AN/UPX-41(C) IFF INTERROGATOR COMPATIBILITY WITH THE NATIONAL AIRSPACE SYSTEM

TOP-LEVEL TEST PLAN
Chesapeake Fixed-Base Experiment

August 4, 2014

Prepared for:

Federal Aviation Administration
800 Independence Avenue
Washington, DC 20591

and

Department of the Navy
Naval Sea Systems Command
Program Executive Office (PEO)
Integrated Warfare Systems (IWS)
Washington Navy Yard, DC 20376

and

Naval Air Systems Command
Program Executive Office
Tactical Aircraft Programs (PEO T)
46579 Expedition Drive, Suite 301
Lexington Park, MD 20653

Prepared by:

Department of Transportation
John A. Volpe National Transportation Systems Center
Cambridge, MA 02142

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE August 04, 2014	3. REPORT TYPE AND DATES COVERED Final Report

4. TITLE AND SUBTITLE
AN/UPX-41(C) Digital Interrogator System Compatibility with the National Airspace System: Top-Level Test Plan

5a. FUNDING NUMBERS
51VHF30000 NLH32
51VHF3A100 NJ1V8

6. AUTHOR(S)
Miles Bellman, Pratik Gandhi, Michael Geyer, Allen Mackey, Vaibhav Shah

5b. CONTRACT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
John A Volpe National Transportation Systems Center
55 Broadway
Cambridge, MA 02142-1093

8. PERFORMING ORGANIZATION REPORT NUMBER
DOT-VNTSC-NAVSEA-15-03

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Department of the Navy
Naval Sea Systems Command (NAVSEA)
Program Executive Office (PEO)
Integrated Warfare Systems (IWS)
Washington Navy Yard, DC 20376

US Department of Transportation
Federal Aviation Administration (FAA)
Spectrum Engineering Services, AJW-1C
800 Independence Ave., SW
Washington, DC 20591

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
This document is available to the public on the Volpe website at http://www.ntl.bts.gov.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
In 2012, the Navy requested spectrum certification for the shipboard AN/UPX-41(C) Digital Interrogator System, Software Version 5.5 with Mode 5. Current operating conditions for the Navy's AN/UPX-41(C) are the same as restrictions imposed on the AN/UPX-37 digital Identification Friend or Foe (IFF) interrogator. A proposed AN/UPX-41(C) Stage 4 certification was developed to allow the Navy to operate under less restrictive parameters but required that the Navy and FAA validate those proposed restrictions. This document constitutes the top-level plan for an experiment that implements the agreed-upon testing of the impact of the AEGIS and SSDS Combat Systems in ships with the AN/UPX-41(C)-based AN/UPX-29(V) Interrogator system on National Airspace System (NAS) Aeronautical Surveillance and Collision Avoidance Systems (ASCAS).

14. SUBJECT TERMS
AN/UPX-41(C), Identification Friend or Foe, IFF, Aeronautical Surveillance and Collision Avoidance Systems, ASCAS, Secondary Surveillance Radar, SSR, Multilateration, MLAT, Traffic Collision Avoidance System, TCAS, ACAS, Automatic Dependent Surveillance – Broadcast, ADS-B, Interference simulation, 1030 MHz, 1090 MHz, Test Plan

15. NUMBER OF PAGES
102

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

Approvals – Navy

Department of the Navy

19 Jun 14 William McLaughlin Principal Assistant Program Manager Program Executive Office Integrated Warfare Systems	Captain D. D. Lack 01 JUL 2014 Program Manager Naval Air Traffic Management Systems NAVAIR PMA213

Approvals – FAA

Federal Aviation Administration

Teri Bristol Chief Operating Officer Air Traffic Organization (ATO)	Edward Bolton Assistant Administrator NextGen

Abstract

The Navy Marine Corps Spectrum Center (subsequently, “the Navy”) requested spectrum certification for the AN/UPX-29(V) Identification Friend or Foe (IFF) system that uses the AN/UPX-41(C) interrogator that is installed in Naval surface vessels, specifically,

- Carriers (CVNs) and Amphibious, including LHAs, LHDs, LPDs and LSDs, as an element of the Ships Self Defense System (SSDS)
- Cruisers (CGs) and Destroyers (DDGs) equipped with the AEGIS Combat System (CS).

AN/UPX-41(C) Stage-4 certification for AEGIS-Class ships was accepted by the joint-agency Spectrum Planning Subcommittee (SPS) in the May 2012 meeting and signed by the National Telecommunications and Information Agency (NTIA) on June 22, 2012. The Stage-4 certification is for a specific hardware and software configuration which includes the Cooperative Engagement Capability (CEC). Some ships/classes with AN/UPX-41(C) systems installed may not currently have a spectrum certification; however, the Navy has submitted a request to add the SSDS-class ships to the existing spectrum certification.

The AN/UPX-41(C) Stage-4 certification contains restrictions in the form of conditions under which systems may operate when in proximity to the National Airspace System (NAS) managed by the Federal Aviation Administration (FAA). The Stage-4 certification also contains a requirement to validate those restrictions — specifically “The FAA and the Navy agree to conduct joint testing to validate the initial operations conditions” [*sic*].

This document constitutes the top-level plan for an experiment that implements the agreed-upon testing of the impact of the AEGIS and SSDS Combat Systems in ships with the AN/UPX-41(C)-based AN/UPX-29(V) Interrogator system on NAS aircraft surveillance and collision avoidance systems (ASCAS) that transmit and/or receive on 1030 MHz and 1090 MHz. This plan identifies

1) Land-based Test Sites (LBTS) with AN/UPX-29(V) Interrogator systems using the AN/UPX-41(C) to be tested — two at St. Inigoes, Maryland and two at Wallops Island, Virginia;
2) NAS ASCAS to be monitored during the experiment*, including (a) Secondary Surveillance Radars (SSRs), (b) Automatic Dependent Surveillance – Broadcast (ADS-B), (c) Traffic Alert and Collision Avoidance System (TCAS), and (d) aircraft transponders,
3) Test sequencing and duration;
4) System metrics to be evaluated; and

* Note: The LBTS were an agreed upon alternative to using shipborne interrogators for availability, economic, and logistical reasons. The placement of the LBTS are too far from multilateration and precision runway monitoring systems to 1) accurately represent the Stage-4 spectrum certification configuration (which covers any NAS location where this configuration could occur), and 2) accurately characterize interference to those systems through live data collection. The performance of these systems will be addressed by using airborne measurements and theoretical analysis (See Section 5).

5) Safety processes to ensure that testing does not adversely impact the NAS.

Planned dates for test-related activities are:

- **July 15-17, 2014**: Pre-test/dry-run involving personnel and procedures to be utilized during live testing, as well as ground-based Navy interrogators and ground-based FAA ASCAS and data collection systems.
- **July 23-25, 2014**: Contingency/backup dates for pre-test/dry-run.
- **August 18-22, 2014**: Live testing involving ground-based Navy interrogators and FAA ground- and aircraft-based ASCAS and data collection systems.
- **August 25-29, 2014**: Contingency/backup dates for live testing.

Table of Contents

List of Figures

List of Tables

1. Background: AN/UPX-41(C) Spectrum Certification

The Navy Marine Corps Spectrum Center requested spectrum certification for the AN/UPX-41(C) used in the AN/UPX-29(V) Identification Friend or Foe (IFF) System (which utilizes the 1030/1090 MHz frequency pair) as installed in AEGIS-Class Cruisers and Destroyers (Ref. 1) controlled by Cooperative Engagement Capability (CEC). The Stage-4 certification was accepted by the joint agency Spectrum Planning Subcommittee (SPS) in the May 2012 meeting and signed by the National Telecommunications and Information Administration (NTIA) on June 22, 2012 (Ref. 2).

A complete copy of the Certification of Spectrum Support (Ref. 2) is included as Section 11 of this plan. Key wording is provided below; added information is in brackets [ ]. Notable in this context is that the Federal Aviation Administration (FAA) is designated by the NTIA as the national coordinator for the 1030/1090 MHz frequency pair.

> "The Spectrum Planning Subcommittee has reviewed this system under the provisions of Chapter 10 of the NTIA Manual, noting that the receiver of the subject system is tuned to center frequency 1090 MHz and the AN/UPX-41(C) has the capability to transmit at 4000 watts peak power [Note: separately, Section 1 of Ref. 2 states that 2000 watts is the *approved* power level], recommends that:
>
> 1. NTIA certify Stage-4 spectrum support for the AN/AN/UPX-41(C) Digital Interrogator System (Shipboard), as specified in Section 1 when operated in conjunction with the OE-120 antenna, the AN/UPX-29(V), the AN/UPX-24 interface Version 2.1.2., controlled by the CEC [Cooperative Engagement Capability], and the interrogation strategy of no more than one 360 degree Mode 4 interrogation scan out of every seven scans. It is recognized that this system has a back-up antenna that will only be used in emergencies and the Navy acknowledge that no more than one back-up antenna will be in operation in the National Airspace System (NAS).
>
> … [text omitted] ...
>
> 5. Navy be aware that the FAA is conducting 1090 MHz congestion and IFF implementation studies to assess the future viability of the 1090 MHz spectrum environment and the performance of NAS aeronautical surveillance and collision avoidance systems. The results of these studies will determine the limitations of future non-NAS interrogator operations in the US&P [United States and Possessions]. The Navy agrees to begin operations of the AN/UPX-41(C) digital interrogator under the following conditions when operating within 100 NM of the US&P. Ships shall maintain the following separation when operating 4 ship interrogators at the same time within the same geographic area, as defined as 250 NM from the next closest ship interrogator:
>
> a. 50 NM from the center point of FAA designated High Aircraft Density Areas as provided in SPS-18692/1 [Ref. 3 to this plan].
>
> b. 30 NM from the center point of FAA designated Low and Medium Aircraft Density Areas as provided in SPS-18692/1.
>
> 6. Navy, when operating less than 4 ship interrogators at the same time within the same geographic area, as defined as 250 NM from the next closest ship interrogator when

operating within 100 NM of the US&P, ships must maintain a 30 NM separation from the US&P coast.

… [text omitted] ...

8. The FAA and the Navy agree to conduct joint testing to validate the initial operations conditions within a target of three to six months of the date of this signed spectrum certification."

2. AN/UPX-41(C) Test Program Overview

This document is the top-level plan for a test program that addresses item 8 in Ref. 2 (also included immediately above) — "joint testing to validate the initial operations conditions". A multi-experiment test program is envisioned, which is expected to extend over multiple fiscal years. Each experiment will involve planning, data collection, data analysis/and interpretation/findings. The envisioned experiments are:

- Chesapeake Fixed-Base Interrogator Experiment — Following Ref. 2, the primary purpose of this experiment is to verify that the Stage-4 restrictions placed on the operation of AN/UPX-41(C) interrogators are sufficient to protect the National Airspace System (NAS) aircraft surveillance and collision avoidance systems (ASCAS). This experiment is planned for August 18-22, 2014 time frame. It will utilize four fixed-base AN/UPX-41(C) interrogators in the Chesapeake Bay region of Maryland and Virginia, configured as described in Section 1, item 1. FAA ground-based ASCAS systems will be monitored, and the FAA will provide measurement aircraft.
- At-Sea Ship-Based Interrogator Experiment — If the findings of the Chesapeake Fixed-Base Interrogator Experiment indicate that the Stage-4 restrictions might be relaxed without causing harm to the NAS, a tentative new set of restrictions may be developed for proof-of-concept as one part of a budget for all IFF systemsThe purpose of this experiment shall be to determine whether the concept of new restrictions would or would not result in interference to the NAS. A possible time frame for this test is notionally late 2015.

This test program is subject to change for a variety of reasons — e.g., unexpected findings of the measurement experiments, shifting priorities of the FAA and Navy, and changes in appropriation levels. The bulk of this document addresses the Chesapeake Fixed-Base Interrogator Experiment.

