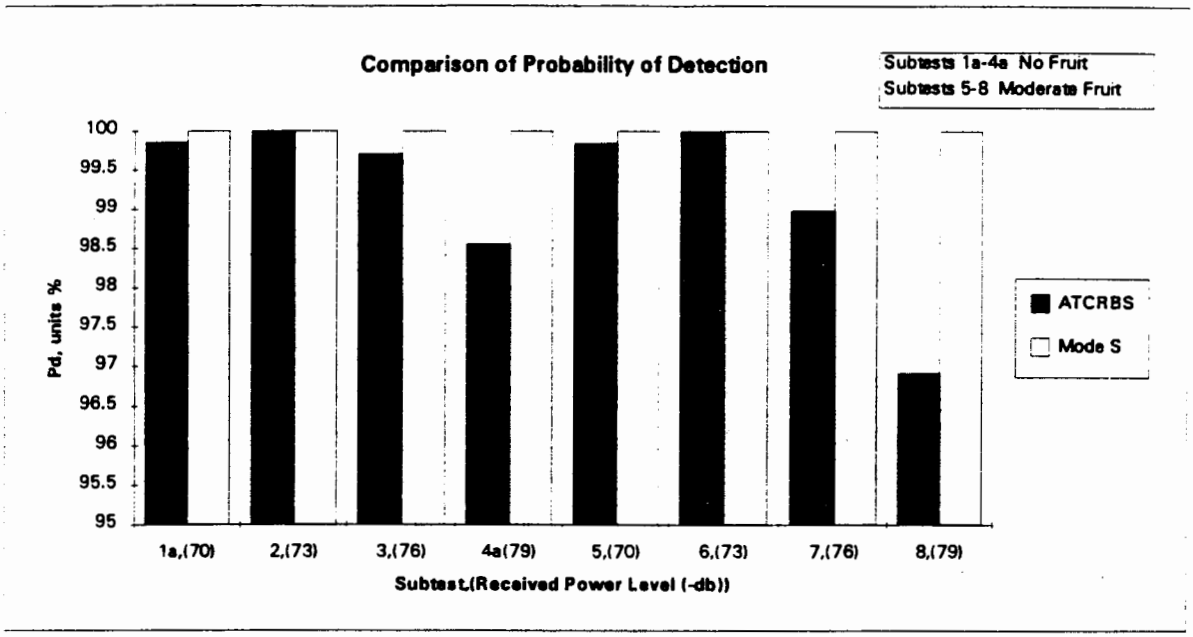

Figure 4.3.3.2-1 - Probability of Detection for ATCRBS / Mode S Targets, (Preliminary Data)

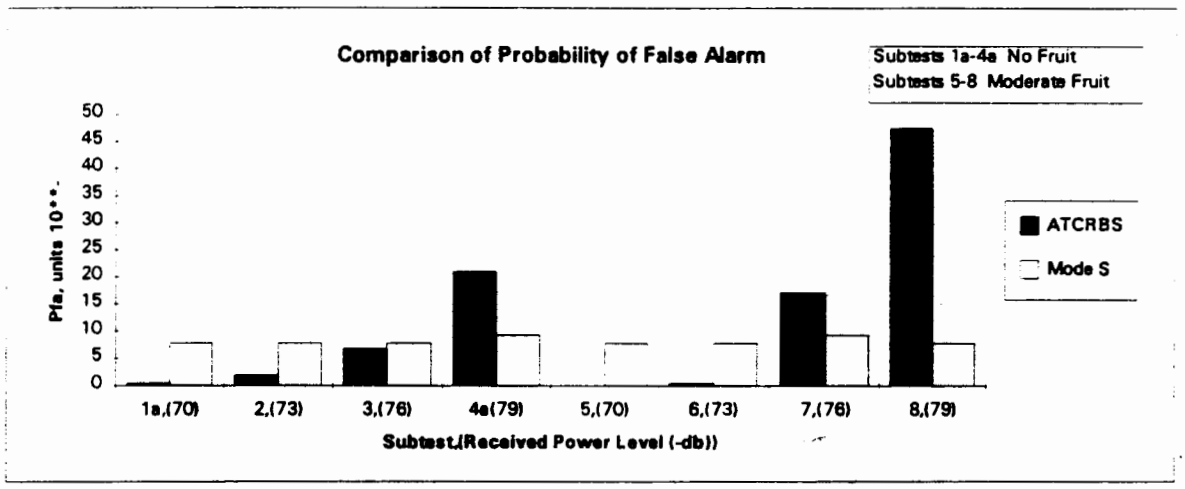

Figure 4.3.3.2-2 - Probability Of False Alarm for ATCRBS / Mode S Targets, (Preliminary Data)

