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Air Traffic Control Radar Beacon System Transponder Performance Study and Analysis

Vol. I: Transponder Test Methodology Results, Analysis, and Recommendations

FAA's Air Traffic Control
Radar Beacon System (ATCRBS)
Analysis Team

September 1986

Final Report

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16. Abstract

This report contains the description and results of the Air Traffic Control Radar Beacon System (ATCRBS) Transponder Study and Analysis. This study represents a two year effort consisting of testing, data collection, and analysis of air carrier, military, and general aviation transponder performance.

The ATCRBS Analysis Team developed a comprehensive test plan which included a validation flight test program, an evaluation of transponder maintenance and calibration programs, and a detailed analysis of general aviation transponder performance.

The study was concentrated in the Atlanta, Georgia area. However, data was collected from many parts of the country. The Mobile Transponder Performance Analyzer (MTPA), developed by the FAA Technical Center, was dispatched to field locations in order to support the data collection and analysis tasks. This effort resulted in identifying a trend of problems associated with the general aviation transponder.

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EXECUTIVE SUMMARY

This study documents the in-depth research, testing, data reduction, and analysis conducted by the Federal Aviation Administration's Air Traffic Control Radar Beacon System (ATCRBS) Analysis Team. The team was formed at the Administrator's request subsequent to the FAA Regional Directors' Meeting on September 21, 1984, at which time the Southern Region presented discussions regarding general aviation and military transponder deficiencies as they relate to poor beacon tracking performance in the Atlanta area.

The ATCRBS Analysis Team developed a comprehensive test plan which covered many areas. An extensive validation flight test program utilizing military and civil aircraft was conducted in the terminal as well as en route air traffic environments. General aviation, air carrier, air taxi, and military transponder maintenance and calibration practices were evaluated. A detailed analysis of general aviation transponder performance was also conducted.

An analysis of the data collected during the study revealed some significant findings which are summarized below:

1. Civil aircraft (air carrier and general aviation) as well as military aircraft, which were inspected and found to meet applicable transponder system and installation specifications, were accurately tracked using the ATCRBS in the Atlanta terminal area.

2. General aviation transponder equipped aircraft in the Atlanta area have been identified as a significant beacon tracking problem. This problem was also identified, by air traffic controllers, in many parts of the country.

3. A trend of problems associated with the general aviation transponder and equipment installation has been identified. This finding is also supported by previous studies and investigations of transponder performance.

The study concluded that general aviation transponder systems are degrading the overall performance of the ATCRBS. This performance degradation could affect future programs such as Mode S transponder, Traffic Alert and Collision Avoidance System (TCAS), and reduced vertical separation above 29,000 feet.

The study contains recommendations with suggested methods of corrective action relative to the findings of the report.

CHAPTER 1

INTRODUCTION

1. PURPOSE. This document constitutes the final report summarizing the overall performance of the Air Traffic Control Radar Beacon System (ATCRBS) within the National Airspace System (NAS). The observations and recommendations of the Federal Aviation Administration (FAA) ATCRBS Analysis Team are the results of in-depth research, analysis, testing, and data reduction processes to determine the current state of ground and airborne systems functioning within the operational environment. These observations and recommendations are further influenced by review of current policies and provisions of the Federal Aviation Regulations (FAR's) as these now govern the standards for maintenance of airborne transponder systems.

2. BACKGROUND. During the FAA Regional Directors' meeting held in Washington, D.C., on September 21, 1984, the Southern Region presented discussions which suggested airborne transponders of both the general aviation and military community were not performing to standards, and may be an important factor limiting the overall performance of the National Airspace System. The deficiencies specifically identified were: (1) excessive coasting; (2) alphanumeric tag drops; and (3) beacon target quality, ranging from no display to weak and intermittent display. The Administrator directed the Associate Administrator for Aviation Standards to conduct an investigation of the alleged conditions and, on October 2, 1984, the FAA ATCRBS Analysis Team was formed to develop a test and analysis plan. In that the proposed test plan required participation by the U.S. Air Force, a briefing was presented to the Directorate of Operations, Headquarters, U.S. Air Force, HQ USAF/XOO, to detail the circumstances and obtain approval for Air Force participation and support for the investigation to be conducted. On November 10, 1984, the test and analysis plan was published and distributed for implementation. Throughout the test program, periodic status reports were provided to the Administrator, HQ USAF/XOO, and the Regional Directors.

3. SCOPE.

a. The test plan was initially designed to analyze the ATCRBS within the terminal and en route environments in FAA Southern Region. As the test progressed, this scope was expanded to include investigation of the Honolulu Air Route Traffic Control Center system and the Honolulu Terminal Control system to address a specific problem identified in the Honolulu Terminal Radar Control Facility (TRACON). The analysis encompassed investigation of ground beacon systems, the performance of airborne transponders installed in Air Force and general aviation aircraft within the known ground beacon system environment, and evaluation of maintenance and calibration practices by Air Force, air carrier, air taxi, and general aviation avionics maintenance and repair stations. The FAA Technical Center provided assistance by placing a transponder test van at selected general aviation airports in the Atlanta area to test and develop a data base on general aviation transponder performance. Also, a visit was made to a transponder manufacturer to study the effectiveness and reliability of quality control systems used on transponders leaving the assembly line.

b. Prior to developing the test plan, the Analysis Team visited the FAA Southern Region to interview the Director and his staff. Working sessions were conducted with personnel from the Air Traffic and Airway Facilities Division to discuss the Southern Region's perception of the stated problem, and to collect information necessary to conduct the test program. The Atlanta TRACON (ASR-7) and the Dobbins Air Force Base (ASR-8) Airport Surveillance Radar sites were visited. Additionally, a visit was made to the Tampa TRACON to view and discuss the Automated Radar Terminal System (ARTS-IIIA) configuration. Visits were also made to the Jacksonville and Atlanta Air Route Traffic Control Centers (ARTCC's). The methodology for conducting this flight test plan constituted the collective inputs from the various sources within the Southern Region and was accepted by the Southern Region as completely adequate.

c. As a special measure, the Atlanta TRACON controllers identified and reported suspected malfunctioning general aviation transponders observed to be operating in the approach control airspace. The FAA Southern Region Flight Standards Division conducted a search for the owners of these suspect aircraft through the Aircraft Registry. Letters were sent to each owner explaining the circumstances and asking for their assistance in bringing the aircraft to an FAA certificated repair facility where the transponder system would be inspected, without charge or regulatory action. This effort was intended to expand the data base and verify conditions reported by controllers as unacceptable with regard to general aviation transponder performance.

d. Subsequent to conducting the flight test program, visits were made to Terminal Radar Control facilities in Atlanta, Orlando, Tampa, Los Angeles, and Burbank, as well as to the El Toro Marine Corps Air Station (Coast TRACON). The purpose of these visits was to observe air traffic which exhibited coasting, tag drop, or intermittent target reception. Tracking data and beacon target reports were recorded during the time periods that air traffic was being observed.

e. Existing FAA Technical Standard Orders, Federal Aviation Regulations, military technical orders, and manufacturers specifications were the basis for determining parameters of all ground and airborne tests, the analysis of all data, and the conclusions reported herein.

f. Special thanks to the United States Air Force for their participation and significant contribution to this effort. This study could not have been undertaken without their excellent cooperation and support.

4. ATCRBS ANALYSIS TEAM MEMBERS.

Raymond E. Ramakis	Team Chief Manager, Aircraft Maintenance Division, AFS-300
John W. Flavin	Deputy Manager, Aircraft Maintenance Division, AFS-300
Lorence H. Bessette	Manager, Avionics Branch, AFS-350
Robert A. Watson	Aviation Safety Inspector Avionics Branch, AFS-350
Lester R. Heavner, Lt. Col., USAF	Military Programs Manager Flight Inspection Operations Branch Aviation Standards National Field Office, AVN-230
James P. Moe	Electronic Engineer, Mode S Program Branch, APM-320
John S. Stasiak	Computer Systems Analyst, FAA Technical Center, APM-162
Robert J. Marlott	Manager, Atlanta Flight Inspection Field Office
Milton Hill	Regional Avionics Specialist, Flight Standards Division, FAA Southern Region, ASO-254
Louis W. Brown (Footnote 1)	Electronics Engineer, Airway Facilities Division, ASO-465 FAA Southern Region

Footnote 1: Designated by the Director, FAA Southern Region, with the concurrence of the Managers, Air Traffic and Airway Facilities Divisions, as Southern Region coordinator for the Analysis Team.

5. AD HOC TEAM MEMBERS.

Russell H. Hutson	DOD AIMS Program Manager
Henry R. Campbell	DOD AIMS Program Technician
Glenn E. Clark	Electronics Technician, Atlanta Flight Inspection Field Office
Howard Burch	FAA Southern Region, Air Traffic Division, ASO-510
Leo Wapelhorst/ Max Greenberg	FAA Technical Center Engineers, Mobile Transponders Performance Analyzer
Billy E. Shipp	Supervisor, Avionics Maintenance Unit, Atlanta Flight Inspection Field Office
Wesley B. Rowland	Headquarters, Air Traffic Plans and Requirements Service, ATR-120

6. PARTICIPATING FACILITIES AND ACTIVITIES.

a. FAA Southern Region:

FAA Atlanta TRACON

FAA Columbus TRACON

FAA Macon RAPCON

FAA Orlando TRACON

FAA Tampa TRACON

FAA Atlanta ARTCC

FAA Jacksonville ARTCC

b. FAA Western-Pacific Region:

FAA Honolulu TRACON

FAA Los Angeles TRACON

FAA Burbank TRACON

FAA Coast TRACON

FAA Honolulu ARTCC

c. FAA Aviation Standards National Field Office:

Atlanta Flight Inspection Field Office

Honolulu Flight Inspection Field Office

d. U.S. Air Force:

9th Airborne Command and Control Squadron (EC-135J)

15th Airbase Wing Avionics Maintenance Support Squadron

19th Air Refueling Wing (KC-135)

94th Tactical Airlift Wing (C-130H)

116th Tactical Fighter Wing (F-4D)

USAF Depot, Avionics Maintenance Center

e. Air Carrier:

Delta Airlines, Maintenance Facility

Eastern Airlines, Maintenance Facility

f. Air Taxi:

Atlantic Southeastern Airlines

Eastern Metro Airlines

g. Repair Stations:

Airtronics South

Collins Avionics

EPPS Air Service

Hangar One

Hill Aircraft

FAA/Atlanta Flight Inspection Field Office Maintenance Facility

h. Manufacturer:

King Radio

i. FAA Technical Center:

Evaluation of Current General Aviation Transponders

CHAPTER 2

TEST PLAN OBJECTIVES AND METHODOLOGY

1. GENERAL. The test plan was designed to encompass an evaluation of ground beacon systems, performance of airborne transponders within the known ground beacon system environment, maintenance and calibration practices, and comparison of transponder and ground systems in areas of overlapping coverage between independent ground facilities.