3. Overview of Experiment

3.1. Purposes

The primary purpose of this experiment is to collect data to validate that the Stage-4 criteria set forth in Ref. 2 do not cause degradation of NAS ASCAS.

A second purpose of the test is to provide data that can be used to validate a simulation of the impact of AN/UPX-41(C) interrogators on the NAS. The intent is that, once validated, this simulation can then be used to predict the impact of AN/UPX-41(C) interrogators, configured as described in Ref. 2, for other scenarios — i.e., number and location of AN/UPX-41(C) interrogators (coastal waters, airborne, and land based); number and location of NAS systems — for which live testing may not be feasible.

The third purpose of this test is to determine the extent (if any) to which the Stage-4 restrictions, and subsequent radio frequency assignments (RFA), can be relaxed without degrading NAS systems. An aggregate analysis that includes all military IFF activity may be required to achieve this outcome.

3.2. Schedule

Planned dates for test-related activities are:

- **July 15-17, 2014**: Pre-test/dry-run involving personnel and procedures to be utilized during live testing, as well as ground-based Navy interrogators and ground-based FAA ASCAS and data collection systems.
- **July 23-25, 2014**: Contingency/backup dates for pre-test/dry-run.
- **August 18-22, 2014**: Live testing involving ground-based Navy interrogators and ground- and aircraft-based FAA ASCAS and data collection systems.
- **August 25-29, 2014**: Contingency/backup dates for live testing.

3.3. Methodology

3.3.1. Methodology Summary

The basic methodology for determining the extent to which non-NAS systems interfere with NAS ASCAS systems is:

1. Determine the metrics that characterize the “operational health” of each ASCAS system type. For the Chesapeake Fixed-Base Interrogator Experiment, these metrics are provided in Section 5 herein.
2. Ranges or thresholds are established for each metric identified in methodology step 1 above — e.g., the threshold between the acceptable and unacceptable ranges. These ranges or thresholds need not be established prior to testing, and may be established after data collection during the data analysis phase. This document does not contain thresholds for metrics with the exception of P_d for the cease buzzer protocol defined in section 7.2.
3. Establish one or more test scenarios. A scenario includes the number, location and technical characteristics of the interrogator being tested as a potential interferer — i.e., the

AN/UPX-41(C) — and the type, number, location and technical characteristics of the potential victim NAS ASCAS systems being monitored. For the Chesapeake Fixed-Base Interrogator Experiment, the potential interferers and victims are listed in the remainder of Section 3.

4. Establish a mechanism for monitoring / assuring safety and procedures for stopping the test if needed.

3.3.2. Methodology Background

The methodology outlined above is essentially the same one that the FAA and the Volpe Center have employed in previous analyses and tests of systems that intentionally radiate electro-magnetic energy — often called Communications, Navigation and Surveillance (CNS) systems in the civil aviation context. Recent applications of this process are described in Refs. 4 and 5. In terms of policy, when a new system requests authorization to transmit in a band having established users, the new system's impact on the systems that already use that band is evaluated. The methodology does not involve the automation systems that utilize the radiating systems' information, for either the candidate "new" or the established systems. This includes FAA, DoD and, Department of Homeland Security (DHS) automation systems that receive surveillance data from NAS ASCAS.

In addition to previous applications to the 1030/1090 MHz surveillance bands, this methodology has been used to assess potential interference situations for VHF air-ground communications (118-137 MHz), Instrument Landing System (ILS) (108-112 MHz), Distance Measuring Equipment (DME) (960-1215 MHz), and Global Positioning System (GPS) (1575 MHz).

3.4. AN/UPX-41(C) Interrogators

3.4.1. Interrogator Locations

The Chesapeake Fixed-Base Interrogator Experiment utilizes four land-based Navy IFF interrogator systems, configured as described in Section 1, item 1. Figure 1 depicts the area involved. It shows the extent of the interrogator main beams and side lobes, as well as the locations of nearby airports.

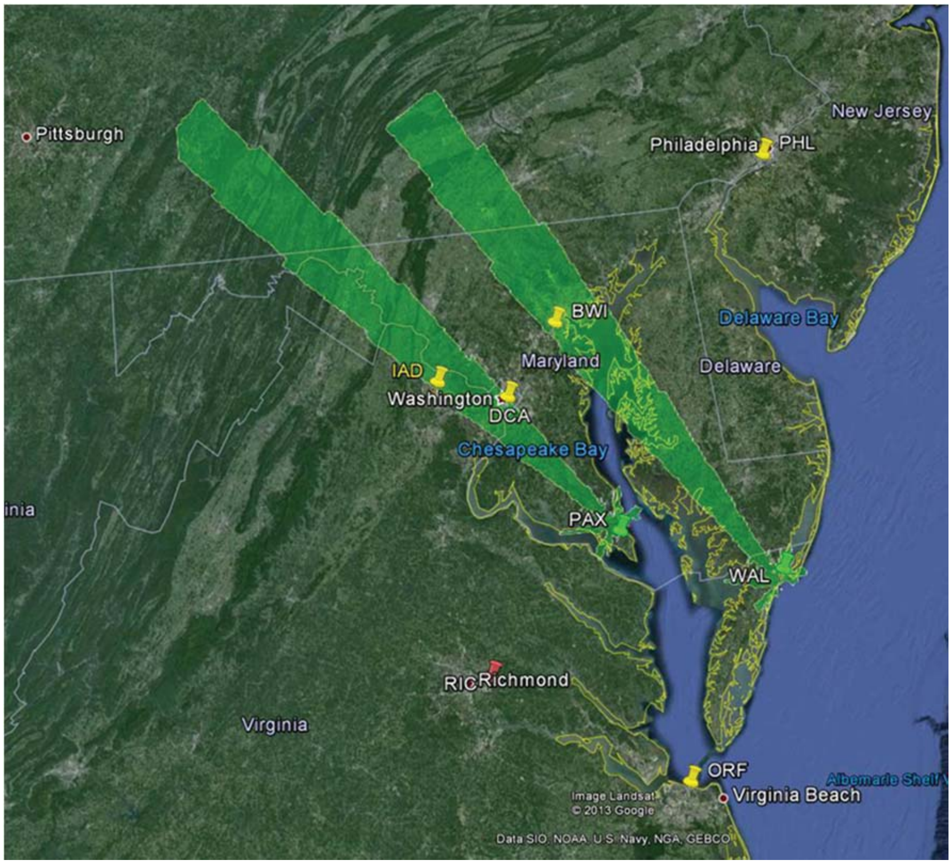


Figure 1 Location of Land-Based Test Interrogators and Nearby Airports, and Coverage Ranges of Interrogator Main Beams and Side Lobes

- Two AN/UPX-29(V) IFF systems with AN/UPX-41(C) interrogators located at the Naval Air Systems Command (NAVAIR) Naval Air Warfare Center Aircraft Division (NAWCAD) Ship/Shore Electronic Systems facility at St. Inigoes, Maryland. A combination of the Webster Field designator, NUI, and part of the building numbers 8225 and 8164, are used as identifiers for these two interrogators. NAWCAD buildings 8225 and 8164 do not have ship combat systems and are stand-alone AN/UPX-29(V) systems with SSDS, CEC, and AEGIS simulators.
- Two AN/UPX-29(V) IFF systems with AN/UPX-41(C) interrogators located at the Naval Sea Systems Command (NAVSEA) Surface Combat Systems Center at NASA Wallops Flight Facility on Wallops Island, Virginia. A combination of the Wallops Flight Facility designator, WAL, and part of the Navy designations, V-10 and V-24 (which are building numbers), are used as identifiers for these two interrogators. Wallops building V-24 houses the configuration which is representative of SSDS, CVN and Amphibious class ship installations. Wallops building V-10 houses the configuration which is representative of AEGIS CG/DDG installations.

Descriptions of the AN/UPX-41(C) interrogator (Section 9.6), AN/UPX-29(V) IFF system (Section 9.7) and CEC (Section 9.8) are provided in an appendix.

These interrogators were selected for a combination of reasons:

- Availability – Interrogators are in-place and some previously had authorizations to transmit. The authorizations have lapsed and need to be temporarily reauthorized for this experiment. The previous assignments had temporary sector blanking requirements which will need to be removed for 360-degree operation.
- Economics – Using land-based interrogators eliminates the need for one or more ships to be put to sea. This results in significant fuel and labor cost savings, and enables experiments to be conducted over a longer duration than would be possible using ship-based interrogators.
- Location – The planned test interrogators are located close to the high-density northeast air traffic corridor.

3.4.2. AN/UPX-41(C) Scan Modes

AN/UPX-41(C) interrogators, configured as described in Section 1, can operate in the three scan modes summarized immediately below. Having an electronically steered antenna enables the AN/UPX-41(C) to virtually instantaneously switch between scan modes.

- 360-degree scan – AN/UPX-41(C) interrogates six full scans (360 degree rotations) of Selective Identification Feature (SIF) Modes (1, 2, 3/A and C) in which every other interrogation is supermoded with Mode 5. The seventh full scan has Mode 4/SIF interlaced modes (1, 4, 2, 4, 3A, 4, C, etc.) and all Mode 4 interrogations are supermoded with Mode 5. The interrogation rate is 250 per second (4000 μsec between interrogations), and there are 1,024 interrogations in a full 360-degrees scan. This scan mode is used most of the time.
- Sector scan – Similar to a 360-degree scan, except interrogations (250 PRF) are made over a smaller band of azimuth values.
- Popup scan – Popups are requests to the AN/UPX-29(V) interrogator from the AEGIS/SSDS ID doctrine, or CEC doctrines and crew, to request immediate identification of a target using specific interrogation modes – SIF (Modes 1,2,3/A,C…) or Mode 4 (4,4,4,4..) with Mode 5 supermoded on every other interrogation. Upon receipt of a Popup request, the AN/UPX-29(V) instantaneously halts 360-degree or Sector interrogations (pausing its rotation), redirects the antenna beginning 20 interrogations (approximately 7 deg) prior to the requested azimuth and conducts the requested interrogations (250 PRF) through 20 interrogations past the requested azimuth (total of approximately 14 deg). Rotation then resumes from the pause point.

3.4.3. Only 360 Degree Scan Mode To Be Tested

As described immediately above, the AN/UPX-29(V) interrogator system using the AN/UPX-41(C) possesses the capability to provide full scan (360 degree rotation) interrogations in combination with requested interrogations from both a Combat System (CS) / Cooperative Engagement Capability (CEC) and from operators. The AN/UPX-29(V) system may also receive Sector requests and Popup requests from the CEC and/or from the host CS without being interfaced with (or bypassing) the CEC.

Popup scans (Popups) redirect the antenna from normal rotation, to 20 interrogations (approximately 7 deg) before the azimuth requested and interrogate at the associated PRF

(250 per sec) until 20 interrogations after the requested azimuth for a total of 40 interrogations. At this PRF, it takes 160 msec of interrogation time per Popup. Popup processing also requires additional 20 msec to provide the target report; therefore, Popups occupy the interrogator for 200 to 250 msec (typically 4 Popups and no more than 5 can be accomplished in one second).

All requested interrogations (Sector or Popup) maintain the same power and interrogation rate (250 per second). Requested modes from all operators are combined with requested modes from combat systems and are interlaced (1, 2, 3A, C, …) continuously or throughout the sector of interest (from Sector Requests).

Target reports resulting from Popups are provided to the CS/CEC for all targets that are ±3 deg and ±1 NM from the requested Popup location. Other targets in the azimuth of these interrogations are not provided to the operator or to the CS/CEC. Immediately after a Popup scan is completed, the AN/UPX-29(V) returns to the last azimuth of full scan rotation prior to the Popup and continues CI/Sector requested interrogations.

While the use of Popups by CEC doctrine is limited to engagement assurance, operators may still request non-engagement popups for targets of interest. Due to the transient and irregular nature of Popup use in CEC, the impact of Popups will be evaluated by modeling and simulation. The Chesapeake Fixed-Base Interrogator Experiment will test 360-deg full rotation scans exclusively.