4.3.4 Surveillance Baseline - Report Parameters

4.3.4.1 Test Description

This test measured the surveillance performance of the sensor under typical target load situations and under capacity situations. ARIES was used to simulate a real world target load and a capacity situation. Three fruit scenarios were also used. These included the no fruit, moderate fruit and intermediate fruit scenarios. The statistics of interest were calculated using data reduction programs.

4.3.4.2 Test Results

This test evaluated Mode S surveillance performance under typical target load situations, including capacity target loads. The test plan requires that each ARIES scenario be run with no fruit, moderate fruit, and heavy fruit. However the sensor is not operational with ATCRBS targets using even an intermediate fruit level between moderate and heavy. When using these fruit scenarios "CW Interference" red codes were observed and the sensor was forced into the IBI mode shortly thereafter. Subtests involving ATCRBS targets and the use of any fruit level higher than "moderate" have not been successfully completed.

Most of the objectives of this tests have been met. The values observed for Beacon Probability of Detection, ID Reliability and validity, and Altitude Reliability and Validity were all acceptable. However, unacceptable numbers of Reinterrogations and False Target Reports have been observed. The reinterrogation failure seems to have been caused by targets close to the sensor. The number of reinterrogations falls to an acceptable level for targets with ranges of greater that 20 nmi. The False Target requirements are less than 0.30% for ATCRBS and less than 0.10% for Mode S. The Reinterrogation Rate requirement for Mode S is less than 0.10 per target. These failures are classified as minor deficiencies. A more complete analysis of these problems will appear in the Final Test Report. The mean values of the Surveillance Parameters are shown in Figure 4.3.4.2-1. False Target Report Rates are shown in Figure 4.3.4.2-2. The variation of reinterrogation rate with range is shown in Figure 4.3.4.2-3. The data presented is a summation of multiple runs of various target mixes and fruit levels.

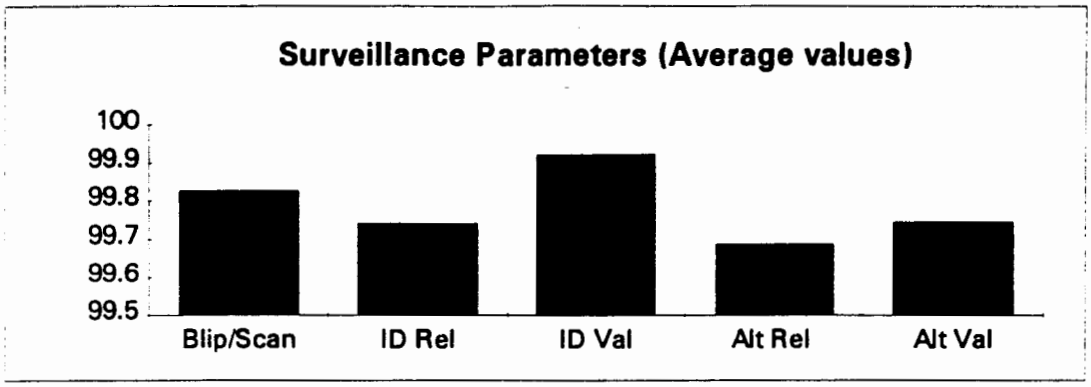

Figure 4.3.4.2-1 - Summary of Surveillance Parameters, (Preliminary Data)

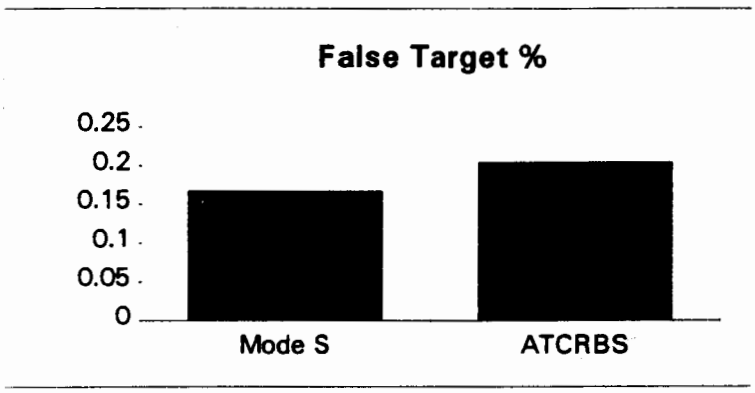

Figure 4.3.4.2-2 - ATCRBS / Mode S False Targets, (Preliminary Data)