2. FLIGHT TEST VALIDATION. Appendices 1 thru 5 of this report contain the flight test validation plan and flight profiles flown at various phases throughout the test program. In each case, an FAA flight inspection aircraft flew the test profile to establish the baseline for transponder operations in the given environment.

a. The Atlanta Terminal Profile (Appendix 2), encompassed overlapping beacon coverage areas from the Hartsfield, Dobbins Air Force Base, Columbus, and Macon terminal area ground beacon systems. The BE-C90 King Air, BE-E55 Baron, F-4D, and C-130H test aircraft were flown though this profile at 5,000 feet MSL.

b. The High Altitude En Route Profile (Appendix 3) was designed to encompass the performance of overlapping long range radar sites utilized by Jacksonville and Atlanta ARTCC's. The route, extending from the Charleston, South Carolina VORTAC, to a point northwest of the Marietta long range radar (LRR) site, was flown by an Air Force KC-135 aircraft and the FAA flight inspection NA-265 Sabreliner at Flight Levels 330 and 350.

c. The En Route And Terminal Profiles flown in the Honolulu systems are portrayed in Appendicies 4 and 5. The enroute tests were accomplished utilizing an FAA B-727 flight inspection aircraft and an Air Force EC-135J aircraft based at Hickam Air Force Base. The terminal tests were conducted utilizing the FAA B-727 and a BE-F90 King Air aircraft.

3. TRANSPONDER TEST. The transponder and antenna system of each aircraft flown in the test program, including the FAA flight inspection aircraft, was inspected to ensure compliance with FAR Part 43, Appendix F, Military Technical Orders, and applicable FAA Technical Standard Orders.

4. DATA ACQUISITION. All radar beacon data pertinent to the test flights were recorded by at least two of three means: (1) Computer extractions were accomplished at all control facilities except Columbus where the radar processor had no provisions for data collection, and the Honolulu TRACON where facility personnel deemed that data extractions would degrade the computer processor and possibly hamper safe air traffic operations; (2) Video recordings of controller displays; and (3) Manual target grading of beacon reports from controller displays.

a. Data extraction recordings were made, where possible, of beacon target reports on a storage medium for subsequent data reduction. A conversion program was used to reformat the recorded data from the various ARTS facilities in order to use selected radar analysis programs incorporated in the IBM 9020 computer system. A review of long range radar (LRR) data available at both the Atlanta and Jacksonville Air Route Traffic Control Centers (ARTCC) was conducted. Due to the large number of LRR that were capable of interrogating the high altitude test flight aircraft, the radar sort box program was used to identify the two primary reporting stations. Both the Marietta and Lincolnton LRR facilities provided data extractions of the high altitude test flight profiles.

b. Video recorders were placed in all participating air traffic control facilities to record the controller's display while the test flight aircraft were within the airspace of that facility. Additional video recordings were made at the Jacksonville and Atlanta ARTCC's of their Direct Access Radar Channel (DARC) displays to individually record the radar representation of the beacon reports.

5. DATA REDUCTION. Upon completion of the test flights, the facilities that were capable of making data extraction recordings of the beacon reports sent the extracted data to the National Automation Engineering Field Support Sector (APM-160) for analysis. All data was in, or converted to the format of a Common Digitizer (CD) recording. All targeted radar facilities' data were subjected to analysis by at least two programs; Common Digitizer Reduction Program (COMDIG) and a comprehensive multifunction plotter program, MULTIPLOT.

a. Program MULTIPLOT generates a plot, via a Calcomp plotter, of each test flight from each target radar facility while that flight is within the area of coverage of that radar facility. Also a composite plot of each test flight with all radar sites of interest was created. Plots contain symbology representing the beacon reply and periodic reports of altitude and time. These plots are contained in Chapters 3 and 4.

b. Program COMDIG provides printouts of each test flight, identified by beacon code, on a scan-by-scan basis. The program contains a tracker which aids in the detection of the beacon report if a garbled or incorrect beacon reply should be reported by the radar facility. The report contains time stamps of each scan the beacon report was detected, range and azimuth of beacon report referenced to radar facility, Mode C and Mode 2 reports if available, and delta time between detected correct Mode 3 reports. COMDIG summaries of flight test aircraft are contained in Appendix 6.

CHAPTER 3

TERMINAL SECONDARY RADAR (BEACON) SYSTEMS

1. ATLANTA TERMINAL AREA.

a. System Configuration. A variety of radar to processor combinations exists within the airspace flown in the low altitude portion of the test. Four ASR radars and 3 control facilities participated in the test. The separate configurations are as follows:

(1) Atlanta TRACON - utilizes two radars; the ASR-7/ATCBI-4 located at Atlanta airport is the primary sensor and the ASR-8/TPX42 at Dobbins, the backup sensor. Both are fed into an ARTS IIIA display processor which has data extraction capabilities.

(2) Macon TRACON - consists of an ASR-7/ATCBI-4 radar system located at Robins AFB which feeds an ARTS II display processor. This system has data extraction capabilities.

(3) Columbus TRACON - consists of an ASR8/ATCBI-5 radar system located at the Columbus Metropolitan airport which feeds a TPX-42 display processor. This system had no data extraction capabilities.

TERMINAL RADAR EQUIPMENT

NAME	ATLANTA	COLUMBUS	MACON	DOBBINS
INDENT	ATL	CSG	MCN	MGE
LAT/ LONG	33 37 44 N 84 25 48 W	32 31 15 N 84 56 39 W	32 38 45 N 83 36 18 W	33 55 14 N 84 31 15 W
ELEV(MSL)	1030'	441'	312'	1032'
ANT HGT (AGL)	17'	67'	37'	77'
PRIMARY TYPE	ASR-7	ASR-8	ASR-5	ASR-8M
PRIMARY ANT	ASR-7	ASR-8	ASR-7	ASR-8
BEACON TYPE	ATCBI-4	ATCBI-5	ATCBI-4	TPX-42A
BEACON ANT	OPA*	OPA*	OPA*	OPA*
DISPLAY PROCESSOR	ARTS-III	TPX-42	ARTS-II	ARTS-III

OPA = FA 9764
* Open Planar Array

b. Data Acquisition. Computer data extractions were performed at the Atlanta ARTS IIIA facility and the Macon ARTS II facility. These extraction tapes were then converted to CD recording format. These recordings were then reduced by the IBM 9020 analysis programs. TV recording and manual scoring of the aircraft returns from controller displays of all four radar from the three control facilities were also made.

c. Results.

(1) The following is a breakdown of each radar facility by flight and each facilities detection rate of the aircraft. All aircraft transponders were operating in normal sensitivity unless otherwise noted:

FAA Sabreliner

Atlanta ASR-7	99.1%
Dobbins ASR-8	87.7%
Robins ASR-5	96.6%
Columbus ASR-8	97.3%
Average	94.1%

FAA Sabreliner (low sensitivity)

Atlanta ASR-7	96.3%
Dobbins ASR-8	93.6%
Robins ASR-5	91.8%
Columbus ASR-8	95.9%
Average	94.7%

USAF F4D

Atlanta ASR-7	98.4%
Dobbins ASR-8	97.0%
Robins ASR-5	97.8%
Columbus ASR-8	99.4%
Average	97.9%

FAA C90

Atlanta ASR-7	97.9%
Dobbins ASR-8	95.1%
Robins ASR-5	94.0%
Columbus ASR-8	99.0%
Average	96.5%

USAF C-130H

Atlanta ASR-7	98.8%
Dobbins ASR-8	87.9%
Robins ASR-5	97.5%
Columbus ASR-8	99.5%
Average	94.3%

BE-E55

Atlanta ASR-7	96.7%
Dobbins ASR-8	95.8%
Robins ASR-5	89.3%
Columbus ASR-8	94.5%
Average	92.4%

(2) The following is a breakdown of each test flight by facility and each facilities' detection rate of the aircraft. All aircraft transponders were operating in normal power and normal sensitivity unless otherwise noted:

Atlanta ASR-7/ATCBI-4

FAA Sabreliner		99.1%
FAA Sabreliner	(low sensitivity)	96.3%
USAF F4D		98.4%
FAA C90		97.9%
USAF C-130H		98.8%
BE - E55		96.7%
	Average	98.2%

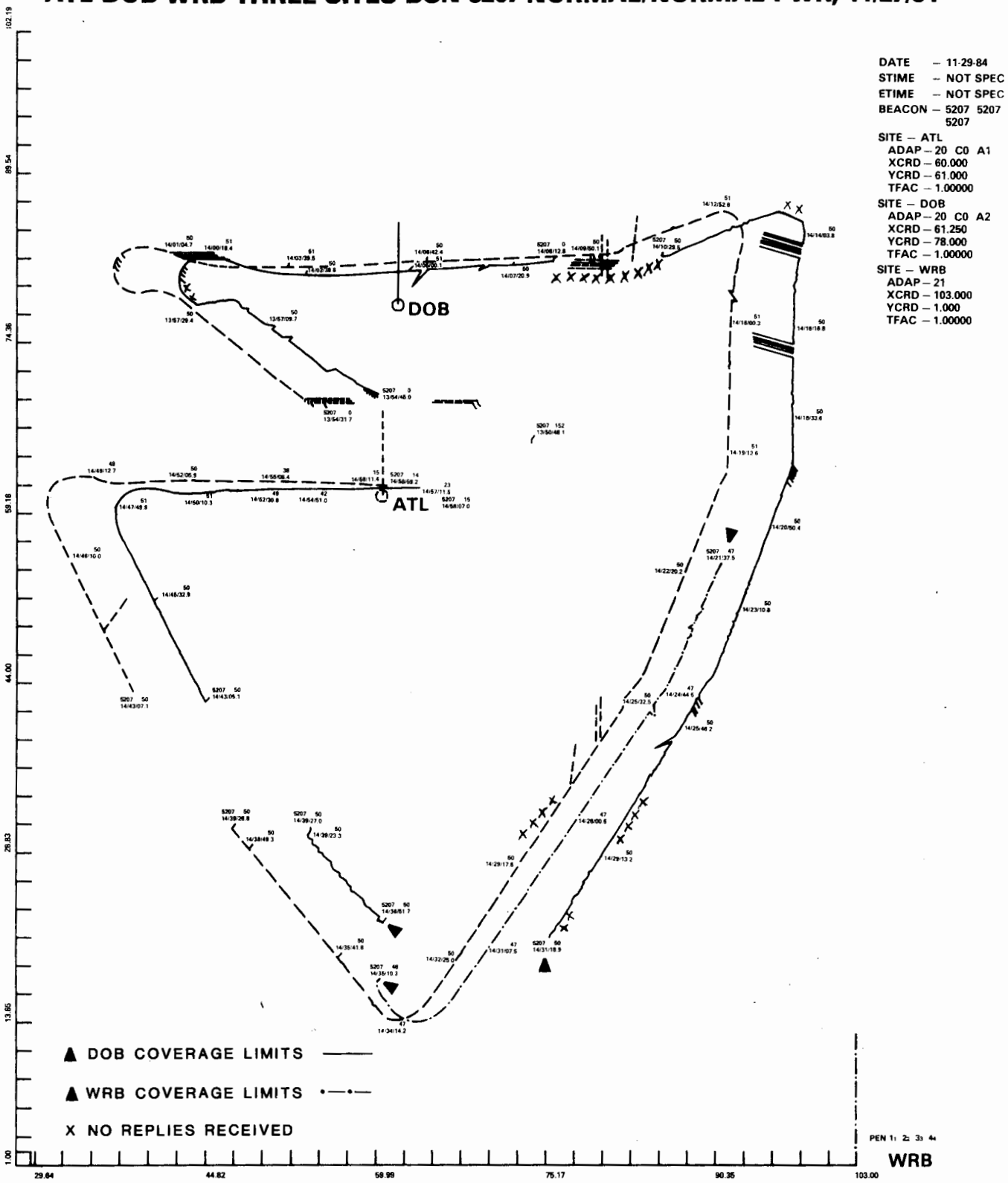
Dobbins ASR-8/TPX-42A

FAA Sabreliner		87.7%
FAA Sabreliner	(low sensitivity)	93.6%
USAF F4D		97.0%
FAA C90		95.1%
USAF C-130H		87.9%
BE - E55		95.8%
	Average	91.6%