3.5. Secondary Surveillance Radar (SSR) Measurement Sites

3.5.1. Measurement Sites

Eight Secondary Surveillance Radar (SSR) measurement sites are planned. These are summarized in Table 1 and shown in Figure 2. Their maximum coverage ranges are color-coded by system type:

- Yellow / Mode S – Washington Dulles International Airport (IAD), Ronald Reagan Washington National Airport (DCA), Andrews Air Force Base (ADW), and Norfolk International Airport (ORF)
- Red / ATCBI-5 – Richmond International Airport (RIC)
- Violet / Condor MK2D Monopulse Secondary Surveillance Radar (MSSR, part of the AN/GPN-30 radar system) – Patuxent River Naval Air Station (Trapnell Field, NHK)
- Dark Blue / ATCBI-6M – Oceana, Virginia (QVR)
- Light Blue / ATCBI-6 – The Plains, Virginia (QPL)

The SSR types, locations and ranges are taken from the FAA's radar data base as of 5/8/2012.

Table 1 Planned SSR Measurement Sites (Total of 8)

Symbol	Location	Owner	Model	Domain	Max. Range	Modes	Traffic Density	On-Site Collection
ADW	Andrews AFB, MD	FAA	Mode S	Terminal	60 NM	A, C, S	High	TBD
DCA	Reagan Airport, VA	FAA	Mode S	Terminal	60 NM	A, C, S	High	TBD
IAD	Dulles Airport, VA	FAA	Mode S	Terminal	60 NM	A, C, S	High	TBD
ORF	Norfolk Airport, VA	FAA	Mode S	Terminal	60 NM	A, C, S	Medium	TBD
RIC	Richmond Airport, VA	FAA	ATCBI-5	Terminal	60 NM	A, C	Medium	TBD
NHK	Patuxent River NAS, MD	Navy	Condor MK2D	Terminal	120 NM	A, C, 2	High	TBD
QVR	Oceana, VA	FAA	ATCBI-6M	En Route	250 NM	A, C, S, 2, 4	—	TBD
QPL	The Plains, VA	FAA	ATCBI-6	En Route	200 NM	A, C, S*, 2	—	TBD

*This radar is currently not configured to transmit Mode S interrogations.

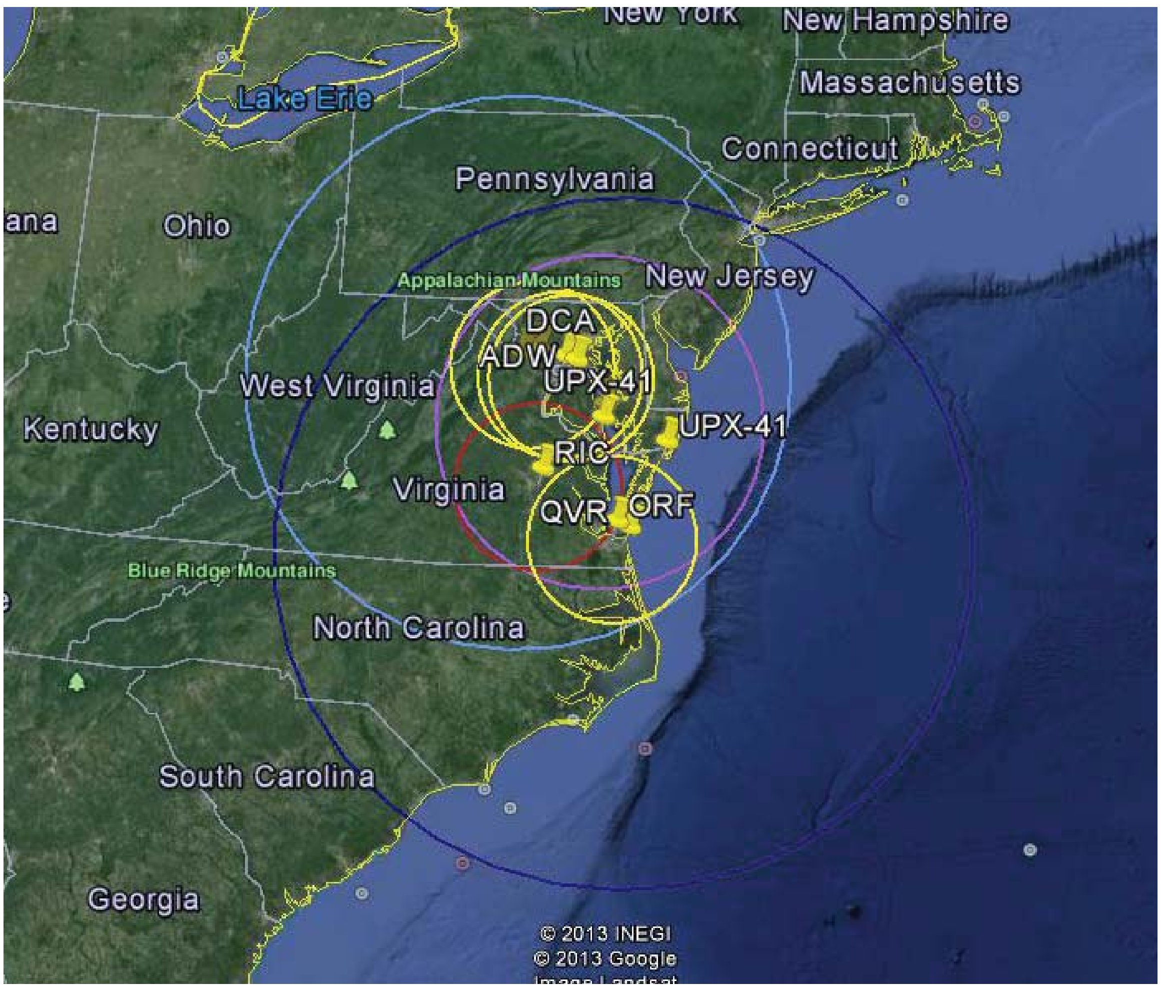


Figure 2 Coverage Areas for SSR Measurement Sites

AN/UPX-41(C) interrogator and SSR coordinates, and approximate interrogator-SSR distances and the bearing angles (clockwise from north) of the SSRs relative to the AN/UPX-41(C) interrogators, are shown in Table 2. Also shown is the approximate minimum altitude (ft, MSL) above an SSR at which the signals from each interrogator can be received. (Minimum reception altitudes were calculated using a 4/3rds earth model and ignoring any terrain blockage that may occur; thus a higher altitude may be required for signal reception.)

All eight SSR locations are within the coverage ranges of all four AN/UPX-41(C) interrogators

Table 2 AN/UPX-41(C) Interrogator - SSR Geometric Relationship

AN/UPX-41(C) INTERROGATOR / SSR			ID / Lat (deg) / Lon (deg) / Ant Elev (ft, MSL)			
			NUI 8225	NUI 8164	WAL V-10	WAL V-24
			38.136226	38.137657	37.856798	37.862263
			-76.432809	-76.437150	-75.466394	-75.457063
SSR			111	93	148.6	184.5
			RANGE* (NM), BEARING† (deg), MIN VIS ALT (ft, MSL)			
ADW	Andrews AFB, MD		45.4	45.2	87.5	87.6
Lat/Lon	38.81222	-76.866944	333.3 / 153.1	333.5 / 153.3	311.3 / 130.5	311.0 / 130.1
Field Elevation (ft, MSL)		280	699	739	3,476	3,324
DCA	Reagan Airport, VA		51.5	51.3	95.2	95.3
Lat/Lon	38.851916	-77.037699	326.6 / 146.2	326.7 / 146.4	309.3 / 128.3	309.0 / 128.0
Field Elevation (ft, MSL)		14.9	986	1,033	4,252	4,780
IAD	Dulles Airport, VA		68.6	68.4	114.5	114.7
Lat/Lon	38.947444	-77.459944	315.5 / 134.8	315.5 / 134.9	305.4 / 124.2	305.2 / 123.9
Field Elevation (ft, MSL)		312	2,048	2,114	6,547	6,346
RIC	Richmond Airport, VA		56.6	56.5	90.8	91.3
Lat/Lon	37.505167	-77.319667	228.4 / 47.8	228.2 / 47.6	257.1 / 76.0	257.0 / 75.9
Field Elevation (ft, MSL)		167	1,263	1,321	3,784	3,664
ORF	Norfolk Airport, VA		75.2	75.3	67.5	68.0
Lat/Lon	36.894611	-76.201222	171.5 / 351.6	171.3 / 351.5	211.6 / 31.1	211.8 / 31.3
Field Elevation (ft, MSL)		27	2,580	2,681	1,833	1,750
NHK	Patuxent River NAS, MD		9.8	9.7	52.0	52.3
Lat/Lon	38.298708	-76.412069	5.7 / 185.8	7.0 / 187.0	300.9 / 120.3	300.3 / 119.7
Field Elevation (ft, MSL)		39	0	0	907	835
QVR	Oceana, VA		80.9	81.1	67.0	67.5
Lat/Lon	36.827500	-76.013889	165.6 / 345.8	165.4 / 345.7	203.2 / 22.8	203.4 / 23.1
Site Elevation (ft, MSL)		26	3,074	3,186	1,799	1,715
QPL	The Plains, VA		74.7	74.5	122.1	122.4
Lat/Lon	38.882222	-77.703333	307.2 / 126.4	307.2 / 126.4	300.9 / 119.5	300.7 / 119.3
Site Elevation (ft, MSL)		1,339	2,520	2,593	7,584	7,373

*Green highlight indicates that the Interrogator-SSR distance is less than the SSR coverage range

†First figure is bearing of connecting path at interrogator; second is bearing of path at radar.

(nominally 280 NM). Thus an aircraft above an SSR at sufficient altitude is visible to all four AN/UPX-41(C) interrogators. For the two AN/UPX-41(C) interrogators at NAWCAD/St. Inigoes, the minimum reception altitudes above the six airports are all less than 3,200 feet and in three cases (ADW, DCA and NHK), are less than 1,000 feet. In fact, the terminal area boundaries (60 NM radius) for ADW, DCA, IAD, RIC and ORF are entirely within the coverage range of all four AN/UPX-41(C) interrogators.

The converse situation — AN/UPX-41(C) interrogators within the coverage range of SSRs — is less significant in terms of interference analysis. However, since the terminal SSR coverage ranges are less than a third of those for the AN/UPX-41(C) interrogators, it provides an indication of the proximity of the interrogator sites to the victim SSR. Six of the SSRs (all but IAD and ORF) have at least two AN/UPX-41(C) interrogators within their coverage range. There are three cases where an AN/UPX-41(C) interrogator is within the maximum coverage range of an SSR for a high-density airspace (ADW, DCA and NHK).