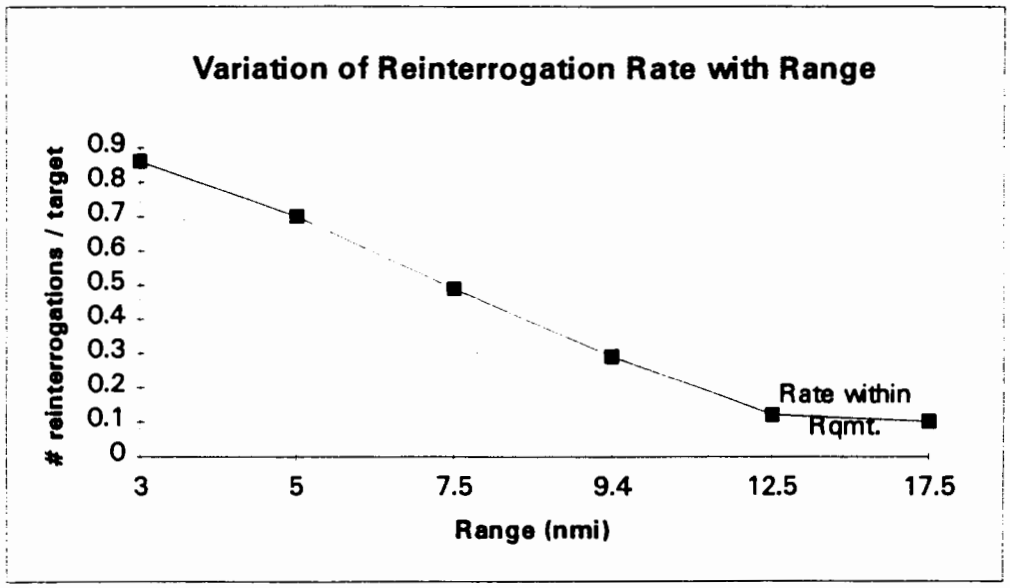

Figure 4.3.4.2-3 - Target Reinterrogation, (Preliminary Data)

4.3.5 Conflict Situations

4.3.5.1 Test Description

This test examined the performance of the Mode S sensor with regard to targets in close spatial proximity. When two targets are in close spatial proximity there is a possibility that the sensor may confuse their identities or garble the replies that it receives. The ARIES was used to simulate multiple conflict situations, including duplicate ID's. The sensor's handling of these conditions was analyzed. A real world scenario was also analyzed.

4.3.5.2 Test Results

This test examined the performance of the Mode S sensor with regard to targets in close spatial proximity. When two targets are close together there is a possibility that the sensor may confuse their identities or garble the replies that it receives.

One failure was identified in the test. In one subtest the track swap limit was exceeded. Only one track swap was observed in this subtest, but the limit was exceeded due to the small number of tracks in the test. It should be noted that the subtest that produced these failing results used a scenario with multiple intentional conflicts and duplicate ID's. The BASIC 41 scenario used a "stress" scenario.

Track swaps have been observed in other subtests, but no limits were exceeded. However, it is possible that with further analysis other failures may be noted. Re-execution of the failed subtest is planned for September.

Because the failure of this test is based on a single fault, that may not be repeatable, this failure is classified as minor deficiency. Not meeting the NAS level requirements for this scenario may not even be a problem. This failure designation is subject to change upon the completion of the analysis.

Some additional garble problems were noted in the test, but no additional failures were observed. As expected, the Mode S interrogation reduces garble. A more complete analysis of these problems will appear in the Final Test Report.

4.3.6 Data Link Baseline

4.3.6.1 Test Description

This test measured the ability of the Mode S sensor to correctly transmit and process communications messages. Two scenarios were used by the ARIES and CID to generate simulated targets and their associated communication messages. Three fruit scenarios were also used. Data collection was taken on the ARIES, CID, Mode S and RTADS.