Robins ASR-5/ATCBI-4

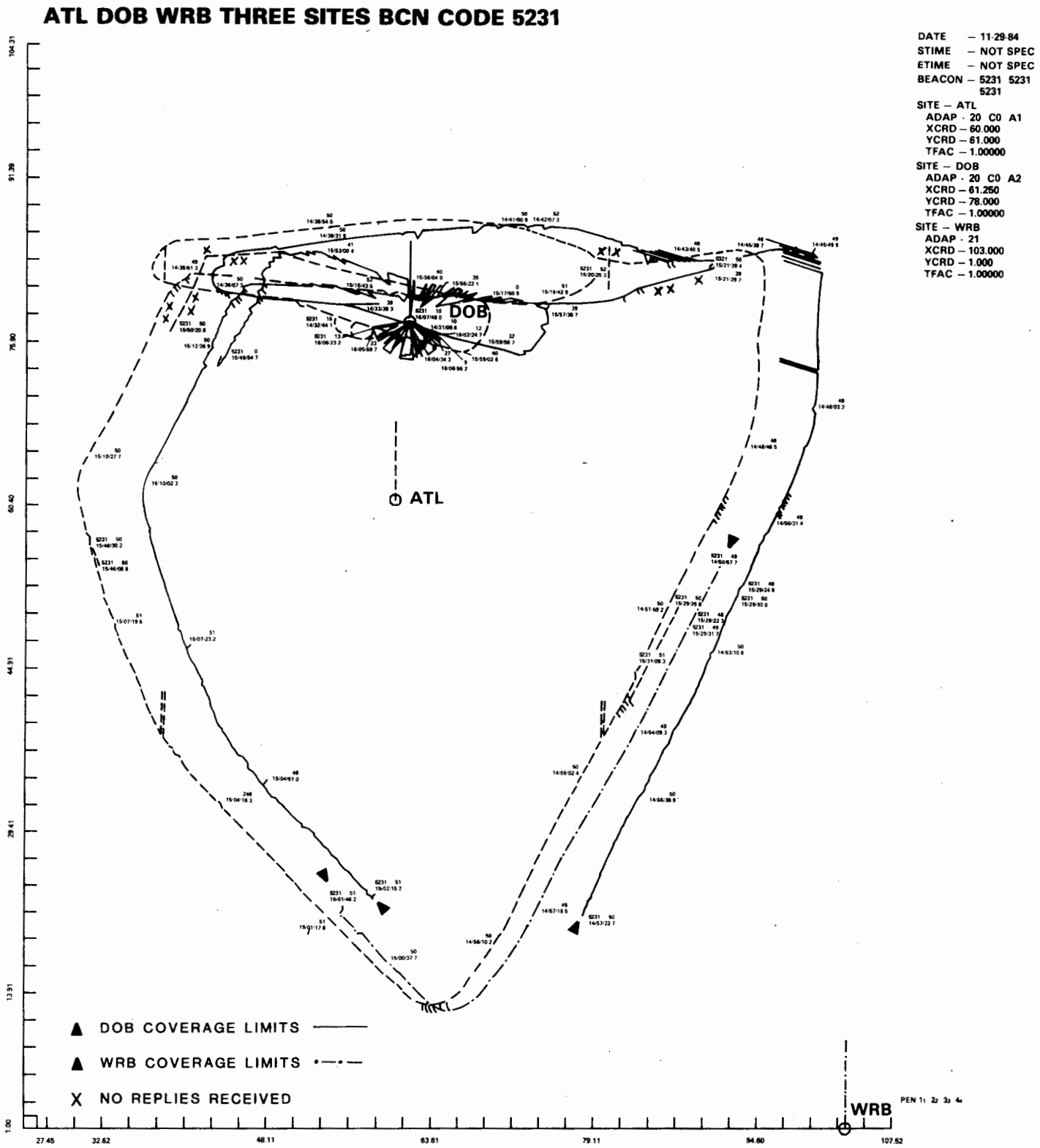
FAA Sabreliner		96.6%
FAA Sabreliner	(low sensitivity)	91.8%
USAF F4D		97.8%
FAA C90		94.0%
USAF C-130H		97.5%
BE - E55		89.3%
	Average	92.9%

ATL DOB WRB THREE SITES BCN 5207 NORMAL/NORMAL PWR, 11/27/84



PLOT NO. 1

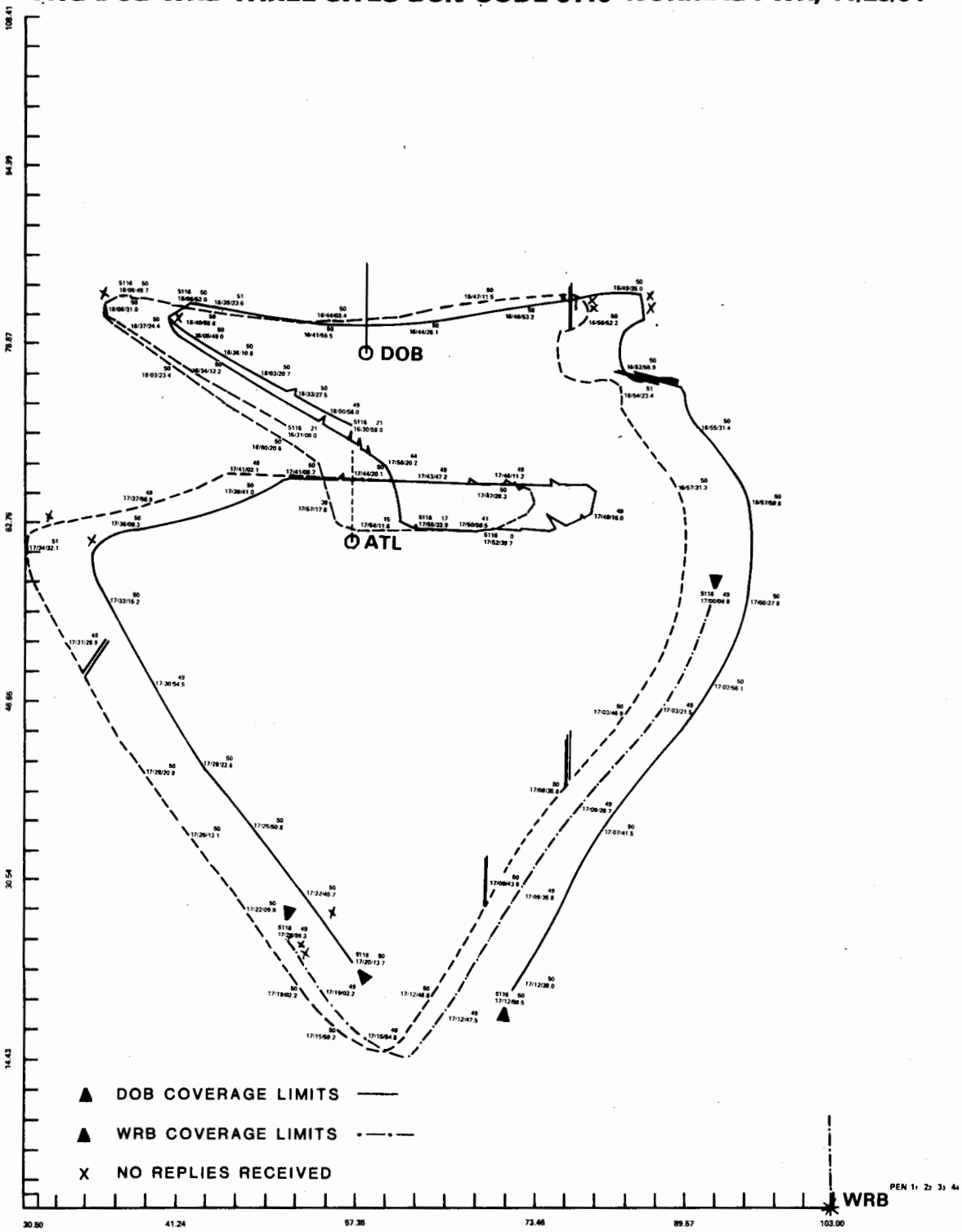
ATLANTA, DOBBINS AND WARNER ROBINS RADAR PLOT OF SABRELINER



PLOT NO. 2

ATLANTA, DOBBINS AND WARNER ROBINS RADAR PLOT OF F-4D

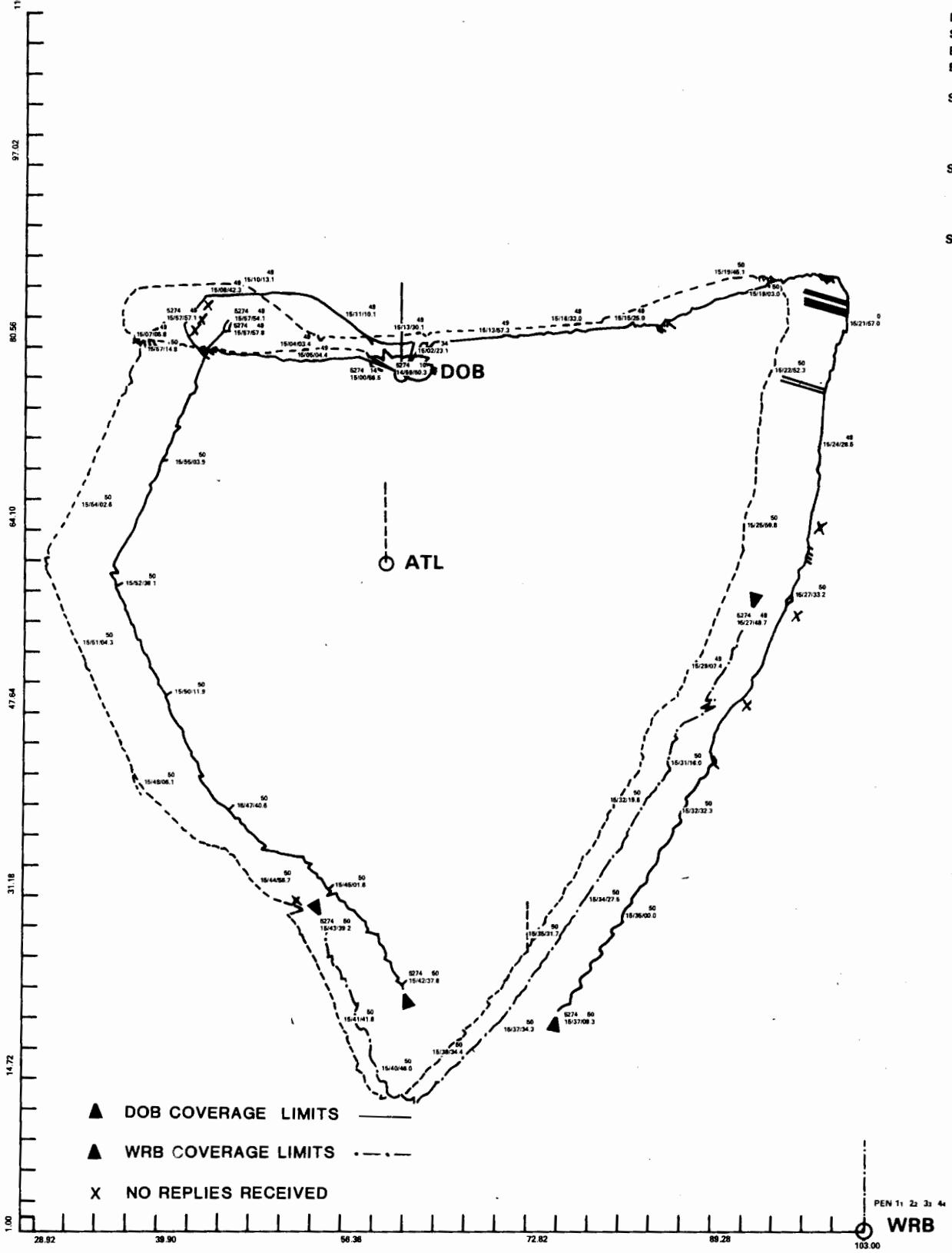
ATL DOB WRB THREE SITES BCN CODE 5116 NORMAL PWR, 11/28/84