Figure 3 is a histogram of the interrogator-SSR ranges in Table 2. The ADW and NHK SSRs are within 50 NM of the two AN/UPX-41(C) interrogators at NAWCAD. The six remaining SSRs are all more than 50 NM from both interrogators. The SSRs having the smallest average range to the four interrogators are: NHK, 30.9 NM; ADW, 66.4 NM; ORF, 71.6 NM; and DCA, 73.3 NM. Thus, this experiment involves interrogator-SSR ranges compatible with a useful assessment of the validity of the Stage-4 requirement that four interrogators, each more than 50 NM from the center of a high-density traffic region, should not degrade NAS ASCAS

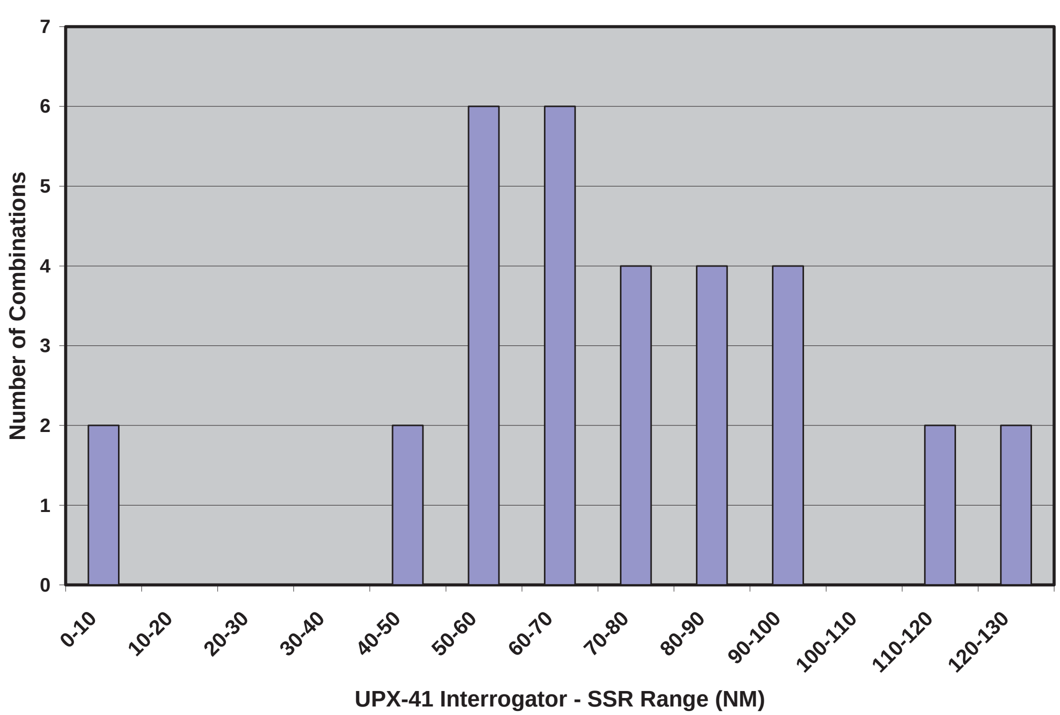


Figure 3 Histogram of AN/UPX-41(C) Interrogator – SSR Ranges

systems. Moreover, there are four interrogator-SSR pairs separated by roughly 50 NM (ADW and DCA relative to the AN/UPX-41(C) systems at NAWCAD).

3.6. ADS-B Radio Station Measurement Sites

3.6.1. Measurement Sites

ADS-B radio stations planned as measurement sites for this test are detailed in Table 3.

Table 3 Planned ADS-B Radio Station Measurement Sites (Total of 10)

Service Volume	Latitude	Longitude	Location
SV171-03	39.1033030	-77.1541929	Montgomery County, MD
SV017-01	38.9786983	-76.3092971	Stevensville (Queen Anne's County), MD
SV186-02	38.8579988	-77.0443940	Reagan National Airport, VA
SV186-01	38.8495016	-77.0410037	Reagan National Airport, VA
SV036-01	38.5493946	-76.9495082	Indian Head (Charles County), MD
SV247-01	38.4909010	-76.1355972	Cambridge (Dorchester County), MD
SV158-04	37.5242972	-76.7640925	Middle Peninsula Regional Airport, West Point (King William County), VA
SV158-01	37.4076962	-77.5215912	Chesterfield County Airport, VA
SV171-02	37.2513986	-75.9744072	Cape Charles (Northampton County), VA
SV143-01	36.6819608	-76.6010589	Suffolk Executive Airport, VA

The ten ADS-B radio station locations, along with those of the AN/UPX-41(C) interrogators and the Class B and C airports in the area, are shown in Figure 4. Unlike terminal radars, which are normally located at the primary airport they serve, ADS-B ground stations are often not located on the primary airport served, preventing interference to the radar. Moreover, the SSR measurement geometry advantage of an airport location — the cross-range resolution degrades linearly with distance from the SSR site — does not apply to ADS-B. All that is required is line-of-sight connectivity to the airspace under surveillance. However, each terminal area served by ADS-B has a designated service volume which may involve utilizing data collected at multiple ADS-B ground stations. These ADS-B stations are used by controllers to provide traffic advisory services. They are not currently used to provide separation services, but will do so in the future (when aircraft ADS-B equipage is more widespread).

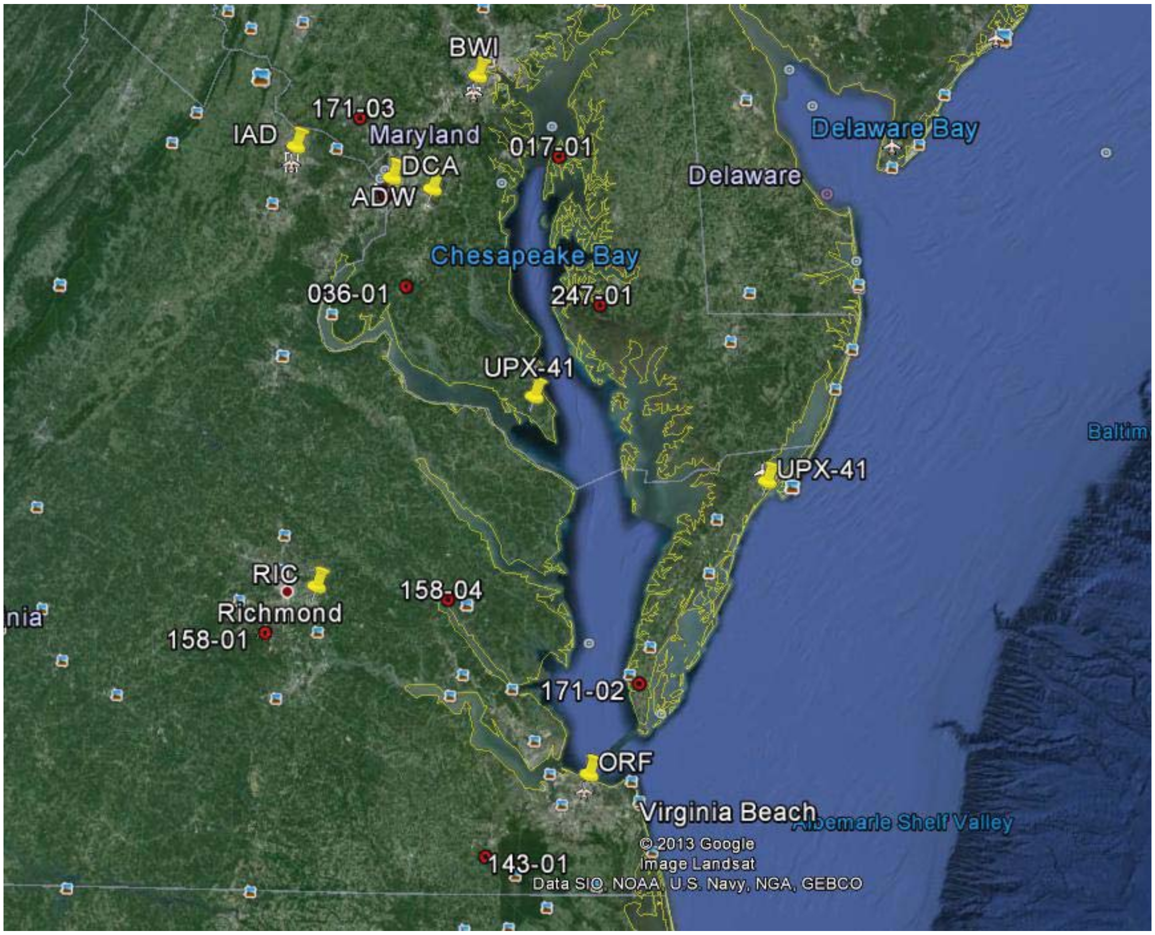


Figure 4 Planned ADS-B Radio Station Measurement Sites

Coordinates for each ADS-B ground station and the range and bearing from the interrogators are given in Table 4. Also shown is the approximate minimum altitude (ft, MSL) above an ADS-B radio station at which each interrogator can be received (calculated using a 4/3^{rds} earth model and ignoring any terrain blockage that may occur).

Similar to the SSRs, all of the ADS-B ground station locations are within the coverage ranges of all four AN/UPX-41(C) interrogators. Thus, an aircraft above an ADS-B ground station at sufficient altitude is visible to all four AN/UPX-41(C) interrogators. For the two AN/UPX-41(C) interrogators at NAWCAD/St. Inigoes, the minimum reception altitudes above nine of the ten sites (the exception being SV143-01) are less than 2,500 feet. Moreover, the region within a 60 NM radius of each ADS-B site is entirely with the coverage range of all four AN/UPX-41(C) interrogators.

Table 4 AN/UPX-41(C) Interrogator-ADS-B Radio Station Distances, Bearings and Minimum Visible Altitudes

AN/UPX-41(C) INTERROGATOR / ADS-B Radio Station			ID / Lat (deg) / Lon (deg) / Ant Ht (ft, MSL)			
			NUI 8225	NUI 8164	WAL V-10	WAL V-24
			38.136226	38.137657	37.856798	37.862263
			-76.432809	-76.437150	-75.466394	-75.457063
			111	93	148.6	184.45
			RANGE* (NM), BEARING† (deg), MIN VIS ALT (ft, MSL)			
SV171-03	Montgomery Co., MD		67.2	67.0	109.1	109.2
Lat/Lon	39.103303	-77.154193	329.9 / 149.4	330.0 / 149.6	313.7 / 132.7	313.5 / 132.4
Site Elevation (ft, MSL)		448	1,950	2,017	5,863	5,664
SV017-01	Queen Anne's Co., MD		50.8	50.8	78.1	78.1
Lat/Lon	38.978698	-76.309297	6.5 / 186.6	6.8 / 186.8	329.7 / 149.2	329.3 / 148.7
Site Elevation (ft, MSL)		12	955	1,008	2,644	2,499
SV186-02	Reagan National A/P, VA		52.0	51.8	95.6	95.8
Lat/Lon	38.857999	-77.044394	326.5 / 146.1	326.7 / 146.3	309.3 / 128.4	309.0 / 128.0
Site Elevation (ft, MSL)		16	1,010	1,058	4,302	4,135
SV186-01	Reagan National A/P, VA		51.5	51.3	95.2	95.3
Lat/Lon	38.849502	-77.041004	326.4 / 146.0	326.5 / 146.1	309.2 / 128.2	308.9 / 127.9
Site Elevation (ft, MSL)		22	984	1,031	4,255	4,090
SV036-01	Indian Head, MD		34.8	34.6	81.5	81.7
Lat/Lon	38.549395	-76.949508	315.6 / 135.3	315.7 / 135.4	301.1 / 120.2	300.7 / 119.8
Site Elevation (ft, MSL)		197	315	341	2,922	2,792
SV143-01	Suffolk Executive A/P, VA		87.5	87.6	88.9	89.5
Lat/Lon	36.6819608	-76.6010589	185.3 / 5.2	185.2 / 5.1	218.0 / 37.3	218.1 / 37.4
Site Elevation (ft, MSL)		64	3,700	3,816	3,626	3,511
SV247-01	Cambridge, MD		25.5	25.5	49.5	49.5
Lat/Lon	38.490901	-76.135597	33.3 / 213.5	33.8 / 214.0	320.4 / 140.0	319.8 / 139.4
Site Elevation (ft, MSL)		6	104	124	788	713
SV158-04	West Point, VA		39.9	39.9	64.9	65.5
Lat/Lon	37.524297	-76.764092	203.3 / 23.1	203.0 / 22.8	252.5 / 71.7	252.4 / 71.6
Site Elevation (ft, MSL)		15	483	523	1,645	1,567
SV158-01	Chesterfield Co. A/P, VA		67.7	67.6	101.6	102.1
Lat/Lon	37.407696	-77.521591	230.2 / 49.5	230.0 / 49.4	255.3 / 74.0	255.2 / 73.9
Site Elevation (ft, MSL)		203	1,986	2,059	4,944	4,808
SV171-02	Cape Charles, VA		57.3	57.5	43.6	44.2
Lat/Lon	37.251399	-75.974407	157.5 / 337.8	157.3 / 337.6	213.9 / 33.6	214.1 / 33.8
Site Elevation (ft, MSL)		20	1,310	1,385	545	500

*Green highlight indicates that the Interrogator-ADS-B distance is less than 60 NM.
†First figure is bearing of connecting path at interrogator; second is bearing of path at ADS-B station.