4.3.6.2 Test Results

This test measured the ability of the Mode S sensor to correctly transmit and process communications messages. Performance parameters include message storage capacity, message delay, and errors in the messages.

The analysis of all available data indicates that the Mode S passed this test. These results are subject to change pending the completion of the test and analysis. Fifty percent of the test still has to be executed. A conclusion based on all test data will appear in the Final Test Report.

4.3.7 Mode S Sensor Coverage

4.3.7.1 Test Description

This test measured the sensor coverage volume and surveillance parameters. Part of this test used live world targets of opportunity received through two adjacent sensors operating in the site address lockout mode. RTADS data collections were taken at each sensor. Some of this test used ARIES scenarios to test the extremes of the sensor coverage.

4.3.7.2 Test Results

This test measured the sensor coverage volume and surveillance parameters. Most of the these tests used live world targets of opportunity received through two adjacent sensors operating in site address lockout mode.

The sensor's coverage at maximum and minimum elevation angles, and azimuth coverage at maximum altitude were verified using simulated scenarios. Figures 4.3.7.2-1, 4.3.7.2-2, and 4.3.7.2-3 below demonstrate the difference in the sensor's performance using ARIES scenarios (from test 4, Report Parameters) and live traffic monitored during test 7. In general the sensor's performance with real and simulated targets are comparable. Only Beacon Probability of detection for ATCRBS targets is noticeably lower using real targets. Also, the split rate is somewhat higher for real targets, as shown in Figure 4.3.7.2-3

All of the sensor coverage limits were verified. The objectives require that the sensor coverage consist of the following:

- Altitude coverage from 0 ft. to 100,000 ft.
- Slant range coverage from 0.5 nmi. to 55 nmi.
- Elevation coverage from 0.5° to 45°
- Azimuth coverage of 360°

A more complete discussion will be found in the Final Test Report.

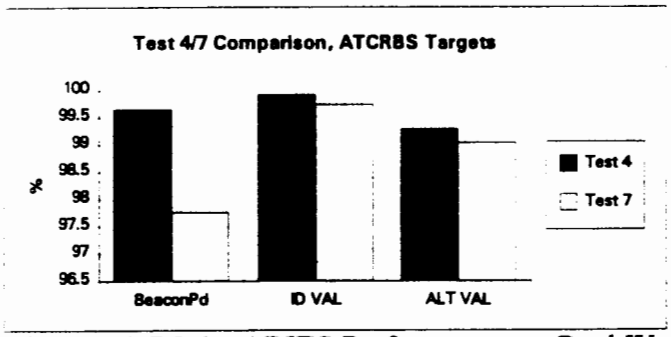

Figure 4.3.7.2-1 - ARIES Performance vs. Real World for ATCRBS Targets, (Preliminary Data)

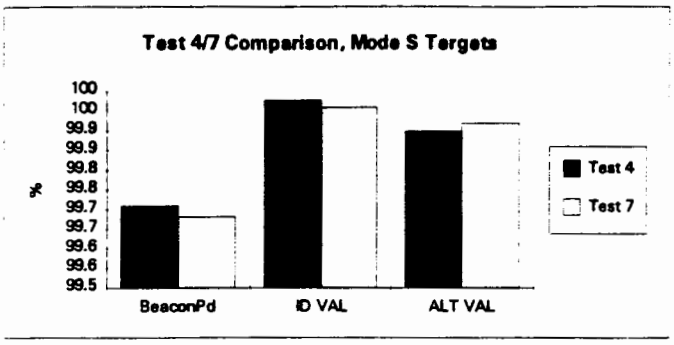

Figure 4.3.7.2-2 - ARIES Performance vs. Real World for Mode S Targets, (Preliminary Data)

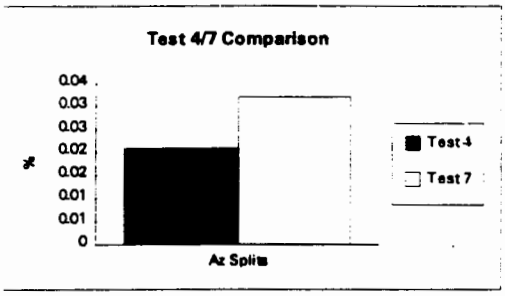

Figure 4.3.7.2-3 - Azimuth splits measured using ARIES Collection vs. Real World, (Preliminary Data)

4.3.8 Mode S Reflection Analysis

4.3.8.1 Test Description

This test measured the sensor's ability to identify reflected false target reports correctly. These tests used the simulated targets provided by ARIES, as well as live targets of opportunity, to test the reflection algorithms. Testing was also performed on the adaptive thresholding feature; it was used to reduce false targets caused by in-beam ground-bounce reflections.