PLOT NO. 3

ATLANTA, DOBBINS AND WARNER ROBINS RADAR PLOT OF C-90

ATL DOB WRB THREE SITES BCN 5274 NORMAL PWR, 11/30/84



PLOT NO. 4

ATLANTA, DOBBINS AND WARNER ROBINS RADAR PLOT OF C-130

Columbus ASR-8/ATCBI-5

FAA Sabreliner		97.3%
FAA Sabreliner	(low sensitivity)	95.9%
USAF F4D		99.4%
FAA C90		99.0%
USAF C-130H		99.5%
BE - E55		94.5%
	Average	97.4%

The analysis of the data showed that all test aircraft performed well in all radar environments with the exception of the BE-E55. This aircraft's transponder exhibited slightly degraded performance (sensitivity measured -59 dbm; TSO requires -69 to -77 dbm) during a check of the unit. The transponder was not adjusted to TSO specifications in order to evaluate its performance.

There were no appreciable deficiencies noted with the participating radar facilities, with the exception of the Dobbins ASR-8/TPX-42A. The Dobbins antenna rotation rate of 3.7 seconds, which is exremely fast, is the probable cause of its low detection. On March 26, 1985, the Dobbins antenna rotation rate was reduced to 4.6 seconds as a result of the previous flight tests. This change significantly increased the detection rate of military and civil aircraft.

Visual observations of the flight test runs were recorded in addition to the display processor extractions and TV recordings. The FAA Sabreliner flights on November 27, 1984, using normal and low sensitivity transponder settings showed no abnormalities in the system. Coasting did occur during garbled replies and maneuvering conditions; however, this is to be expected. Two runs were made on November 28, 1984, using an Air Force F-4D, one at normal sensitivity, and the second at low sensitivity. The first run at normal sensitivity showed no evidence of unexplained coasting. The second run at low sensitivity produced the expected result, i.e., considerable coasting and was monitored for most of the run by primary radar only. (This is acceptable in that the low sensitivity setting of -54 dBm is used to reduce ring-around and is not intended for normal operation.) An FAA King Air aircraft made two runs on November 28th, the first at normal and the second at low sensitivity. No coasting was evident at normal sensitivity. Coasting occurred during turns at the checkpoints, however, no tracks were lost. A final run on November 28th, with the King Air transponder set to low power and low sensitivity, resulted in coasting during the checkpoint turns and track was lost at the Dallas and Logan intersections.

It should be noted that transponders in use today no longer have a low sensitivity setting. This is due to the use of sidelobe suppression circuitry incorporated into the transponder. This circuitry is designed to prevent the transponder from replying to an interrogation being radiated from a sidelobe of the Air Traffic Control Beacon Interrogator (ATCBI) antenna and thus reducing tracking errors. The ATCBI radiates a P1-P3 pulse group from the directional antenna. The ATCBI also radiates a control (P2) pulse (2 microseconds after the P1 pulse) from an omni-directional antenna. The peak power of the P2 pulse is approximately 24 db down from the P1-P3 peak power. Whenever the transponder receives an interrogation from the main beam of the ATCBI directional antenna (the P1 pulse amplitude will be greater than the P2 pulse), the transponder must transmit a reply. Whenever the transponder receives an interrogation when the main beam is away from the aircraft (sidelobe interrogation), the P2 pulse amplitude will appear equal to or greater than the P1 pulse. Under these conditions, the transponder must suppress replies.

2. HONOLULU TERMINAL AREA.

a. System Configuration. The Honolulu TRACON is served by an ASR-8/ATCBI-5 located at the airport. The antenna is a five-foot open array. No back-up radar system is available.

b. Data Acquisition. Data Acquisition was accomplished at the Honolulu TRACON by making video recordings of controller's display of the test aircraft and manual scoring of the test aircraft by controllers.

c. Results. Results of the test did not disclose any notable deficiencies in the system. All six test flights performed well with few unexplained misses. All observed coasting occurred when the test aircraft were in turning maneuvers, in a garble situation, when on approach, or came within 1 to 2 miles of the radar antenna. These results are based on visual observations of the test team members present.

CHAPTER 4

EN ROUTE SECONDARY RADAR (BEACON) SYSTEM

1. ATLANTA/JACKSONVILLE ARTCC's.

a. System Configuration. The flight test of the high altitude en route system involved the Jacksonville and Atlanta ARTCC's. Each ARTCC utilizes common or overlapping radar sites in their target presentations. Each ARTCC sector is subdivided into sections with the Radar Sort Box Program controlling prioritized radar sites for each section.

(1) The seven long range sites listed below provide multiple overlapping coverage throughout the flight profile for the Atlanta ARTCC.

ATLANTA ARTCC DATA.

NAME	ATLANTA	MAIDEN	LINCOLNTON	HALEYVILLE	MONTGOMERY	GROSSVILLE	VALDOSTA
IDENT	ATL	CLT	QNK	QPC	MGM	QRV	VAD
LAT/ LONG	33 53 39 N 84 29 55 W	35 36 38N 81 14 18W	33 45 34.7N 82 28 01.7W	34 24 56 N 87 32 23 W	32 12 58 N 86 10 00 W	35 52 05 N 84 53 39 W	30 58 32 N 83 12 48 W
ELEV (MSL)	1043'	899'	517'	1175'	276'	2820'	233'
ANT HGT (AGL)	71'	71'	67'	65'	62'	90'	39'
PRIMARY TYPE	ARSR-1E	ARSR-1E	ARSR-3	FPS 67B	ARSRI-10	-------	FPS-20A
PRIMARY ANT	ARSR-1E	ARSR-2	ARSR-3	MK 748:MIL	ARSR-2	-------	ARSR-1
BEACON TYPE	ATCBI-4	ATCBI-3	ATCBI-5	ATCBI-3	ATCBI-3	ATCBI-5	ATCBI-3
BEACON ANT	NADIF	NADIF	ARSR-3	NADIF	NADIF	BEACON ONLY OPA*	NADIF
IDENT FOR COMPUTER ADAPTION	1	2	5	9	4	7	8

* OPA - Open Planar Array

(2) The six long range sites listed below provided the multiple overlapping coverage throughout the flight profile for the Jacksonville ARTCC.

JACKSONVILLE ARTCC DATA.

NAME	JEDBURG	LINCOLNTON	VALDOSTA	BENSON	MONTGOMERY	WHITEHOUSE
INDENT	QRJ	QNK	VAD	QRL	MGM	NEN
LAT/ LONG	33 04 11.5 N 80 13 14 W	33 45 34.7N 82 28 01.7W	30 58 32 N 83 12 48 W	35 30 40 N 78 32 58 W	32 12 42 N 86 10 06 W	30 20 45 N 81 52 26 W
ELEV (MSL)	54'	517'	233'	282'	276'	91'
ANT HT (AGL)	69'	67'	39'	62.4'	62'	62'
PRIMARY TYPE	ARSR-60M	ARSR-3	FPS-20A	ARSR-1D	ARSR-1D	ARSR-60M
PRIMARY ANT	ARSR-2	ARSR-3	ARSR-1	ARSR	ARSR-2	ARSR-2
BEACON TYPE	ATCBI-5	ATCBI-5	ATCBI-3	ATCBI-5	ATCBI-3	ATCBI-5
BEACON ANT	NADIF	ARSR-3	NADIF	NADIF	NADIF	NADIF
IDENT FOR COMPUTER ADAPTION	1	6	Ø	4	5	3

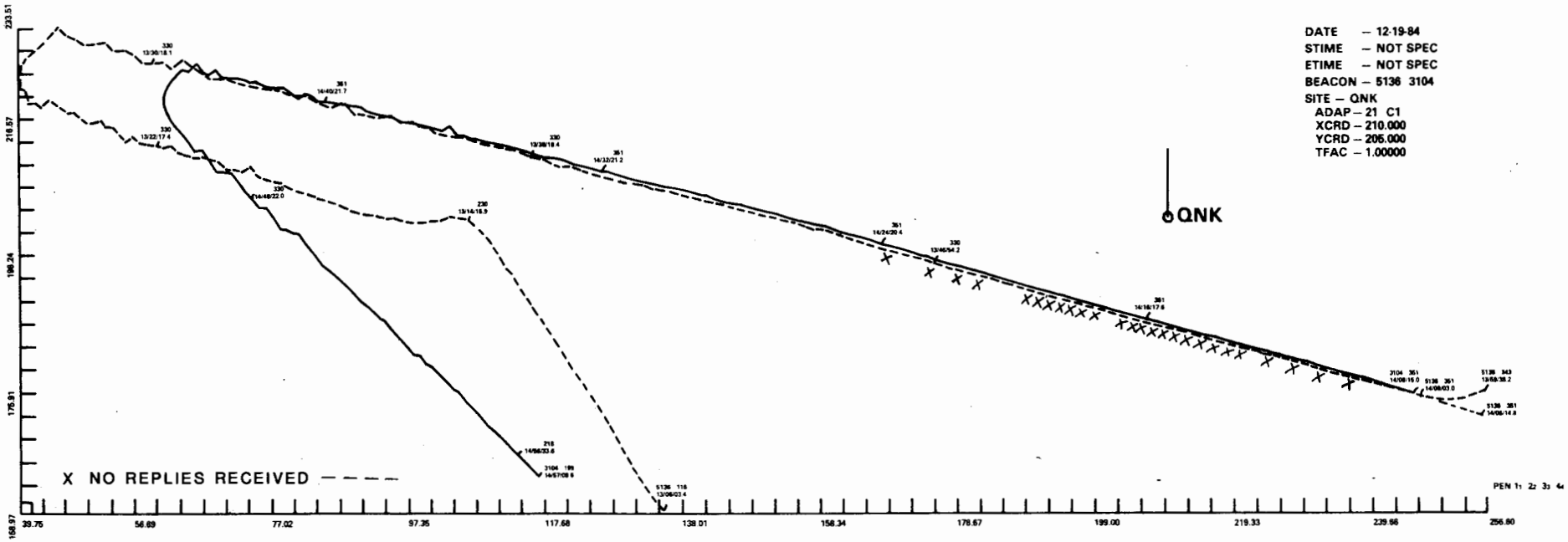
b. Data Acquisition. CD recordings were made at the Atlanta and Jacksonville ARTCC's using equipment available at the centers. The CD recordings were then reduced by the IBM 9020 analysis programs. TV recordings were made of the NAS and DARC radar data system and target strength was graded and manually recorded by air traffic controllers.