The converse situation — AN/UPX-41(C) interrogators within a given range of an ADS-B site — is less significant in terms of interference analysis. However, it provides an indication of the proximity of the interrogator sites to the victim site. Seven of the ADS-B sites have at least two AN/UPX-41(C) interrogators within their coverage range.

Figure 5 is a histogram of the interrogator-ADS-B ranges from Table 4. Since the ten planned ADS-B measurement sites are distributed throughout the test area, the interrogator-ADS-B station ranges are more evenly distributed than the interrogator-SSR ranges are. Included in this distribution are ten interrogator-ADS-B combinations with ranges of less than 50 NM. Thus the ADS-B stations are well positioned to provide useful data on the impact of AN/UPX-41(C) interrogators on ADS-B functionality.

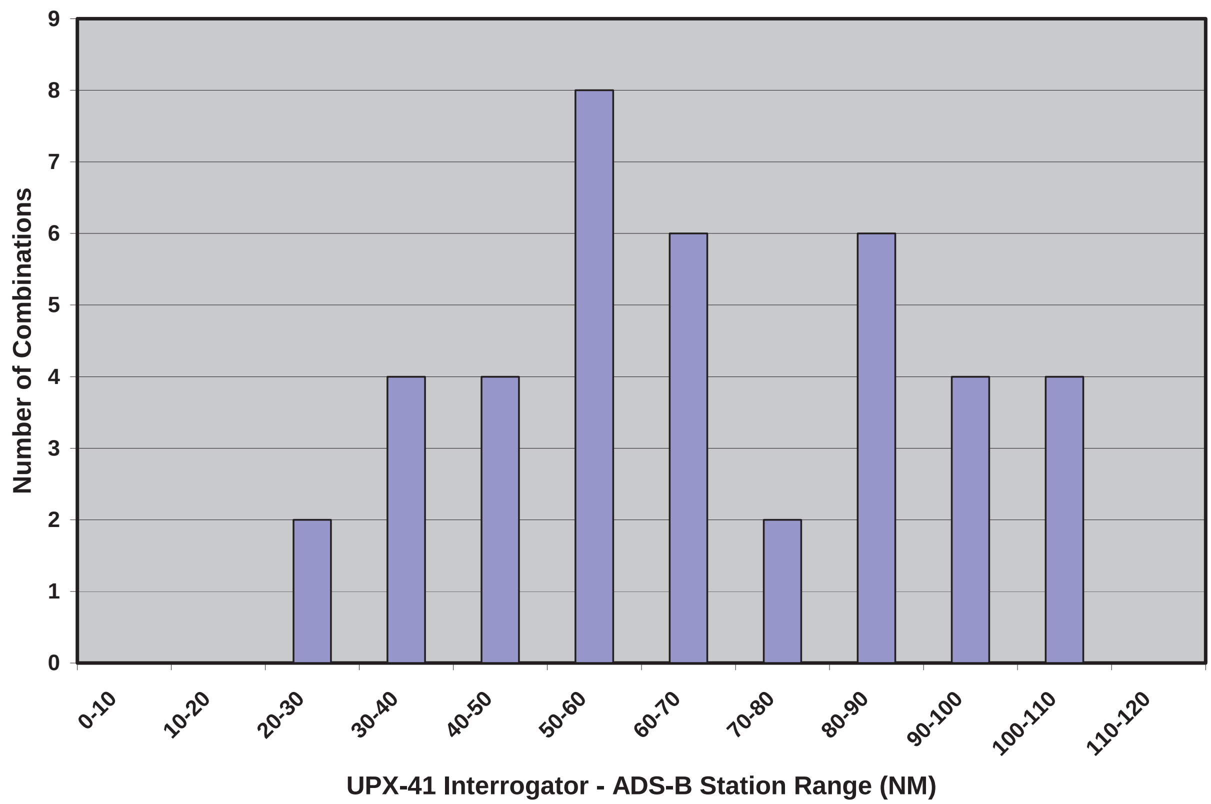


Figure 5 Histogram of AN/UPX-41(C) Interrogator – ADS-B Radio Station Ranges

Measurements at ADS-B ground sites will include both received (air-to-ground) and transmitted (ground-to-air) messages. During post-test analysis, ground station measurements will be "matched" with flight test aircraft measurements.

3.7. Measurement Aircraft

For this experiment, the FAA William J. Hughes Technical Center Technical (WJHTC) will provide an aircraft instrumented to collect 1030 MHz and 1090 MHz data that enable post-test evaluation of the impact of AN/UPX41(C) interrogators on:

a) Transponder occupancy — An issue for SSR uplink and TCAS performance;
b) False Replies Unsynchronized In Time (FRUIT) levels — An issue for the performance of TCAS, SSR downlink, and ADS-B IN applications;

c) ADS-B OUT — Messages broadcast by the FAA WJHTC aircraft, supporting estimation of ADS-B air-to-ground performance;
d) ADS-B IN — Messages received from ground stations for the Traffic Information Services – Broadcast (TIS-B) and Automatic Dependent Surveillance – Rebroadcast (ADS-R) services, supporting estimation of ADS-B ground-to-air performance; and
e) ADS-B IN — Messages received from other ADS-B equipped aircraft, supporting estimation of ADS-B air-to-air performance.

Measurement aircraft flight test trajectories will be selected to foster accomplishment of these evaluation objectives. To support the measurement of the impact of the AN/UPX-41(C) on SSR uplinks and downlinks, measurements will be collected in airspace regions of varying densities — e.g., over airports and along heavily traveled routes. Also, in support of determining the AN/UPX-41(C) impact on occupancy, measurements will be collected while flying toward, directly over and away from an AN/UPX-41(C) interrogator, in order to assess the effect and extent of the AN/UPX-41(C) side lobes.

Concerning items c) and d), estimating the impact of the AN/UPX-41(C) on ADS-B will require simultaneous data collection at ADS-B ground stations. To estimate the impact on ADS-B air-to-ground performance, the aircraft will record transmitted ownship ADS-B messages and their time of transmission. To estimate the impact on ADS-B ground-to-air performance, the aircraft will record received Automatic Dependent Surveillance – Rebroadcast (ADS-R) and Traffic Information Services – Broadcast (TIS-B) messages. In both cases, messages recorded on the aircraft will be compared with those recorded by the ground stations.

Concerning item e), estimating the impact of the AN/UPX-41(C) on ADS-B air-to-air performance, the measurement aircraft will collect and record ADS-B messages broadcast on 1090 MHz by Target of Opportunity (TOO) aircraft.

To ensure the applicability of the test results to the future NAS, the FAATC aircraft must be equipped with a transponder that is compliant with RTCA Minimum Operational Performance Standards (MOPS), DO-260B (Ref. 6).

3.8. TCAS Role in Experiment

The WJHTC flight test engineering group will determine the impact to TCAS from the AN/UPX-41(C) using analysis and simulation. TCAS data will be collected by the WJHTC measurement aircraft under conditions where the AN/UPX-41(C) interrogators are ON and OFF, and will include:

(1) 1030 and 1090 MHz TCAS surveillance interrogations and replies,

(2) 1030 MHz TCAS air-to-air coordination interrogations and broadcast interrogations

3.9. ASCAS Systems Not Involved in Experiment

The four NAS ASCAS systems identified immediately below will not be involved in the Chesapeake Fixed-Base Interrogator Experiment, as none has an installation suitable for testing in the region. The impact of the AN/UPX-41(C) on these systems will be addressed by simulation.

- ASDE-X Multilateration –Airport Surface Detection Equipment, Model X, (ASDE-X), employs multilateration (on aircraft transponder replies) for surveillance of aircraft on the surface of major airports. The nearest ASDE-X installations to the AN/UPX-41(C) interrogators planned to be used in the Chesapeake Bay Test is at Ronald Reagan Washington National Airport (DCA). The minimum altitude visible to the AN/UPX-41(C) interrogators used in the experiment is 986 ft, MSL. Thus, aircraft on surface of DCA will not be visible to the AN/UPX-41(C) interrogators.
- PRM-A – Precision Runway Monitor – Alternate (PRM-A) performs the function of a PRM radar, but uses multilateration technology. PRM-A ground stations are generally located on both sides of the approach corridor contain the closely-spaced parallel runways of interest. Currently, the only operational PRM in the NAS is at Detroit Metropolitan Wayne County Airport (DTW).
- WAM – Wide Area Multilateration (WAM) performs the function of an en route radar, but uses multilateration technology. There are two WAM installations in the United States – in Western Colorado and the Juneau, Alaska area.
- PRM – Precision Runway Monitor (PRM) is a high-interrogation-rate, high-precision beacon radar that uses ATCRBS Mode A and Mode C interrogations and replies to monitor simultaneous instrument approaches to closely-space parallel runways. Airports at which PRM is in use in the United States include Minneapolis, St. Louis, Philadelphia, San Francisco, and Atlanta. The FAA is evaluating replacement of the PRM systems at these locations with PRM-A.

4. Participating Organizations

4.1. Points of Contact

4.1.1. Department of the Navy

Naval Sea Systems Command (NAVSEA)
Program Executive Office (PEO)
Integrated Warfare Systems (IWS)
William McLaughlin, william.p.mclaughlin@navy.mil
Robert Langan, Robert.Langan@navy.mil
Robert Rumbaugh, Robert.Rumbaugh@navy.mil

Naval Air Systems Command (NAVAIR)
Naval Air Warfare Center Aircraft Division (NAWCAD)
Identification Systems, Ship & Shore Based Electronics Systems
Mark Cianflone, Mark.Cianflone@navy.mil

Johns Hopkins University Applied Physics Laboratory (JHU APL)
Richard Talbott, richard.talbott@jhuapl.edu

4.1.2. Federal Aviation Administration (FAA)

ATO Technical Operations, Spectrum Engineering Services Group
Chris Tourigny, Chris.Tourigny@faa.gov

ATO Program Management Organization
Robert Nichols, robert.nichols@faa.gov

NextGen Organization
James Baird, james.baird@faa.gov

William J. Hughes Technical Center Technical (WJHTC)
Michael Prata, michael.prata@faa.gov

4.1.3. US DOT Volpe Center

Technical Center for Air Traffic Systems and Operations
Air Navigation and Surveillance Division
Allen Mackey, Allen.Mackey@dot.gov

4.2. Subject Matter Experts (SMEs)

The FAA will provide Subject Matter Experts (SMEs) who will: (a) determine the parameters (metrics) to be used to assess the impact of AN/UPX-41(C) interrogators on NAS ASCAS systems; and (b) to assess the degree (e.g., by assigning a threshold to each parameter) of the impact, taking into account future traffic densities and the need to reserve spectrum for all other IFF systems. Candidate parameters/metrics are provided in Chapter 5. Additionally, a SME will advise the project team on the most effective ways to coordinate with FAA Air Traffic Operations personnel on the conduct of a test involving NAS systems.

A current list of SMEs is given in Table 5.