4.3.8.2 Test Results

This test measured the sensor's ability to identify reflected false target reports correctly. This test used simulated ARIES targets as well as targets of opportunity to test the reflection algorithms and adaptive thresholding.

This test used an uplink reflection scenario. The scenario consists of 16 pairs of targets, each pair consists of a reflected target and a true target. The 16 reflection surfaces that could cause reflections have been calculated. The reflection map, containing the range, orientation, and azimuth of the 16 reflectors was loaded into the sensor. All combinations of reflected target quadrant and true target quadrant were tested. The data analysis revealed that the sensor correctly identified 100% of the reflected targets.

A downlink reflection scenario was also used. The scenario simulated ground bounce replies and was designed to test the sensor's adaptive thresholding circuitry. Pairs of moving targets were generated (with the same azimuth but different ranges). The range difference of each pair was varied from completely separated to fully overlapped. The true reply's intensity was 20 dB greater than that of the ground bounce reply.

Data analysis revealed that without the adaptive thresholding on, the simulated multipath data during the cases when it overlapped with the real reply data, was being detected with a Round Reliability of 26.8% . After the adaptive threshold was activated with the SAP set to 15 db, a marked improvement was seen. The average Round Reliability for the simulated multipath targets that overlapped the real ones was 6.0%. For the cases when the simulated multipath targets were separated from the real ones, the average Round Reliability without adaptive thresholding on was found to be 78.7%. After the adaptive threshold SAP was changed to 15 marked improvement was seen. Reflected targets were filtered out, but not entirely. The average Round Reliability for the reflected targets that were separated from the real ones was 17.50% using adaptive thresholding. Further investigation is needed to determine the effect of adaptive thresholding on system performance. This is considered a minor deficiency.

4.3.9 Sensor Accuracy

4.3.9.1 Test Description

This test measured the accuracy of the Mode S position detection, using internal (14 bit azimuth and 16 bit range) Mode S system target report data, for both moving and stationary targets. A test aircraft tracked by a precision tracker flew planned routes to provide moving target position data. Differences between the tracker and the Mode S detected position determine the success of the test.

4.3.9.2 Test Results

This test measured the accuracy of Mode S position detection, for both moving and stationary targets. A test aircraft was tracked by a precision tracker and the Mode S while flying planned routes (radials and orbitals). The two position reports were analyzed.

The position reporting accuracy required of the Mode S sensor is a mean range error of less than ±30 ft. and a mean azimuth error of less than ±0.033°. The standard deviations should be less than 25 ft. for range and less than 0.060° for azimuth. This analysis requires as input data, very accurate transponder delay times for the results to be considered valid. These delay times are not currently available. The data presented in Table 4.3.9.2-1 was obtained using typical transponder delay times. A more accurate analysis will be conducted using the actual delay times and aircraft cable measurements and any other real world affects which may have impacted the results. The results of this analysis will be presented in the final report.

	RANGE ERROR (FT.)		AZIMUTH ERROR (DEG.)	
TARGET TYPE	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION
MODE S	64.75	16.175	-0.07425	0.0565
ATCRBS	18.10	26.900	-0.06075	0.0385

Table 4.3.9.2-1 - Preliminary Accuracy Results
(Preliminary Data)

4.3.10 Sensor Resolution

4.3.10.1 Test Description

The capability of the Mode S sensor to detect two closely spaced aircraft was determined in addition to the accuracy of the resultant position reports. Two aircraft simultaneously performed a series of pre-planned converging flights. A precision tracker and the Mode S

sensor tracked the aircraft. The sensor's internal target report data and tracker measurements were compared to determine the sensor's target resolution limit.

4.3.10.2 Test Results

This test measured the sensor's ability to detect two closely spaced aircraft. It also tested the accuracy of the resultant position reports. The test aircraft were tracked by a precision tracker and the Mode S while flying planned routes.