c. Results. Visual observations were made of the FAA Sabreliner and Air Force KC-135 runs between Atlanta and Jacksonville on November 29th, 1984. The first run was at FL 330 from the VU 344 /49 nm fix to the CHS VORTAC with the KC-135 transponder set to low sensitivity (-62 dBm) and the Sabreliner transponder set to normal (-74.5 dBm). In the region east of the Atlanta ARTCC, starting at approximately 25 miles and extending out to 100 miles, the KC-135 transponder did not reply to interrogations for a considerable portion of the flight leg. The course was reversed and flown at FL 350. The KC-135 was switched to normal sensitivity (-74.2 dBm) and both antennas. Again, the KC-135 transponder did not reply east of Atlanta ARTCC. During both runs the Sabreliner followed the KC-135 by 10 miles and transmitted consistent replies. During the second run the KC-135 was switched to only the bottom antenna, with no improvement. A third run at FL 330, with the KC 135 unit set to low sensitivity and bottom antenna only had the same results (transponder did not reply east of Atlanta). A fourth run at FL 350, normal sensitivity and using both antennas had the same results. The Sabreliner made two runs on the afternoon of November 29th; the first run at FL 330 using normal power (320w) and low sensitivity (-69 dBm). The second was at FL 350 using low power (120w) and low sensitivity (-69 dBm). Consistent replies were received during each of the four Sabreliner test flights with one exception. Transponder replies were not received during brief periods of aircraft maneuvering and due to garbling (this is a normal condition of the ATCRBS).

A considerable number of replies were not received from the KC-135 between 25 and 100 miles east of Atlanta; however, consistent replies were received from the Sabreliner. This condition suggests a possible incompatibility between the KC-135 transponder (APX-64) and the FAA radar beacon system. On November 30, 1984, Robins AFB was visited and a detailed examination of the APX-64 transponder, installed in the test flight KC-135, was made. During the examination, it was discovered that the side lobe suppression (SLS) response of the transponder was significantly different than that of transponders used in civil aircraft. In order to meet the TSO requirements for transponder side lobe suppression over the dynamic range of the unit, transponder response is typically adjusted so that suppression occurs when the received P2 pulse amplitude is 5 db down from the P1 pulse (-5 db). The APX-64 was found to be adjusted for SLS to occur with the P2 pulse 9 db down (-9 db) from the P1 pulse. This condition resulted in the transponder being more sensitive to SLS signals (excessive reply suppression), at various received signal strengths, than units adjusted to the typical -5 db point. The APX-64 was adjusted in accordance with the applicable Air Force Technical Order (TO).

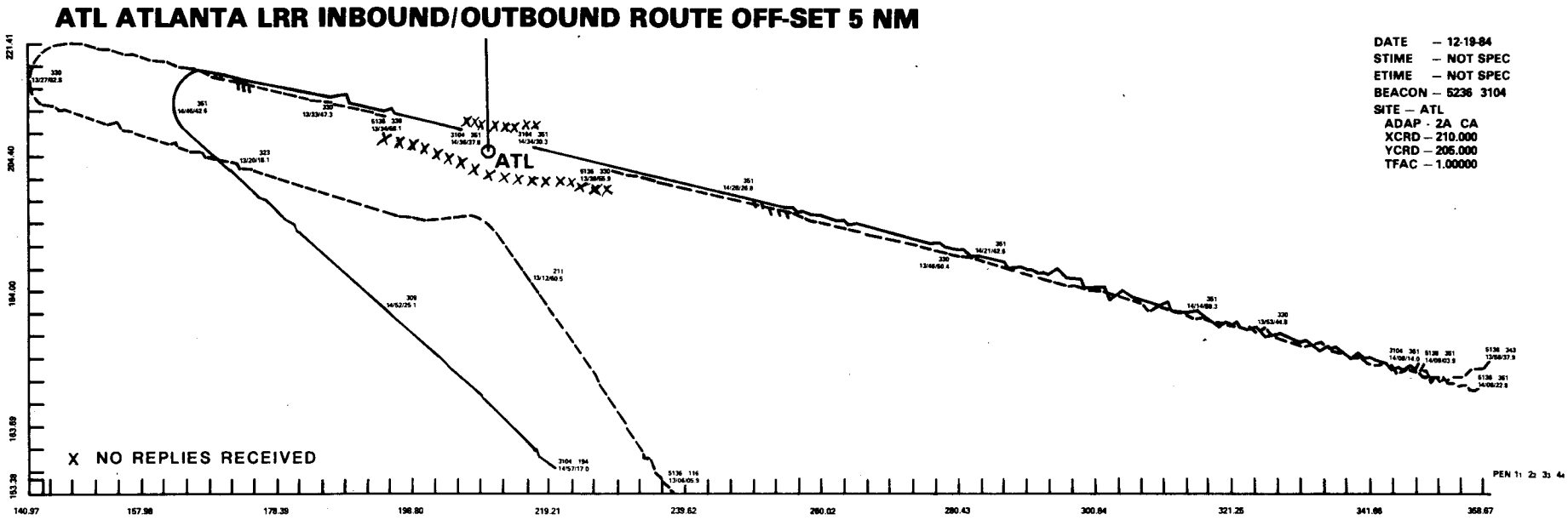
The region of poor transponder replies from the KC-135 is covered by the Lincolnton ARSR-3 long range radar. The ARSR-3 sites are required to radiate more SLS power to cover side lobes and control run length than other radar types. This region of poor transponder replies was also noted in the cone-of-silence over the Marietta long range radar site. A validation flight was performed on December 19, 1984, using two APX-64 transponders, one adjusted to a -9 db SLS response point and the second

QNK LINCOLNTON INBOUND/OUTBOUND ROUTE OFF-SET 5 MILES



PLOT NO. 5

LINCOLNTON LONG RANGE RADAR PLOT OF KC-135



PLOT NO. 6

ATLANTA LONG RANGE RADAR PLOT OF KC-135

adjusted to -5 db. The KC-135 flew from over the Marietta LRR to the Atlanta ARTCC boundary at FL 330 with the -9 db transponder. In the same area as before, a considerable number of replies were not received. The computer analysis indicated a 69 percent probability of detection. The cone-of-silence over the Marietta LRR was 37 miles in diameter. The transponder was replaced with an APX-64 unit adjusted to -5 db. The aircraft reversed course at the Atlanta ARTCC boundary and flew back over the Marietta LRR at FL 350. No misses were noted and the computer analysis indicated a probability of detection of 100 percent (one miss out of 300+ scans) and the cone of silence over the Marietta LRR was reduced to 17 miles in diameter.

The DOD AIMS Program Manager and the FAA jointly reviewed the results of the December 19th validation flight tests. Jointly, procedures for correcting the APX-64 SLS alignment specified in military technical orders were tested in the Air Force Avionics Maintenance Center.

The tests proved that new procedures for P2 response adjustment were useable. These procedures were, in fact, a reimplementation of the maintenance and alignment procedures and tolerances which had been specified and published prior to a change to the TO in 1978. An attempt was made to determine the reason for the change. It was learned that in 1978, a request-for-change to the TO was submitted from Hickam Air Force Base. The specific reason for the change could not be determined; however, the change was related to a problem involving ATC tracking of aircraft in the Honolulu terminal environment.

The realization that no historical records were available to accurately define the 1978 problem and rationale for the TO change required on-site testing and validation flights of the Honolulu radar systems. Accompanied by participation from the DOD AIMS Program Management Office, tests and validation flights were conducted in Hawaii during the week of March 11-15, 1985, to determine if there were unique circumstances to be considered.

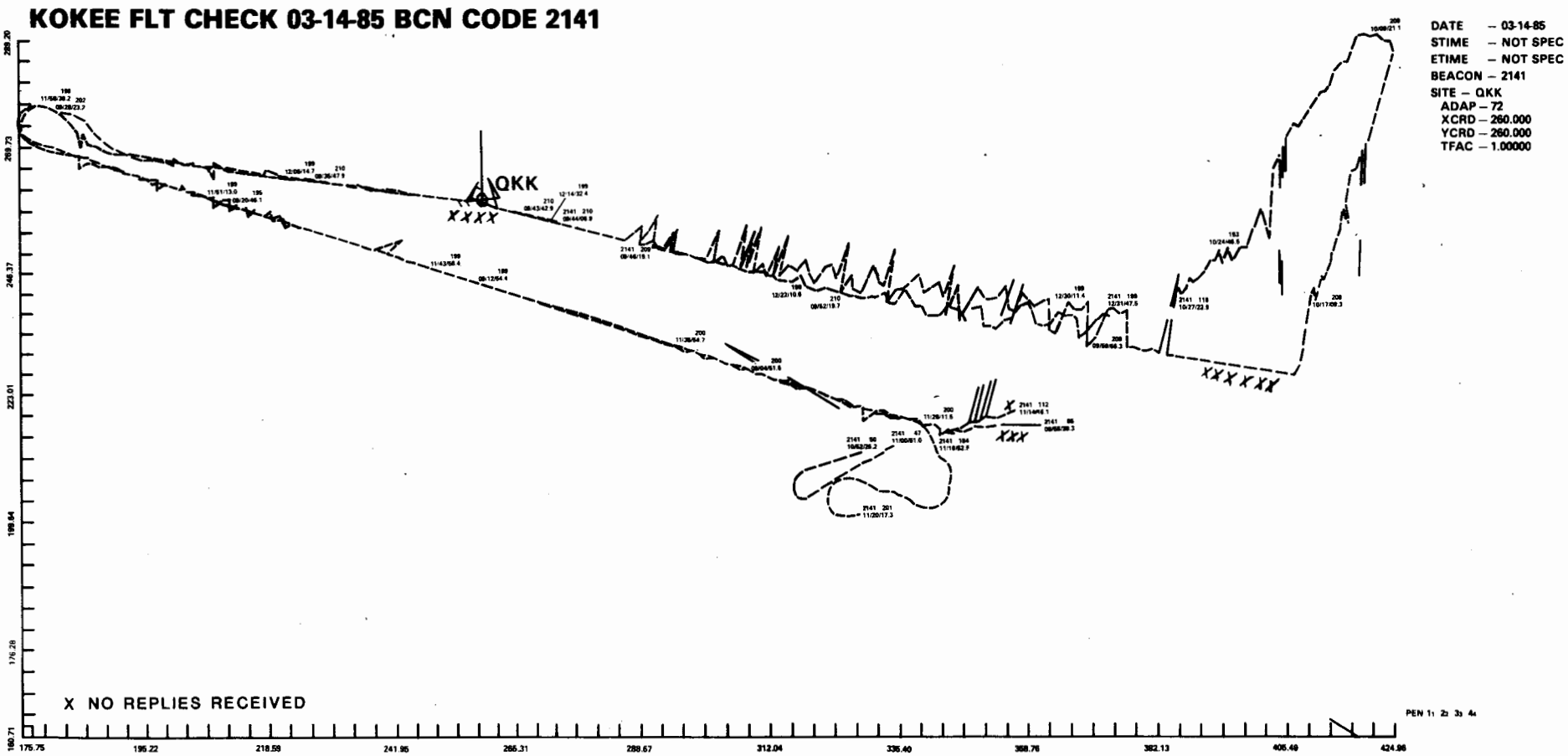
2. HONOLULU ARTCC.