Table 5 Planned SMEs and Area of Expertise

Area of Expertise	SME	Organization	Duty Station
Mode S SSR	Joe Yannone	FAA ATO AJW-1451	WJHTC
ATCBI-5 SSR	Andy Leone	FAA ADA ANG-E55	WJHTC
ATCBI-6/6M SSRs	Michael Thurston	FAA ATO AJW-1472	MMAC
Condor MK2D (ASR-11 SSR)	Diane Fenton	FAA ATO AJW-1471	MMAC
ADS-B	Andy Leone	FAA ADA ANG-E55	WJHTC
Multilateration	Ray McDonald	Regulus / FAA ATO AJM-23	FAA HQ
TCAS	TBD	FAA WJHTC	WJHTC
Aircraft Measurements	Thomas Pagano	Regulus/FAA WJHTC	WJHTC
Air Traffic Operations	TBD	Regulus	TBD

4.3. Intra- and Inter-Agency Coordination

This test will include monitoring and evaluation of AN/UPX-41(C) impacts to NAS ASCAS systems. This test will build upon previous analysis that investigated impact in terms of transponder occupancy and the additional number of transponder replies generated by the aggregate of ship interrogators. The desired outcome of this test and analysis effort is to:

1. Acquire sufficient data (parameters and amounts) for the FAA offices responsible for each NAS ASCAS to conduct analysis of the impact of the AN/UPX-41(C) on their ASCAS system
2. Determine if the safety risk mitigations specified in Ref. 2 are sufficient to protect each ASCAS system

In order to accomplish this test effort, the FAA has laid-out the following order of events:

1. Request the FAA office responsible for each NAS ASCAS to define scenarios to be tested and performance metrics
2. Determine what specific airborne data is required and what system performance monitoring is needed (parameters)
3. Develop test approach document (this document)
4. Obtain Navy's approval of the test approach
5. Obtain FAA approval of the test approach
6. Determine logistics of test, to include location, time, personnel, scenarios, and safety risk mitigations, including CEASE BUZZER procedures
7. Navy apply for frequency assignments for platforms participating in the test event at least 90 days in advance of the test.
8. Schedule FAA aircraft at least 90 days prior to the test
9. Conduct the test
10. Analyze data collected
11. Perform data post- analysis for ground-based systems
12. Perform post-analysis for airborne systems
13. Conduct future capacity prediction study that shows no impact and produces interference thresholds
14. Develop report, which includes drafting with recommendations/ safety risk mitigations on initial criteria and suggestions for increasing the number of platforms that takes into account the aggregate impact of all non-NAS DoD interrogators

15. Obtain concurrence for final report from the Navy and FAA
16. Vet the report through each NAS system owner/OSD for decision on acceptability
17. Publish the safety risk management documentation with risks identified, mitigations identified, and risks accepted by signature.

5. NAS ASCAS Data Collection/Analysis Parameters

5.1. SSR Installations – Mode S, ATCBI-5, ATCBI-6, ATCBI-6M, Condor MK2D

Basic characteristics of the SSR installations to be tested during this experiment are shown in Table 1 and in Section 3.5.1. Descriptions of SSRs are presented in Section 9.1, and a summary table of ASCAS characteristics, including those of SSRs, is presented in Section 10. Specifications for selected SSRs can be found in Ref. 7 (ATCBI-6) and Ref. 8 (PRM).

Subsection 5.1.1 presents generic parameters that are often used to characterize SSR performance. However: (a) In implementation, each generic parameter may result in multiple actual parameters — for example, probability of detection is often quantified separately by target type (ATCRBS, Mode S, Mode 2, etc.); and (b) SSR designs may not be conducive to providing data for a particular parameter. Subsections 5.1.2 and 5.1.3 discuss methods for testing Mode S and the ATCBI-6/ASR-11 SSRs, respectively. Subsections 5.1.5 address the RBAT and MDAS software tools for analyzing SSRs.

5.1.1. SSR Generic Performance Parameters

Round Reliability – Round reliability is the probability that a single interrogation by the SSR elicits a reply that the SSR decodes correctly, and is determined separately for ATCRBS and Mode S interrogations. Reduction in round reliability may be caused by the AN/UPX-41(C). To facilitate interpretation, it is useful to know the 1030/1090 MHz environment (interrogation and fruit levels) when round reliability is measured.

Round reliability requires recording at the SSR site, and is not available from RBAT. Some SSRs must be initiated ("booted") in a special test mode to monitor round reliability and some do not have this capability. Conversely, Mode S radars monitor and can record the results of each interrogation. For Mode S SSRs, MSAT computes the percentage of interrogations with a valid reply – i.e., round reliability. Collecting round reliability data requires coordination with system owner and/or operator.

Mode S Re-interrogation Rate – For SSRs capable of interrogating and receiving messages utilizing the Mode S protocol (i.e., Mode S, ATCBI-6, and ATCBI-6M), the increase in the rate that aircraft are re-interrogated when one or more AN/UPX-41(C)s are operating is of interest. Mode S re-interrogation rate should be determined separately for intervals when the AN/UPX-41(C) is ON/OFF. To facilitate interpretation, it is useful to know the 1030/1090 MHz environment (interrogation and fruit levels) during the same time period. Re-interrogation rate is not available from RBAT but is available from MSAT. Collecting re-interrogation data requires recording at the SSR site ("data extraction"), which entails coordination with the site owner/operator.

Run Length – Run length, also known as hit count, is the number of transponder replies that are observed as the antenna beam of an ATCRBS sensor scans past a specific aircraft. Run length may be reduced by interrogations from one or more AN/UPX-41(C) systems. Run length pertains to the individual interrogations of an SSR, and is sometimes used as a surrogate for round reliability. RBAT has an included program, Scan Summary, which calculates the run length or a related parameter, hit count.

Identity Confidence and Reliability – Identity confidence is the percent of times that the Mode A code is high confidence. Identity reliability is the percent of times that the Mode A code from the beacon message and the track confidence are the same as the Mode A code from the existing track and track confidence. Confidence and reliability statistics are available in RBAT.

Altitude Confidence and Reliability – Altitude confidence is the percent of times that the track has a positive altitude and the altitude is a high confidence Mode C beacon message. Altitude reliability is the same as altitude confidence, but adding a check that the beacon message high confidence altitude is within an altitude window from the existing track. The altitude window is 800 ft for a 4.7 second scan rate. This is prorated for other scan rates. Confidence and reliability statistics are available in RBAT.

Probability of Detection, P_d – Decrease in the rate of valid target-reports (messages sent to interfacing automation system(s)) per scan of the SSR when AN/UPX-41(C) are operating. This parameter is sometimes called the plot probability or blip/scan ratio. To facilitate interpretation, it is useful to know the 1030/1090 MHz environment (interrogation and fruit levels) during the same time period. Detection probability is available from RBAT, for individual aircraft and for aircraft grouped by combinations of range, azimuth and altitude bins.

Detection probability is a less sensitive indicator of interference than round reliability or re-interrogation rate. The latter are measures of the likelihood of success of an individual interrogation. In contrast, detection probability is an indicator of the success of a radar detecting a target within a beam dwell, during which the SSR may interrogate the target multiple times.

Number of Targets Per Scan – The RBAT analysis program, Scan Summary, lists the number of ATCRBS and Mode S targets recorded per 360° scan. With data from a monopulse SSR, targets are filtered by ATCRBS ID in transition, ATCRBS ID correlated, ATCRBS ID replaced, ATCRBS ID high confidence, Mode S reinforced, illegal Mode S, and Mode S transponder not compliant. With data from a sliding window SSR or a Mode S SSR in IBI mode, targets are filtered into bins by length of hit count.

FRUIT Rate – Increase in FRUIT rate while AN/UPX-41(C) interrogators are operating. FRUIT are transponder replies received by a specific SSR that were not elicited by that SSR. An AN/UPX-41(C) interrogator elicits replies for Mode 1 (DoD aircraft only), Mode 2 (DoD aircraft only), Modes 3/A (civil and DoD aircraft), Mode 4 (DoD aircraft only) and Mode C (civil and DoD aircraft). FRUIT rate is not calculated by RBAT, but is available from MSAT. FRUIT can degrade the ability of an SSR receiver to decode elicited replies.

False Targets – Increase in False Targets due to synchronized transponder replies detected by an SSR that were not elicited by that SSR while one or more AN/UPX-41(C) interrogators are operating. (False targets can also be inadvertently elicited by an SSR — e.g., via interrogations by the sidelobes or reflections of the main beam from objects. These false targets are not of interest when testing the AN/UPX-41(C) interrogators.)

The average PRF of both the AN/UPX-41(C) and the ATC radar would have to be close enough or the same to cause this to be a concern. RBAT provides false target percentages. As the PRF of the ATC radars under investigation are likely different than the AN/UPX-41(C), this effect will also need to be investigated through analysis to expand the results to the entire NAS. RBAT has an included program, Beacon False Target Summary, which estimates false targets that can arise from eight mechanisms.

Transponder Occupancy — Aircraft transponder occupancy is the time that a transponder is unavailable to detect and reply to an interrogation because it is responding to a previous interrogation or is suppressed. Transponder occupancy will be determined based on measurements by the FAA Technical Center flight test aircraft. For this test of the effect of AN/UPX-41(C) interrogators, occupancy will be considered to have two components, both of which will be tested: (a) responses to interrogations while in the main lobe of a AN/UPX-41(C) (which extend to approximately 280 NM), and (b) suppressions while in the side lobes of an AN/UPX-41(C) (which extend to approximately 30 NM).

Comment:

- AN/UPX-41(C) interrogators can impact either the up or down links, as follows: For the uplink (“occupancy”), the aircraft transponder may not be available to SSR interrogations because it is replying to AN/UPX-41(C) interrogations and AN/UPX-41(C) caused suppressions. For the downlink (“FRUIT”), a reply from AN/UPX-41(C) interrogation of a different aircraft can interfere with reception of a reply from an SSR interrogation.
- Degraded uplink and/or downlink performance can lead to decreased round reliability, increased re-interrogations and (generally to a lesser degree) decreased probability of detection.
- For some SSR models, performance tables have been generated in a laboratory environment. These tables depict the dependence of one or more of the above performance parameters on the power level and/or rate of interfering uplink or downlink messages — e.g., the probability of a given transponder detecting interrogations from a given SSR as a function of the power and interrogation rates of other 1030 MHz interrogators. It would be informative to compare the measurements from this experiment with such performance tables. Such comparisons could lend confidence to the test results and provide a basis for making projections of possible future scenarios, taking into account traffic growth and other IFF system activity.

5.1.2. Mode S SSR Performance Assessment

Mode S SSRs were designed with the capability for data extraction at the SSR site. By utilizing both extracted data (analyzed using MSAT (Subsection 5.1.5)) and data provided to the WJHTC (analyzed using RBAT (Subsection 5.1.5)), statistics will be found for almost all of the generic performance parameters listed in Subsection 5.1.1. Specific examples of such statistics are shown in Table 6 and Table 7.

A performance parameter that cannot be measured at the SSR or WJHTC facility is transponder occupancy. Occupancy will be estimated from interrogation/reply time of arrivals and power levels as measured by the WJHTC flight test aircraft's 1030 MHz recorder for areas where reception of mainlobe and sidelobe energy is expected. Transponder occupancy will be calculated using typical and MOPS standard times (Ref. 9) and will be used to validate analytical models of transponder occupancy, allowing use of the analytical model to predict transponder occupancy for anywhere in the NAS.

5.1.3. ATCBI-6, ATCBI-6M and Condor MK2D SSR Performance Assessment

Available Parameters — The ATCBI-6, ATCBI-6M and Condor MK2D SSRs are similar systems. All are manufactured by the same firm (the Raytheon component previously known as Cossor) from the same basic design. Relative to Mode S radars, the principal difference in the availability of performance parameters for the Raytheon SSRs is that they were not designed for data extraction at the radar site. Thus, certain parameters, particularly those that involve individual interrogations and replies, will not be available. Available generic parameters include: probability of detection, and false target rate. Unavailable generic parameters include: round reliability, run length, re-interrogation rate, FRUIT rate and transponder occupancy. Simulation analysis will be performed to address the gap in available parameters.

NAS surveillance system subject matter experts (SMEs) have made the hypothesis that the AN/UPX-41(C) operating under the Stage-4 criteria will have little to no effect on these SSRs probability of detection (P_d). If demonstrated by measured data, this would be a positive result for both the FAA and the Navy, and could be interpreted as confirming the Stage-4 agreement.