The resolution flights consist of three phases. The first phase required that both aircraft tracked outbound on the 242 radial (0 azimuth separation). The second phase required that there be 1° separation between the aircraft. The third phase required that there be 2° separation between the aircraft.

The data reduction program needed to analyze the resolution data has compatibility problems with the current Mode S extraction data. Therefore no significant analysis has been performed. Work is proceeding to render the program operational, and the results of this test will be presented in the final report.

4.3.11 Sensor Stochastic Acquisition

4.3.11.1 Test Description

This test measured the sensor's ability to acquire Mode S tracks using the stochastic acquisition process. Three co-located transponders were used to establish a garble situation. For half of each subtest the sensor was reset and the targets were acquired via the initial stochastic process. The other half of the subtests required that the transponders be turned off for two minutes and then turned on again. The targets were then acquired via the adaptive stochastic process.

Three different sets of SAPs were used during the test. Each set was a variation of the S1 SAP configuration with the following exceptions:

- The first set used reply_prob=2 and sai_scans=1
- The second set used reply_prob=2 and sai_scans=3
- The third set used reply prob=4 and sai_scans=3

4.3.11.2 Test Results

This test measured the sensor's ability to acquire Mode S tracks using the stochastic acquisition process.

When the initial and adaptive Stochastic Acquisition occurred, all test targets were acquired. Figures 4.3.11.2-1 and 4.3.11.2-2 below illustrate how long it took the sensor to acquire the targets. Investigation is continuing to determine why there are such wide swings in acquisition times.

Results indicate that the sensor took less time to acquire all the targets, during initial acquisition, than it took later to acquire three targets, during adaptive acquisition. This issue requires investigation.

Also of interest, is the length of time it took for adaptive acquisition to occur. It is possible that modifying the SAPs could decrease these times.

The non-lockout interval of the first 78 scans after cold start is a problem, but it did not appear to affect target acquisition significantly. Both the initial and adaptive acquisitions occurred within the first 78 scans.

This is considered a minor deficiency. This designation is subject to change upon the completion of the analysis. A definitive conclusion will be provided in the final report.

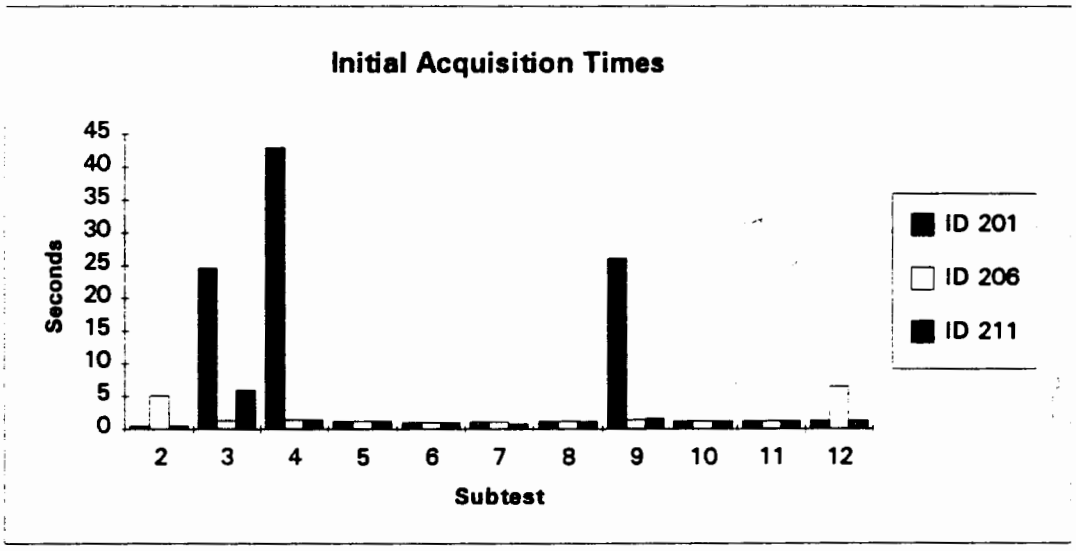

Figure 4.3.11.2-1 - Initial Acquisition of Targets, (Preliminary Data)

NOTE: Complications prevented data collection for subtest 1.