a. System Configuration. The Honolulu ARTCC is an en route automated radar tracking system (EARTS) utilizing radar beacon data from the Mt. Kaala ARSR-3/ATCBI-5, the Maui ATCBI-5, the Pahoa ATCBI-5, and the Kokee UPX-14 as backup. Radar sort box programs were not available in the EARTS. Individual radar data is displayed on discrete displays.

b. Data Acquisition. CD recordings were made of the Mt. Kaala ATCBI-5 beacon data and the Kokee UPX-14 beacon data. This data was then reduced by the IBM 9020 analysis programs. TV video recordings were made of all test flights.

c. Results. Tests of the APX-64 transponder operation in the en route environment were conducted March 11-15, 1985. The tests were intended to duplicate previous complaints in this area of poor operation of military transponders and to verify that the changes in the alignment of the transponders had corrected the problem. The complaints consisted of intermittent or sporatic replies and Mode C problems. During meetings held on March 6, 1985, at Honolulu, the Mode C problems were identified as missing or changing altitude reports at the Honolulu TRACON in 1978. It was discovered that the APX-64 alignment had been changed so that the SLS response point occurred when P2 was 9 db below P1, rather than 5 db in response to these Mode C problems. This SLS response change caused the transponders to be more sensitive to suppression over their dynamic range. Two APX-64 transponders were aligned and tested--one with the SLS response set to -5 db and the other set to -9 db.

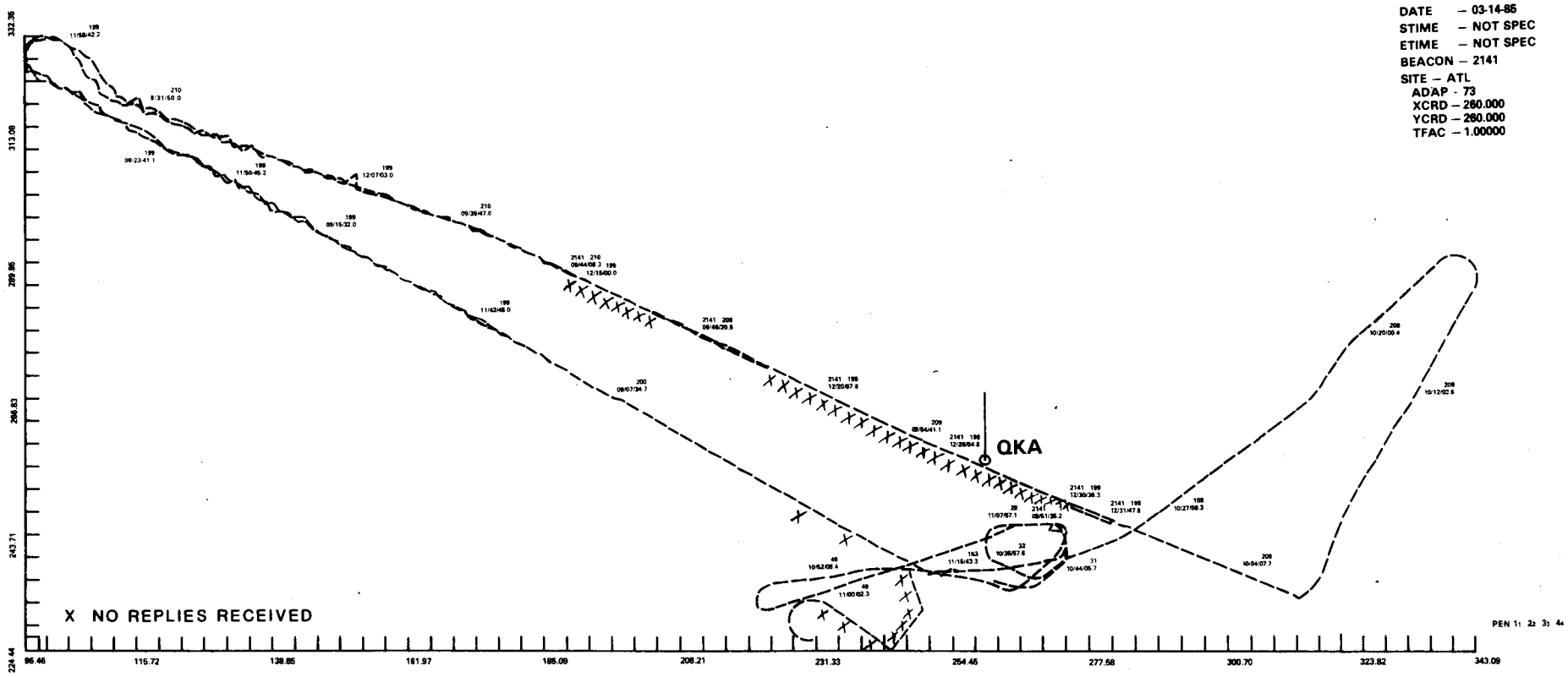
Air Traffic defined areas that have exhibited problems with military aircraft north northwest (NNW) from Oahu to Kauai and east from Oahu over Maui then north. A flight test profile was developed and on March 14, 1985, this profile was flown in an EC-135J using a -5 db and -9 db calibrated APX-64 unit. No problems were found with the -5 db unit. From 100 miles NNW of Oahu to 44 miles east, the probability of detection was 96 percent. From 50 miles NNW of Oahu to 44 miles east, the probability of detection was 95 percent. Both of these percentages are considered very good. The EC-135J was put in a holding pattern for approximately 5 minutes while the transponder was changed to the -9 db unit and the flight profile was repeated. Since the bench checks showed no major differences in the SLS response of the two transponders (compared to other units tested) it was anticipated that no significant differences would be found in the flight test results. Instead, the -9 db transponder operation was extremely poor. From 100 miles NNW of Oahu to 24 miles east, the probability of detection was 62 percent. From 50 miles NNW of Oahu to 24 miles east, the probability of detection was 40 percent. These percentages are unacceptable for controlling aircraft. The EC-135J flew at FL 210 continuously within the problem areas. Normal military flights only pass through small sections of these problem areas; thus, the problem had not been as evident as it was with the test aircraft. The test was concluded prematurely at 24 miles east of the site, due to the poor performance of the -9 db transponder. It was determined by all observing test team members that continuation of the test with a low approach to Honolulu International Airport could compromise aviation safety.



PLOT NO. 7

KOKEE LONG RANGE RADAR PLOT OF EC-135J

MT. KAALA FLT CHECK 03-14-85 BCN CODE 2141



PLOT NO.8

MT. KAALA LONG RANGE RADAR PLOT OF EC-135J

CHAPTER 5

ANALYSIS OF TEST FACILITIES AND TRANSPONDERS

1. BACKGROUND. To assess the effectiveness of airborne transponder equipment operating in the National Airspace System and the periphery systems that support the airborne transponder equipment, an analysis was conducted of selected air carriers, air taxis, military, a general aviation manufacturer, and repair stations.

2. METHODOLOGY.

a. An evaluation of the types of test equipment being used at each test facility was conducted. Test equipment calibration records were reviewed for frequency of calibration and traceability to the national standard. A determination was made as to how the aircraft antenna system testing was accomplished. Maintenance programs and bench calibration procedures were evaluated for compliance with existing Federal Aviation Regulations, military technical orders, and manufacturers' specifications. Transponder records were reviewed to determine the frequency of failure and repair. A visit was also made to a transponder manufacturers facility to inspect manufacturing procedures and spot check units on the production line.

b. The airborne transponder systems in the FAA Sabreliner, B-727, C-90 and F-90 King Air, the BE-E55 Barron, and military F-4D, C-130H, KC-135, and EC-135J aircraft selected to fly the test profiles, as well as backup aircraft, were examined to determine that the systems were operating within their prescribed tolerances and specifications. These tests were conducted by an FAA Avionics Team utilizing a specially equipped test van. Each transponder was examined on the bench and then installed in the test aircraft and re-examined with the antenna system and auxilliary equipment to ensure system integrity prior to the test flight. Fifteen transponder parameters were examined and recorded.

c. General Aviation transponder checks were conducted at Fulton County-Brown Field, DeKalb-Peachtree, and McCollum Airports in the Atlanta area using a Mobile Transponder Performance Analyzer (MTPA) housed in a bus dispatched from the FAA Technical Center. The "one minute" test analyzed 15 transponder parameters while cooperating pilots stopped their aircraft on the ramp or taxiway.

d. Suspect malfunctioning general aviation transponders were identified by air traffic controllers at the Atlanta TRACON. Letters were sent to each registered owner by the Southern Region Flight Standards Division requesting their support in the project by having their transponders ramp-tested by the MTPA bus at the FAA Flight Inspection Field Office at Fulton County-Brown Field Airport. Aircraft which were identified as having possible transponder problems as a result of the test were requested to have their transponders tested by an FAA Certified Repair Station and the results mailed to the FAA Avionics Team for further analysis.

e. An Accident Prevention Aviation Safety Education Seminar was held in the Atlanta area. The user public was educated on the project efforts to provide data to enhance flying safety while operating in the present Air Traffic Control Radar Beacon System and the proposed future Mode "S" transponder environment. Following this meeting, general testing of transponders began at Fulton County-Brown Field and continued on to DeKalb-Peachtree and McCollum Airport, March 22 thru April 14, 1985, using the MTPA bus. Information concerning the tests was disseminated to the general public using the Notice to Airman (NOTAM) System, Automatic Terminal Information Service (ATIS), brochures, handouts, and other public information media.