Limitations of P_d — While P_d is logistically simple to collect, there are more sensitive measures of the impact of an interrogator. Because P_d combines the results of multiple interrogations, it can mask degradation at the individual interrogation level. Measures such as round reliability, transponder occupancy and run length or hit count can indicate degradation by an interrogator that would not be reflected in P_d. A consequence of basing a decision on P_d is that it is expected to be more difficult (if not possible) to directly extrapolate the tests results to scenarios that relax the Stage-4 limitations. A more sensitive metric such as round reliability would presumably show an approximately linear degradation as a function of the number of interfering interrogators, allowing the measured data to be extrapolated to predict the impact of more interrogators. Conversely, a positive finding that four interrogators have little impact on P_d cannot be used to determine how many interrogators beyond four would have an adverse impact.

Analysis Methodology — To use a model or simulation as a surrogate for a live test, the simulation must be validated such that its signal environment closely approximates that seen in measured data. In addition, this model must accurately represent the processing and operation of the ASCAS systems. Thus, the first step in this methodology is to validate the Volpe simulation using as many measurement types as possible. Traditional measurement types for validation comparison include interrogation rate seen at a transponder, transponder occupancy, and cumulative power distribution function of 1090 MHz FRUIT at airborne receivers and ground-based surveillance systems.

By comparing simulated and measured quantities — for both the baseline condition (without AN/UPX-41(C) interrogators operating) and test conditions (with AN/UPX-41(C) interrogators operating) — differences in the simulated and measured environments can be reconciled. While the Volpe simulation itself will not be changed to produce FRUIT rates comparable to measurements — this would only serve to show the ability to create an aircraft distribution that matches a measured FRUIT distribution — knowledge of the differences can be used to infer the amount that metrics of interest would change due to the AN/UPX-41(C).

Relating P_d to FRUIT Levels and Transponder Unavailability — The Volpe Simulator produces victim SSR metrics that include FRUIT levels in the mainbeam and sidelobes as well as the reply unavailability of transponders. The relation of these lower level metrics to probability of detection has been quantified in "bench tests" performed in support of the 2009 FAA Surveillance and Broadcast Services (SBS) "Final Report on 1090 MHz Spectrum Congestion in 2035 and Performance of Systems Operating in the Band" (Ref. 4). For this report AJP-7A5 and AJW-147 were requested to measure the effects on radar performance by utilizing the Aircraft Capacity Environment Simulator (ACES) as a means of injecting, at RF, high target loads with reduced target round reliability and various high FRUIT level scenarios. The bench test measured the performance of the four Monopulse Secondary Surveillance Radar (MSSR) configurations most likely to be affected in the future: terminal Mode S, en route Mode S, en route ATCBI-6, and terminal ASR-11 MSSR systems. .

5.1.4. ATCBI-5 SSR Performance Assessment

The ATCBI-5 is the SSR that employs the oldest technology of those being tested; it has a non-monopulse antenna, using the sliding window technique instead, and only interrogates with ATCRBS waveforms. Relative to more modern SSRs, this technology has characteristics — e.g., higher interrogation rate and greater susceptibility to synchronous garble — which makes it important for the Chesapeake Bay test to include such a system.

RBAT (Subsection 5.1.5) will be the primary tool for analyzing the ATCBI-5. RBAT's Surveillance Analysis program will be used to determine probability of detection as a function of aircraft position, the beacon false target rate, and the beacon hit count. The latter is expected to be the most sensitive indicator of the effects of interference.

5.1.5. SSR Data Processing: RBAT and MDAS

Two FAA-developed software tools for analyzing secondary radar systems will be utilized for post-test analysis of SSR behavior — the Radar Beacon Analysis Tool (RBAT, Ref. 10) and Mode S Data Analysis Software (MDAS), a 3-year spinoff of the original Mode S Analysis Tool (MSAT, Ref. 11), that is used by the FAA Mode S SSR Technical Operation Support Team. Both are available, without charge, from the FAA. RBAT was developed first, and can be used to analyze parameters common to any secondary radar system, including Mode S systems. MDAS, similar to RBAT, is used to analyze certain capabilities and parameters specific to Mode S systems. In addition to analyzing different parameters, the two programs utilize different input file formats.

RBAT version 9.6 (dated March 5, 2014) will be used for this analysis. RBAT v9.6 accepts data in three formats: Common Digitizer, version 2 (CD-2); Airport Surveillance Radar, Model 9 (ASR-9); and ASTERIX. Consistent with these formats, RBAT analyzes data that is provided by an SSR to an automation system; it does not address “low level” parameters that are only available at a radar site. RBAT is intended as an engineering tool to be used by trained personnel; it does not have some of the user-friendly features present in commercial software. Although, on this project, RBAT will only be used for analysis of SSRs, it can also be used to analyze ATC primary (“search”) radars and combined primary/secondary radar systems.

RBAT is actually a suite of analysis and utility programs that use common file formats and are accessed from a menu screen. Brief summaries of the capabilities of RBAT’s 23 analysis programs are provided in Appendix Section 12.1. The most useful analysis programs for this project is Surveillance Analysis, which is addressed in the remainder of this section.

Surveillance Analysis’s outputs consist of tabular files and plot files that can be read by RBAT utility programs. Most data are presented in several ways. For example, Surveillance Analysis generates plots of Probability of Detection (P_d) as a function of target range, altitude and azimuth; examples are shown in Appendix Section 12.3. Also, target tracks are tabulated and plotted individually. Summary statistics are also provided; Appendix Section 12.2, Table 12, is an example — statistics for the radar system (ARSR-3 and ATCBI-5) at Key West Naval Air Station (Boca Chica Field) on Jan. 28, 2014.

The system-level statistics in Table 12 within Appendix Section 12.2 pertain to a single radar site and a fixed period of time. The statistics are divided into seven categories (rows in Table 12) – DISCRETE, NON-DISCRETE, ATCRBS, Mode 2, BEACON, SEARCH and TOTAL. If an SSR has the capability to interrogate Mode S and/or Mode 4, there are categories for those as well. The ATCRBS category is also broken down into two subcategories, namely DISCRETE and NON-DISCRETE. The DISCRETE category contains all the ATCRBS tracks for which the ATCRBS ID (Mode A code) has a ‘1’ in at least one of the six least-significant bits (i.e., expressed in octal, the ID does not end in 00). The NON-DISCRETE category is all the tracks in the ATCRBS category that are not in the DISCRETE category. Discrete codes are generally assigned by ATC. The BEACON category contain the ATCRBS and Mode 2 tracks. The TOTAL category contains the BEACON and the SEARCH tracks.

The system-level statistics (columns in Table 12) generated by RBAT's Surveillance Analysis program are described in Table 6.

Table 6 RBAT Surveillance Analysis Program Key Parameters Generated

Parameter	Definition
Track Life	Number of Target Reports used to generate a track
Probability of Detection (ATCRBS Discrete)	Percent of times a message correlates with a track, for all aircraft under track having ATCRBS transponders with a discrete beacon code assigned
Probability of Detection (Mode S)	Percent of times a message correlates with a track, for all aircraft under track having Mode-S transponders
ATCRBS Identity Reliability	Percent of times the identity code from the beacon message is the same as the identity code from the tracker (for tracker high-confidence bits only)
ATCRBS Identity Confidence	Percent of times, when the Mode 3/A code from a message and the tracker match, that the Mode 3/A code confidence from the correlated beacon message is high confidence.
Altitude Reliability	Percent of times that the altitude from the correlated beacon message is within the altitude window* of the altitude from the track.
Altitude Confidence	Percent of times, when the altitude code from a message and the tracker match, that the altitude confidence from the correlated beacon message is high confidence.
Beacon False Targets	Target report from an aircraft that either does not exist or exists but at a different position than that specified in the target report

*The altitude window is 800 feet for a 4.7 second antenna scan time, and is prorated for other scan times

Before Surveillance Analysis can be executed, several parameter and flag values can be selected – e.g., radar antenna location and height; minimum/maximum limits on range azimuth, altitude and elevation; minimum number of target reports needed to create a track; number of consecutive coasts (lack of target reports) for a track to be dropped; and probability of detection (P_d) "low". In most cases, the default values for these parameters/flags are reasonable and should be selected. The "P_d low" flag defaults to OFF because numerical values are provided, but can be set to ON (the default level is 95% for tracks longer than a minimum number of reports) to provide a measure of assurance that a low P_d condition will not be overlooked.

MDAS measures certain performance parameters for a Mode S system. MDAS only uses data recorded in the Mode S extraction file format. For this project, MDAS version 2.2 (dated April 25, 2011) will be used. MDAS is intended as engineering tool to be used by trained personnel; it does not have some of the user-friendly features present in commercial software.

For the purpose of assessing the effect of interference caused by AN/UPX-41(C) interrogators, the most important MDAS parameters are described in Table 7. These parameters are computed on both a per-aircraft and aggregate basis, and can be examined for specific time intervals. The MDAS parameters shown in Table 7 naturally divide into four groups.

- The first group (three parameters) pertains to the beam dwell on a target (the number of times a target is "painted" by a radar) and the number of interrogations and re-interrogations within a dwell.
- The second group (two parameters) pertains to the number of interrogations and re-interrogations per dwell that are competed successfully and result in a range measurement.

Table 7 MDAS Key Parameters Generated

Parameter	Definition
Beam Dwells	Count of the number of times the target was illuminated by the beam. It is the denominator for the next seven statistics.
Interrogation Rate (Ave. Number per Dwell)	Average of the number of roll call interrogations of a target within a beam dwell
Re-Interrogation Rate (Ave. Number per Dwell)	Average of the number of roll call interrogations that are re-interrogations within a beam dwell
Range Completion Int. Rate (Ave. Number per Dwell)	Average of the number of roll call interrogations of a target within a beam dwell for which a range measurement is made
Range Completion Re-Int. Rate (Ave. Number per Dwell)	Average of the number of roll call interrogations that are re-interrogations for which a range measurement is made
Range Completion (Percentage of Dwells)	Percentage of beam dwells on a target that have a range measurement.
Azimuth Completion (Percentage of Dwells)	Percentage of beam dwells on a target that have a valid monopulse azimuth measurement.
Target Completion (Percentage of Dwells)	Percentage of beam dwells on a target that have all transactions completed successfully.
Number of Expected Replies	Number of expected reply windows, containing both successful and unsuccessful replies, per target. It is the denominator for the next five statistics, the reply failure code percentages.
Valid (Percentage of Interrogations)	Percentage of interrogations with a valid reply.
No Azimuth (Percentage of Interrogations)	Percentage of interrogations with a reply that does not have a valid monopulse measurement.
Invalid (Percentage of Interrogations)	Percentage of interrogations with a reply that has an uncorrectable decoding error.
No Reply (Percentage of Interrogations)	Percentage of interrogations for which no reply preamble is detected.
No Time (Percentage of Interrogations)	Percentage of interrogations for which there is insufficient remaining channel time to schedule a reply.

- The third group (three parameters) pertains to the percentage of beam dwells that result in accepted measurements of range, azimuth and both of these quantities.
- The fourth group (six parameters) quantifies the Mode S sensors performance on a per-interrogation (as opposed to a per-dwell) basis.

5.2. ADS-B Air-to-Ground (ADS-B OUT)

System: ADS-B messages transmitted by aircraft and received by ground radio stations provide surveillance information to controllers. Characteristics of the ADS-B ground radio stations involved in this experiment are shown in Table 3 and in Section 3.6.1. A description of all three ADS-B functionalities (air-to-ground, ground-to-air and air-to-air) is presented in Section 9.2, and a table summarizing all ASCAS characteristics, including those for ADS-B, is presented in

Section 10. Overall ADS-B capabilities/functionalities are presented in Ref. 12. Reference 13 contains the specification for ADS-B air-to-ground services.