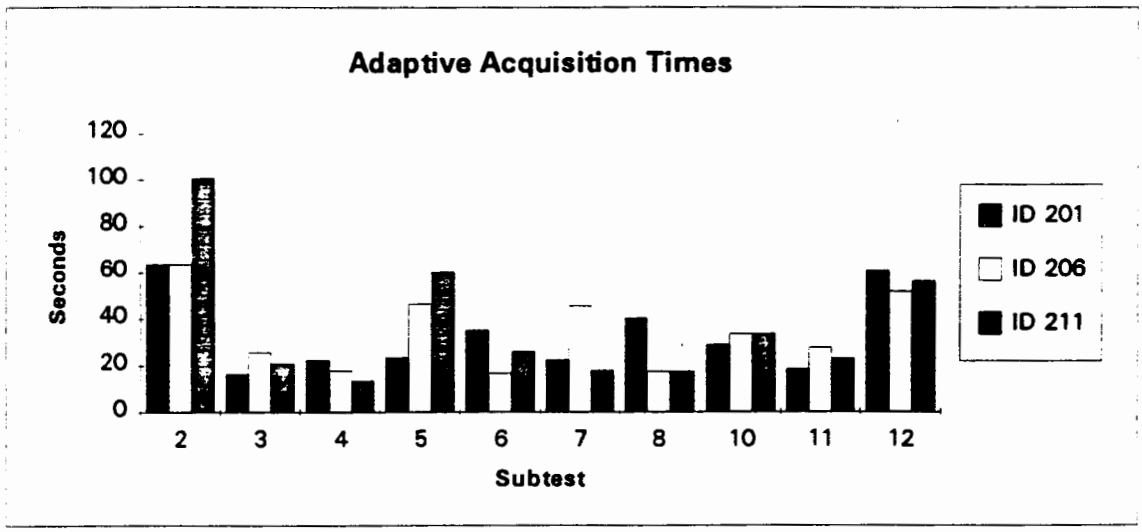

Figure 4.3.11.2-2 - Adaptive Acquisition of Targets,
(Preliminary Data)
NOTE: Complications prevented data extraction for subtests 1 and 9.

5. CONCLUSIONS

This Mode S OT&E Quick Look Report has provided a preliminary evaluation of the terminal configuration of the Mode S system and has identified issues which will impact deployment of the system into the field. Complete analysis of the test data will continue over the next two months but there are currently no indications there are any additional significant issues which will surface that will impact deployment to the field. The issues which have been identified as major or moderate level deficiencies must be resolved prior to any field commissioning of Mode S equipment operating in a fully functional terminal configuration.

The test results in the area of Mode S surveillance performance indicate that quality and accuracy of the data provided to ATC has significantly improved over currently fielded systems. This was substantiated both quantitatively and qualitatively from the test results. These results were expected due to the improved performance achievable with the monopulse reply processing subsystem and discrete interrogation function of the Mode S system. Mode S system capacity testing indicates no significant performance degradation occurs due to target load, target mix or data link communication load. The noted deficiency of the Mode S sensor not being able to operate at high Mode S and ATCRBS asyncronous reply interference rates (fruit) did limit the performance tests. The omission of the tests using high fruit levels will require retesting in the area of surveillance processing once the deficiency is corrected. Since the suspected function affected by high fruit is Performance Monitoring, surveillance performance is expected to perform within requirements even at the high fruit levels.

Integration of the Mode S with existing terminal NAS equipment at the signal and protocol level was accomplished without any significant problems noted. Preliminary dry run testing over the previous year had already identified issues concerning the Mode S to ASR-9 interface which were corrected prior to the start of the formal OT&E effort. These changes were necessary to conduct the formal tests and the respective ASR-9 changes (EEM Chapter 18) will need to be distributed to the field sites in parallel with the Mode S deployment in order to assure proper operation at Mode S/ASR-9 sites.