3. SCOPE.

a. Air Carrier. Two major air carriers were visited in the Atlanta and Miami areas. Each air carrier was briefed regarding the transponder system performance problem in the NAS. Both air carriers gave their support and cooperation by providing the required technical personnel and facilities to perform the tests. In reviewing their test procedures, there were no provisions for the testing of aircraft coaxial cables and antennas. Both air carriers used the ramp test method (radiated test signal) to test the entire transponder system every 24 months. The test consisted of checking the transponder system for proper frequency, sensitivity, and side-lobe suppression in conformance to FAA requirements. During the test, the type of test equipment used and the calibration frequency were recorded. All test equipment used during the test was in calibration. Both air carriers were asked to remove two transponders from two different types of aircraft for a complete bench check. The bench check consisted of testing the transponders for conformance to the national standard. The 15 parameters tested were:

1. Dead time
2. Suppression time
3. Reply power
4. Frequency
5. F1 Pulse width
6. F2 Pulse width
7. Sensitivity
8. Delay time defference
9. Reply Jitter
10. Mode A delay
11. Mode C delay
12. F1-F2 pulse spacing
13. Side-Lobe Suppression (SLS) decode accuracy
14. Mode A decode accuracy
15. Mode C decode accuracy

There were no significant discrepancies noted during the bench tests. Following the bench tests, the same transponders were ramp-tested in the air carrier's aircraft using their transponder portable test equipment and testing instructions. The placement of the ramp test antenna to the aircraft's bottom mounted antenna was critical to the measuring equipment; however, when the test antenna was properly positioned, the test was made with satisfactory results. A review of transponder repair records and pilot complaints for a 6-month period revealed an acceptable mean time between failures, based on each air carrier's Maintenance Reliability Program.

b. Air Taxi. Two commuter air taxi operators were visited in the Atlanta area and were briefed regarding the transponder system problems. Both commuters gave their support and cooperation. A review of each commuter's approved maintenance program for transponders revealed that both commuters utilized contract FAA certificated repair stations to ensure compliance with FAR 43, Appendix F, requirements. This is a common and acceptable practice used by air taxi organizations to meet this requirement. Transponder repair records and pilot complaints were reviewed with no significant findings for a 3 month period. Both commuters made arrangements to have their transponders tested at a FAA-appproved repair station located in the Atlanta area. The repair stations were then examined.

c. Repair Stations. Six FAA certificated repair stations were visited in the Atlanta area and briefed regarding the transponder system problems. Each repair station gave their support and cooperation. In reviewing each repair stations' test procedures, there were no provisions for checking aircraft coaxial cable and antennas. Each used the ramp test method (radiated test signal) to test the entire transponder system every 24 months. The ramp test consisted of checking the transponder system for proper frequency, sensitivity, and side-lobe suppression (SLS) for conformance to FAR 43, Appendix F requirements. For the purposes of this test, each repair station was asked to accomplish a bench check of 15 parameters in addition to the ramp test. The 15 parameters tested were:

1. Dead Time
2. Suppression Time
3. Reply power
4. Frequency
5. F1 Pulse width
6. F2 Pulse width
7. Sensivity
8. Delay time difference
9. Reply Jitter
10. Mode A delay
11. Mode C delay
12. F1-F2 pulse spacing
13. Side Lobe Suppression (SLS) decode accuracy
14. Mode A decode accuracy
15. Mode C decode accuracy

The type and calibration frequency of the test equipment used was recorded. The bench test results showed that some of the parameters measured were not within the required tolerances. Less expensive models of general aviation transponders generally fell into this category. Low output power, improper frequency, and receiver sensitivity were common, although pulse width and spacing deficiencies were observed in some units. A review of repair station records disclosed a significant number of intermittent transponder problems associated with the less expensive units. The most common discrepancies were transmitter output power tube failure, transmitter cavity problems, receiver sensitivity, and pulse-shaping circuitry problems. There appeared to be a gradual deterioration of these circuit parameters. This condition may be associated with low cost

light-weight design construction and exposure to harsh environmental conditions and may necessitate more frequent testing. A further study is needed to assess the manufacturing processes and fabrication techniques associated with the general aviation transponders (Class 2) which are inherently different from the air transport transponders (Class 1).

d. Manufacturer. One leading manufacturer of general aviation transponders was visited to assess the effectiveness and reliability of quality control systems used on transponders leaving the assembly line. Final acceptance tests were evaluated and found acceptable in ensuring the degree of reliability required for each completed transponder unit. Differences were pointed out in the design and manufacturing processes between general aviation and air carrier transponders. The air carrier transponders (Class 1) are designed with user expectation of higher utilization and increased reliability. The general aviation transponders are designed and manufactured with user expectation for low cost and lightweight construction. Design criteria and fabrication techniques were found to be based on these user expectations with proper regard for minimum performance standards (MPS) as specified in the FAA Technical Standard Order (TSO). In order to assure transponder units will meet the needed operational characteristics in the environmental conditions in which they will operate, each class of transponder is designed to meet a specific range of environmental conditions. The air carrier transponders are required to meet a more comprehensive environmental specification than the general aviation units. The MPS under standard conditions are virtually the same for respective classes of air carrier and general aviation transponders (Class 1A, 2A and 1B, 2B); however, air carrier transponders generally produce a higher number of transmitted replies per second (reply rate) and higher peak power output is available as compared to general aviation units. Both classes of transponders, however, meet the MPS requirements. The only other notable difference between transponder classes is the antenna requirement. Air carrier transponders (Class 1) are required to utilize a vertically polarized omnidirectional antenna which provides a vertical beamwidth of at least $\pm$ 30 degrees from the horizontal plane. Also, the voltage standing wave ratio (VSWR) of the antenna and transmission line must not exceed 1.5:1 on the receive (1030 MHz) and transmit (1090 MHz) frequencies. In contrast, there is no requirement for the antenna and transmission line, connected to a Class 2 transponder, to exhibit a specific VSWR. In mid-1985, a survey of manufacturers of general aviation transponders revealed that current production units meet the (Class 1) requirements.

e. Military. Four Air Force avionics shops were evaluated by the FAA Avionics Test Team covering a wide variety of aircraft, transponder and periphery equipment, calibration equipment, and procedures. Those organizations were the 116th Tactical Fighter Wing, Georgia Air National Guard and the 94th Tactical Airlift Wing, Air Force Reserve, Dobbins AFB, Georgia; the 19th Air Refueling Wing, Robins AFB, Georgia, and the 15th Air Base Wing, Hickam AFB, Hawaii. In addition, the Air Force Directorate of Maintenance, Airborne Electronics Division, Depot Maintenance facility

at Robins AFB was visited. Excellent support and cooperation was received from all Air Force and DOD components. Avionics maintenance areas were well maintained and complied with all technical requirements. The technical competence and practices of all personnel was excellent.

During each visit, the FAA Avionics Test Team noted the type of transponder test equipment and frequency of equipment calibration in use. In each case, it was determined that the test equipment and calibration intervals met all applicable military requirements. Additionally, all calibration standards were traceable to the National Bureau of Standards. The Air Force Airworthiness Maintenance Program for transponders, as well as specific transponder calibration and maintenance procedures, was reviewed. The review revealed that a continuous airworthiness maintenance program and an approved aircraft inspection program was being followed. It was noted that transponder maintenance is accomplished on an "on-condition" basis. It was also noted that antennas and coaxial cables are not tested on a periodic basis.

Each Air Force aircraft selected to fly the test profiles, as well as back-up aircraft, were examined to determine that the systems were operating within Air Force and FAA tolerances and specifications. The tests were conducted by the Avionics Test Team utilizing a specially equipped FAA test van. Each test aircraft's transponder was removed and examined on the bench. Subsequently, the transponder was reinstalled on the test aircraft and re-examined with the antenna system and auxilliary equipment to ensure system integrity, prior to the test flight. A time domain reflectometer was used to check the electrical condition of the antenna and transmission line of each aircraft. The 15 parameters tested were:

1. Dead Time
2. Suppression Time
3. Reply power
4. Frequency
5. F1 Pulse width
6. F2 Pulse width
7. Sensivity
8. Delay time difference
9. Reply Jitter
10. Mode A delay
11. Mode C delay
12. F1-F2 pulse spacing
13. Side Lobe Suppression (SLS) decode accuracy
14. Mode A decode accuracy
15. Mode C decode accuracy

Aircraft with a top and bottom antenna switching system were examined to determine if the system was operating within the prescribed tolerances. A counter and an oscilloscope were used to determine if the optimum antenna switching rate was being achieved. All data was recorded. No differences could be found in overall system performance between the top and bottom-mounted antenna.

The team found that in all cases the transponders analyzed met the requirements of Federal Aviation Regulation Part 43, Appendix "F". Transponder Performance Test Data for the 15 parameters measured, Transponder Calibration Verification measured at the antenna, Transponder Configuration Diagrams, and the Transponder System Analysis Calibration Procedures for each system analyzed are contained in Appendix 7.

During the en route profile phase of the Flight Validation Test using the KC-135 aircraft from the 19th Air Refueling Wing equipped with an AN/APX-64 transponder, an area of concern developed regarding SLS response calibration. The SLS calibration standard was set to the upper limit of -7 db to -9 db which resulted in excessive suppression of transmitted replies over the transponders' dynamic range. The team determined that the transponder could meet the TSO requirement for SLS over the dynamic range of the unit by adjusting the SLS response to -5 db. Several additional test profiles were flown using the APX-64 transponder with the SLS response set at -9 db and -5 db. The unit set at -5 db resulted in a significant improvement in APX-64 performance in the National Airspace System.

Random APX-64 transponders were selected and tested at the Airborne Electronics Division, Depot Maintenance Facility, at Robins, AFB. It was determined that the APX-64 transponder SLS response could be set to -5 db and would satisfactorily perform through its dynamic range. Two transponders were calibrated by the Depot Facility, one with the SLS set at -9 db and the other at -5 db. These units were shipped to Hawaii and used in the flight validation test on an EC-135J aircraft from the 9th Airborne Command and Control Squadron, Hickam AFB. Calibration was verified by a bench check at the 15th Avionics Maintenance Support Squadron at Hickam. Testing of the transponders, antenna systems, and periphery equipment installed in the aircraft were repeated. An evaluation of the shop and test procedures was also repeated. The test with the SLS set at -5 db again showed a significant improvement in APX-64 performance in the National Airspace System. The test analysis is contained in Appendix 7.

As a result of the Flight Validation Tests, the Director of Materiel Management, Item Management Division, Robins AFB, issued a Time Compliance Technical Order requiring that all APX-64 transponders in the Air Force inventory be realigned for SLS response at -5 db. The DOD AIMS Program Manager and the team briefed representatives from the Chief of Naval Operations and a similiar technical order change was issued by the Naval Air Systems Command (NAVAIR) Air Rework Facility, Pensacola NAS, Florida. These actions affected approximately 2900 APX-64 units installed in the B-52, C-141, C-130, C-5A, C-135, VC-137, and F-111 Air Force aircraft. Approximately 800 units in Naval and Marine Corps A-4, A-7, C-2, T-2 and OV-10 aircraft were effected. A complete list of DOD aircraft equipped with the APX-64 transponder is contained in Appendix 8 of this report.

CHAPTER 6

ANALYSIS OF GENERAL AVIATION TRANSPONDER PERFORMANCE

1. POTENTIAL PROBLEM AIRCRAFT. The FAA Southern Region Flight Standards Division was requested to send letters to operators of aircraft identified by the Atlanta TRACON air traffic controllers. These aircraft were identified as having potential transponder problems associated with poor radar beacon tracking. Approximately 50 aircraft were identified and letters were sent to the operators requesting their participation in the test program. Operators were requested to either bring their aircraft to Fulton County-Brown Field for a free transponder test using the Mobile Transponder Performance Analyzer (MTPA) bus or take the aircraft to a certified FAA repair station and have the transponder checked. Operators were asked to mail the results of the repair station tests to the FAA Avionics Test Team. Approximately 95 percent of the operators receiving letters were located outside the Atlanta metropolitan area. No operator took advantage of the MTPA test; however, 8 operators did contact the team and indicated their aircraft were not available. Only 1 operator reported having his transponder tested at an FAA-certified repair station and forwarded a copy of the work order which showed that corrective action was taken. This transponder had problems with improper reply frequency and pulse distortion.