Two major deficiencies were identified during the operational testing. The first dealt with data delays to the ARTS IIIA. This issue will seriously impact ATC operations because of the increased number of track coasts which will occur and which will increase as target loading increases. The ARTS IIIA system currently operates under certain premises with existing field configurations with respect to the timing relation of the antenna location to receipt of target data. These premises are impacted by the additional data delay added by Mode S data processing. The target tracking function of Mode S is the major source of the delay but this function is one of the Mode S features which improve the data quality. Since the ASR-9 system already has a function which will adjust the timing relation of antenna pointing angle to target data input, the ASR-9 is the most appropriate place to resolve the issue. This change must be analyzed carefully at a NAS system level to assure there is no adverse impact on other ATC functions. The second major deficiency noted during operational testing, no beacon video to the ARTS IIA with a Mode S/ ASR-7/8 configuration, is not a Mode S system deficiency but rather a NAS system level deficiency. The Mode S system is operating as designed since no beacon video is expected for Mode S equipped aircraft and only five to six replies are

expected with ATCRBS equipped aircraft. The two most obvious methods to resolve the issue are to either add a video reconstituter to those sites having the configuration or to change ATC operating procedures to allow operation with no beacon video. Resolution of this issue will impact deployment to sites with this configuration.

The deficiencies noted during the degraded operation tests were categorized into deficiencies in either system control/status functions or initialization/recovery functions. Those in the control/status area are considered to be the most crucial to a successful field deployment. The AF and AT personnel in the field must be able to unambiguously know the state of the equipment and maintain positive control at all times. The addition of status reporting , even while in the IBI mode, raised several discussions during the operational evaluation. The information currently available to AT concerning beacon equipment status is merely indication of which channel is selected. There are certain degraded states of Mode S where automatic functions are not active and a channel which appears to be functioning properly has a red status. These degraded states of Mode S may warrant revision of operational procedures with respect to the interaction of AF and AT during such states. There is lower level status information available to AF personnel which may impact AT's decision process of which channel to select or do aircraft control procedures need to be changed while in the degraded state. The deficiencies noted in the initialization/recovery area are considered at this time to be minor in nature because of the high hardware reliability noted over the last 18 months with the two Mode S systems at the Technical Center. The system currently exhibits symptoms of an initialization/recovery design which breaks down with multiple faults and timing variations of the occurrence of those faults. The testing which revealed these problems forced both primary and redundant hardware faults in a short time interval across both channels, a real world condition which is expected to have an extremely low probability of occurrence. Those cases where a single fault was induced, the system reacted as designed, either performing an in-channel recovery or a cross-channel recovery. The current proposal to resolve the initialization/recovery deficiencies is to undergo a complete redesign of the function. This would be done in the next major software release by the program. Given the performance of the system hardware's reliability and stability noted with systems currently being utilized, the initial deployment to the field should not be impacted by these type problems.

6. RECOMMENDATIONS

The testing conducted on the Mode S terminal configuration, comprised of baselined hardware and software version TR21.2, identified a set of major and moderate level deficiencies which must be resolved prior to deployment of this configuration to the field for operational usage. Resolution of these issues includes;

1) Conduct of formal OT&E regression tests to verify correction of the noted deficiencies and to verify that other functions have not been affected by the changes.

2) Upgrading of the Mode S baseline along with that of the ASR-9, ARTS IIIA and ARTS IIA to their respective current fielded baselines.

3) The scope of the regression tests must include controller evaluation of the ARTS IIIA operation and Mode S status/control functions since these are subjective issues which the end user must asscess.

4) Quantitative data must be collected to verify proper surveillance performance.

A deployment recommendation can be made upon successful conclusion of the OT&E regression test.

GLOSSARY

Beacon Probability of Detection - Beacon probability of detection is the percent of times a beacon message correlates with the correct track.

Identity Rel - Identity reliability is the percent of times the Mode 3/A code from the correlated beacon message is the same as the Mode 3/A code from the track.

Identity Val - Identity validity is the percent of times the Mode 3/A validity from the correlated beacon message is set.

Altitude Rel - Altitude reliability is the percent of times the Mode C code from the correlated beacon message is within 800 feet of the Mode C code from the track.

Altitude Val - Altitude validity is the percent of times the Mode C validity from the correlated beacon message is set.

Range Error - Average value of the absolute value of the range difference between the correlated beacon message and the track prediction in nautical miles (nmi).

Azimuth Error - Average value of the absolute value of the azimuth difference between the correlated beacon message and the track prediction in degrees.

Azimuth splits - Azimuth splits occur when beacon replies of a target are interrupted and two targets are declared.

Ringaround - Side lobe replies and ringaround are considered to be equivalent terms, and are used to describe the appearance of false targets that are caused by side lobe replies.