2. MOBILE TRANSPONDER PERFORMANCE ANALYZER (MTPA).

a. Data Acquisition. The FAA Technical Center placed the MTPA into operational status and dispatched the vehicle to Atlanta in support of the ATCRBS Analysis Team. The purpose was to position the unit at selected general aviation airports where aircraft operators could take advantage of the opportunity for a courtesy transponder ramp test sponsored by the FAA. Additionally, the data collected from these tests would provide a sampling of the condition of general aviation transponder equipment installed in aircraft.

The airports selected were DeKalb-Peachtree, Fulton County-Brown Field, and McCollum. The total number of airplanes based at those general aviation airports was 1,188. Although the van was manned from 7:30 a.m. until 5:00 p.m. for seven consecutive days at each airport, only 154 aircraft operators took advantage of the one-minute ramp test sponsored by the FAA.

b. Data Analysis. While Appendix 9 of this report contains the FAA Technical Centers comprehensive report of the results of 154 aircraft tested, the results are summarized as follows:

Parameter	Percentage of transponders that failed
Frequency	9% (Note 1)
F1/F2 spacing	3%
Pulse width	5%
Mode A decode accuracy	5%
Mode C decode accuracy	8%
Suppression time	14%
Side Lobe Suppression	11%
Pulse spacing	59% (Note 2)
SLS Amplitude Characteristics	13% (Note 3)
Altitude Comparison	3% (altitude data outside of tolerance)
Reply Power	21% (Note 4)
Sensitivity (Mode A)	25%
Sensitivity (Mode C) Altitude Reporting	25%

Note 1. One of the operators had received a letter from the FAA indicating a problem with his transponder. This transponder never reached a 90% reply rate in any of the tests.

Note 2. A large number of transponders responded to the P2 pulse when it exceeded the pulse spacing tolerance specified in the TSO.

Note 3. Of these, 4 failed to suppress at all, two failed to suppress the required 99%, and 12 failed to respond at a 90% rate. One aircraft which had been reported as a problem by ATC personnel fell into this category.

Note 4. Most of the failures were due to high reply output power above the TSO specification.

c. Conclusions.

(1) Detailed investigation of the test results showed that the SLS pulse spacing response of the transponder was too wide in almost all cases. Most of the units tested still suppressed when the P1-P2 spacing was 2.8 microseconds (the TSO requires SLS to occur with P1-P2 spacing of 2.0$\pm$ 0.15 microseconds).

(2) During the past ten years, the FAA MTPA has been placed at numerous locations throughout the country to offer courtesy transponder tests to the general aviation community. Each MTPA visit has been documented by a formal report published by the FAA Technical Center containing an analysis of the test results. The results of the Atlanta MTPA testing in support of the ATCRBS Analysis Team combined with data gathered at various TRACON facilities supports a finding that a performance deficiency exists in general aviation transponders operating in the National Airspace System. Appendix 10 lists the transponder analysis reports which encompass the past 10 years.

d. New Manufactured Transponder Tests. On March 18, 1986, new manufactured transponders received from three general aviation manufacturers were tested utilizing the MTPA. The analyzer was setup at the FAA Technical Center's transponder laboratory for these tests. Each transponder was connected directly to the analyzer using coaxial transmission line. The testing criteria used for these units was the same as that used for the field tests performed in Atlanta. The test results are shown graphically in Appendix 10A. All three transponders exhibited performance characteristics in the areas of pulse width discrimination and pulse position which did not meet the requirements of TSO C74c. The test transponders replied to interrogations and suppressed replies nearly 100% when the width of P1, P2, and P3 transmitted pulses were reduced to 0.1 microsecond. The TSO allows a maximum of 10% reply or suppression action under these conditions. The test transponders also suppressed replies when the spacing between P1 and P2 was reduced to 1.3 microseconds. The TSO requires the spacing between P1 and P2 to be 2.0$\pm$ 0.15 for suppression. The other parameters measured on the test units met the TSO requirements.

3. TRACON VISITS

a. Data Acquisition. In order to evaluate general aviation transponder performance from the ATC operational standpoint, visits were made to various terminal radar control (TRACON) facilities. During the period from December 10, 1985, to January 15, 1986, visits were made to TRACON facilities located in Atlanta, Orlando, Tampa, Los Angeles, and Burbank as well as to the El Toro Marine Corps Air Station (Coast TRACON). During these visits, observations were made of air traffic which exhibited coasting, alphanumeric tag drop, or intermittent beacon target reception. Tracking data and beacon target reports were recorded during the time periods that aircraft were being observed. A follow up visit was made to the Tampa and Orlando TRACON facilities during the period from March 25 to March 28, 1986. The purpose of the visit was to run the Data Reduction and Analysis Maintenance (DRAM) Program. This program has the capability to validate the performance of the data acquisition and processing systems as well as providing an extensive editing capability for data analysis.

b. Data Analysis. An analysis of the acquired data from all facilities revealed that all monitored air traffic exhibiting beacon tracking problems in the NAS was almost exclusively general aviation aircraft. The types of tracking problems observed were unreceived transponder replies, invalid beacon codes, and invalid Mode C altitude reports. In order to further evaluate target coasting, additional data was evaluated at the Tampa and Orlando TRACON facilities. The DRAM Software Program was run to evaluate the data processing functions and perform an indepth analysis of beacon targets which exhibited coasting. The analysis revealed that beacon targets being tracked met the signal quality requirements built into the data processing software. Whenever the signal quality decreased below the minimum requirements for beacon reply recognition, a coast message would be displayed. The DRAM analysis also provided a complete validation of the data processing system and no anomalies were detected. Further analysis was conducted at the FAA Technical Center. A simulation of a degraded transponder reply was performed in an attempt verify performance of the terminal data processing system. The results were consistent with the DRAM analysis. No system anomalies were detected during the simulation. Acceptable performance of the data acquisition and processing system is predicated upon a good quality transponder reply.

c. Facility Comments. At each facility visited, air traffic controllers identified a beacon tracking problem associated with general aviation aircraft. Air traffic controllers, particularly in Atlanta, commented that beacon tracking of military aircraft has noticeably improved over the last 6 months. During informal conversations with data systems specialists (DSS) at each TRACON, they commented on the difficulty in reducing and analyzing aircraft tracking data for such purposes as documenting operational errors, NMAC reports, aircraft accidents, and support of the ATCRBS Analysis Team. The difficulty is due to the lack of enhanced radar analysis programs available for the Univac terminal radar data system. Aircraft tracking data is currently being hand-plotted from position data manually read from tracking data messages and/or beacon target reports. Enhanced radar analysis programs are used extensively in the ARTCC environment as part of the IBM en route radar data system.

4. ATLANTA RADAR ENVIRONMENT. During the Atlanta tests, some concern was raised as to whether the high density radar beacon environment in the Atlanta area could be a contributing factor in transponder performance (a large number of FAA and military ATCRBS interrogators operate in the Atlanta area). In an effort to determine if this condition contributes to transponder performance a contract was awarded to the Massachusetts Institute of Technology Lincoln Laboratory to conduct a study. The objective of the study was to determine the 1030 MHz ATCRBS interrogation environment in the Atlanta area. This study was supported by a survey of the radio frequency environment conducted by the FAA Spectrum Engineering Department (AES-500) during June and July of 1985. The survey did not find any technical deficiencies or problems associated with the ground equipment. On October 30-31, 1985, the Lincoln Laboratory Airborne Measurement Facility (AMF) conducted airborne measurements of ATCRBS interrogators. The analysis of the data collected using the AMF indicates that there is no over-interrogation or over-suppression of transponders in the Atlanta beacon environment.

CHAPTER 7

RECOMMENDATIONS

1. RECOMMENDATION: Collect and analyze data relating to specific general aviation transponder equipped aircraft known to have caused beacon tracking difficulties in the national airspace system. This data is necessary to effectively evaluate applicable transponder TSO's for their adequacy, identify equipment malfunction trends, and identify maintenance/installation problems directly relating to system performance in the National Airspace System. A survey of approximately 600 aircraft would be required to establish a data base to sufficiently evaluate performance related transponder system problems.

   DISCUSSION: Atlanta tests using the mobile transponder performance analyzer as well as previous studies and investigations indicate a high incidence of out-of-tolerance conditions with general aviation transponders. However, there is very little data available correlating specific transponder system problems to known instances of beacon tracking difficulties. A data base identifying specific performance related problems would significantly aid in determining a plan of corrective action.

2. RECOMMENDATION: Conduct a study for possible application in FAR 43, Appendix F, to determine adequate and useable testing parameters and testing frequency for total transponder system performance verification. The study should include the integration of a bench check of the unit and a ramp check with the transponder reinstalled in the aircraft. The study should also include developing procedures for inspection/verification of the antenna and transmission line (VSWR measurement and physical examination) as well as all peripheral equipment.

   DISCUSSION: The performance of general aviation transponders degrades the overall ATCRBS performance and if not corrected, provides the potential for degradation of Mode S and TCAS performance. General aviation transponder performance could be enhanced by a complete system performance inspection. Federal Aviation Regulation, Part 43, Appendix F, does not currently specify requirements and specifications for an integrated transponder system performance check. The data base suggested in recommendation No. 1 could be used to determine effective inspection requirements.

3. RECOMMENDATION: The Air Traffic Facility Operation and Administration Handbook, 7210.3H, be amended to include a prescribed reporting system through which facility management reports ATCRBS deficiencies, believed to originate from airborne transponders, to regional air traffic, airway facilities and flight standard offices. This reporting procedure could be an integral part of the data gathering process suggested in recommendation No. 1.

   DISCUSSION: During facility interviews in the Atlanta air route traffic control center, controllers advised the team of KC-135 transponder abnormalities which has persisted for a number of years. Further research and inquiry revealed that these abnormalities apparently had not been reported outside of the facility. As a result, a problem trend could not be detected and no corrective action would be indicated.

4. RECOMMENDATION: Evaluate the ARSR-3 long-range radar SLS omni-directional transmitted signal with the intent of reducing the radiated power output.

   DISCUSSION: During the en route test flights conducted in Hawaii and Atlanta, utilizing the ARSR-3 long-range radar facilities, the transpondersadjusted for -5 db SLS response had a much higher probability of detection than the -9db units. This difference in target detection probabilities was greater than would normally be expected. A contributing factor to this condition is thought to be the high-power level of the SLS omni directional signal transmitted from ARSR-3 sites.

5. RECOMMENDATION: Establish a procedure whereby the FAA and appropriate military organizations coordinate any activities which may affect ATCRBS performance in the National Airspace System. Participation by Flight Standards on the Department of Defense (DOD) ATCRBS Identification Mark X/XII System (AIMS) Steering Committee could meet this requirement.

   DISCUSSION: In 1978,a military technical order change was made which affected the calibration procedure for APX-64 transponders. This change significantly affected the sidelobe suppression response of transponders installed in approximately 2,900 military aircraft. As a result, APX-64 transponder performance in the National Airspace System was degraded.

6. RECOMMENDATION: Make available enhanced radar analysis programs (similar to those in use in the en route centers) for terminal applications. Also continue to encourage FAA Technical Center evaluation of adopting the IBM PC to provide extensive radar analysis capabilities.

   DISCUSSION: During visits to various TRACON facilities, it was noted that radar analysis involving beacon tracking was accomplished by handplotting data read from tracking messages and/or target reports. This is a very time-consuming process for the data systems specialist. This type of data reduction has been an automated function at en route facilities for some time.