For this test two data formats will be evaluated, the first being ASTERIX CATEGORY 33 (CAT033) (an output from the ground sites) and the second being Downlink Format (DF) =17 (messages broadcast by aircraft and received by ground stations).

Downlink Format (DF) =17 messages originate from aircraft equipped with Mode S Extended Squitter (ES) transponders and are broadcast on the 1090 MHz link to ADS-B ground stations. A single DF=17 transponder message does not contain all the information needed to form a report for ATC services. Instead, multiple 1090ES DF=17 messages must be collected before creating ASTERIX CATEGORY 33 (CAT033) messages used by ATC. These are analogous to the target reports an SSR provides to an automation platform.

The primary ADS-B analysis tool will be the SBS Analysis Tool (SAT), which is a PC Windows-based application used by, but not limited to, ADS-B analysts, field technicians, and system maintenance personnel throughout the various FAA facilities. SAT analyzes SBS Monitor data extraction or Capture files that contain SBS data.

SAT does not measure certain lower-level parameters associated with the DF=17 messages that an aircraft transmits; however, during this test an ADS-B test ground station will be available at PAX, through a cooperative agreement between the FAA and Selex Sistemi Integrati S.p.A. This test ground station will have the capability to record the lower level DF=17 messages. This data will be recorded and made available for post processing analysis. The tool set associated with decoding of these messages has yet to be identified.

Parameters:

DF=17: Change (reduction) in probability of message reception over each cycle interval. Probability of message reception is the fraction of aircraft broadcast messages that are successfully received (correctly decoded) by the ground station. The change in probability of message reception will be calculated against the information in Table 8.

CAT033: Change (reduction) in update interval over each cycle. Analysis on the CAT033 data will look at changes in update intervals per target for each ground station to determine if the AN/UPX-41(C), when operating, has an impact. The change in update interval will be calculated against the SBS Critical Services System Specification (Ref. 13) which specifies that the ADS-B service shall generate an ADS-B report in CAT033 format upon the occurrence of an ADS-B message containing position information. Based on the broadcast rates in Table 8, and knowing that position reports can only be made after a globally unambiguous CPR decode has been successfully performed (one “even” and one “odd” format position messages) (Ref. 13), the update interval should be one second averaged over 60 seconds. Additionally, a comparative analysis will be conducted to look at changes in update interval between the on and off cycling periods of the AN/UPX-41(C).

Table 8 1090 MHz Extended Squitter ADS-B Message Broadcast Rates of DF=17 messages

Transponder Register	Event-Driven Message Priority	1090ES ADS-B Message	Broadcast Rate: On-the-Ground, not moving	Broadcast Rate: On-the-Ground and moving	Broadcast Rate: Airborne
BDS 0,5	N/A	Airborne Position	N/A	N/A	2 / 1 second (0.4 – 0.6 sec)
BDS 0,6	N/A	Surface Position	LOW RATE 1 / 5 seconds (4.8 – 5.2 sec)	HIGH RATE 2 / 1 second (0.4 – 0.6 sec)	N/A
BDS 0,8	N/A	Aircraft Identification and Category	LOW RATE 1 / 10 seconds (9.8 – 10.2 sec)	HIGH RATE 1 / 5 seconds (4.8 – 5.2 sec)	HIGH RATE 1 / 5 seconds (4.8 – 5.2 sec)
BDS 0,9	N/A	Airborne Velocity	N/A	N/A	2 / 1 second (0.4 – 0.6 sec)
BDS 6,1	TCAS RA = 1 Emergency = 2	Aircraft Status (Emergency/Priority Status, Subtype=1) (TCAS RA Broadcast, Subtype=2)	TCAS RA or Mode A Code Change 0.7 – 0.9 seconds		
			No TCAS RA, No Mode A Change 4.8 – 5.2 seconds		
BDS 6,2	N/A	Target State and Status (TSS)	N/A	N/A	1.2 – 1.3 seconds
BDS 6,5	N/A	Aircraft Operational Status	4.8 – 5.2 seconds	No change NIC_{SUPP}/NAC/SIL 2.4 – 2.6 seconds	TSS being broadcast or not No change TCAS/NAC/SIL/NIC_{SUPP} 2.4 – 2.6 seconds
				Change in NIC_{SUPP}/NAC/SIL 0.7 – 0.9 seconds	TSS being broadcast Change in TCAS/NAC/SIL/NIC_{SUPP} 2.4 – 2.6 seconds
					TSS not broadcast [2] Change in TCAS/NAC/SIL/NIC_{SUPP} 0.7 – 0.9 seconds

N/A = Not Applicable

Notes:

1. *Transmitters are limited to no more than 2 Event Driven messages per second. Therefore, the average of 2 Airborne Position, 2 Airborne Velocity, 0.2 Identification, and 2 Periodic Status and Event Driven messages per second, averaged over any 60 second interval, yields the required 6.2 messages per second.*
2. *Not all aircraft broadcast the Target State and Status Message (see Table 2-3).*

Interference Environments: The FAA SBS Essential Services System Specification Document (SSD), FAA-E-3006 (Ref. 14), specifies that vendors shall provide surveillance services in four different interference environments (low, medium, high, and very high) that correspond to service volumes that have varying densities of aircraft and ground-based interrogators. The Volpe Simulator will be used to determine interference environments seen at ADS-B ground receivers for the baseline and UPX-41(C) scenarios. From this, a determination of the interference impact of the UPX-41(C) interrogators, relative to the specification for the interference environments in which vendor equipment must operate, can be made.

Comments:

- The AN/UPX-41(C) can degrade an ADS-B ground station probability of message reception by causing FRUIT, which results in the ground station reception of the ADS-B message being disrupted by another aircraft's reply to an AN/UPX-41(C) interrogation.
- Measuring the probability of message reception is expected to require collecting data on the transmitting aircraft and at the ground radio station(s), neither of which in normally saved.

5.3. ADS-B Ground-to-Air (ADS-B IN)

System Characteristics: ADS-R and TIS-B messages transmitted by ground radio stations and received by ADS-B IN-equipped aircraft provide surveillance information to pilots. Characteristics of the ADS-B radio stations (ground sites) to be used for testing AN/UPX-41(C) impact on ADS-B ground-to-air capability are shown in Table 3 and Table 4 in Section 3.6.1. A description of all three ADS-B functionalities (air-to-ground, ground-to-air and air-to-air) is presented in Section 9.2, and a table summarizing ASCAS characteristics, including those for ADS-B, is presented in Section 10. Overall, ADS-B capabilities/functionalities are described in Ref. 12. Reference 13 is the specification for ADS-R ground-to-air services. Reference 14 is the specification for TIS-B ground-to-air services.

The ADS-B ground-to-air test configuration will utilize the ground stations from Table 3 to broadcast test targets according to the SBS Critical Services System Specification for generating ADS-B Test Reports (Ref. 13).

Parameter: Change (reduction) in probability of message reception by the aircraft throughout the ground station's service volume, over each one-hour interval. Probability of message reception is the fraction of a ground station's broadcast messages that are successfully received (decoded) by the aircraft. The average fruit level shall also be noted for each cycle interval, as well as the AN/UPX-41(C) on/off status.

Comments:

- The AN/UPX-41(C) can degrade the probability of message reception at the aircraft by increasing the FRUIT rate, increasing the likelihood that the aircraft's reception of ADS-R or TIS-B messages will be disrupted by another aircraft's reply to an AN/UPX-41(C) interrogation.
- Measuring the probability of message reception requires collecting data at the transmitting ground radio station(s) and flight test aircraft.
- Note that the transmission and reception of DF17 ADS-R/TIS-B broadcast messages are needed.

5.4. ADS-B Air-to-Air (ADS-B IN)

System Characteristics: ADS-B messages transmitted by one aircraft and received by a second aircraft that is equipped with ADS-B IN capability provides surveillance information to the air crew of the second aircraft. A description of the three ADS-B functionalities (air-to-ground, ground-to-air and air-to-air) is presented in Section 9.2, and a table summarizing ASCAS characteristics, including those for ADS-B, is presented in Section 10. Overall ADS-B capabilities/functionalities are described in Ref. 12. Reference 13 is the specification for ADS-B air-to-air services.

Parameter: Update intervals for receiving state vectors (via 1090ES) from at least 95% of the observable user population supporting an application. Applications are categorized by the range between ADS-B-equipped aircraft as specified by the Minimum Aviation System Performance Standards for ADS-B, DO-242A (Ref. 15).

Comments:

- The AN/UPX-41(C) can degrade the probability of message reception at the aircraft by eliciting FRUIT (aircraft reception of the ADS-B message is disrupted by another aircraft's reply to an AN/UPX-41(C) interrogation).
- Ideally, measuring the 95% update intervals would be accomplished by collecting data on broadcasting and receiving aircraft, requiring instrumentation of at least two aircraft. To reduce cost, during the Chesapeake Fixed-Base Interrogator Experiment, Target of Opportunity (TOO) aircraft with ADS-B OUT capability will be used as the broadcasting aircraft and the WJHTC measurement aircraft will be used as the receiving aircraft. During post-test analysis, it will be assumed that the ADS-B messages are broadcast in accordance with the applicable RTCA Minimum Operational Performance Standards (MOPS), Ref. 6.

5.5. ASDE-X/ASSC Multilateration on the Airport Surface

System: Messages transmitted by aircraft transponders and received by three or more ASDE-X multilateration subsystem remote units on/near an airport are used to generate surveillance information concerning aircraft on the airport surface or approaching/departing within 5 NM of the airport. This information is provided to tower controllers. Reference 16 is the specification for the ASDE-X system. Reference 17 is the specification for Airport Surface Surveillance Capability (ASSC), the successor to ASDE-X for airport surface surveillance, which employs similar multilateration technology.

FAA subject matter experts (SMEs) have made the hypothesis that the AN/UPX-41(C) operating under the current Stage-4 criteria will have little to no observable effect on multilateration (MLAT) probability of detection (P_d). At the scheduled test dates, the nearest ASDE-X installation to the AN/UPX-41(C) interrogators to be used is at Ronald Reagan Washington National Airport (DCA). The minimum altitude visible to the AN/UPX-41(C) interrogators used in the experiment is 986 ft, MSL, whereas the airport elevation is 14.9 ft, MSL. Thus, aircraft on the surface of DCA (or within approximately 3 NM on approach) will not be visible to the AN/UPX-41(C) interrogators. Consequently, there would be little benefit to expending the resources needed to record live data at DCA MLAT sites.

Since live data will not be recorded at MLAT sites, a different methodology will be employed to assess MLAT performance at both the P_d and interrogation-reply levels using the Volpe Simulator. This method will allow for a performance assessment both with the Stage-4 configuration as well as other configurations with relaxed restrictions where there is a greater expectation of measureable performance difference for an MLAT system.

Methodology Validation — To use a model or simulation in lieu of a live test, the simulation must utilize a signal environment that closely approximates that seen in measured data. Thus, the first step is to validate the Volpe simulation using as many measurement types as possible. Traditional measurement types for validation comparison include interrogation rate seen at a transponder, transponder occupancy, and cumulative power distribution of 1090 MHz FRUIT at airborne receivers and ground-based surveillance systems.

By comparing simulator and measured quantities — for both the baseline condition (without AN/UPX-41(C) interrogators operating) and test conditions (with AN/UPX-41(C) interrogators operating) — differences in the simulated and measured environments can be reconciled. While the Volpe simulation itself will not be changed to produce FRUIT rates similar to those measured — this would only serve to show the ability to create an aircraft distribution that matches a measured FRUIT distribution — knowledge of the differences can be used to infer the amount that metrics of interest would change due to the AN/UPX-41(C).

With validation of the simulation, the transponder unavailability and the FRUIT seen at the MLAT RUs will be consistent with the values seen in real life.

Determining P_d — The methodology for the probability of detection analysis derives directly from the 2009 FAA Surveillance and Broadcast Services (SBS) "Final Report on 1090 MHz Spectrum Congestion in 2035 and Performance of Systems Operating in the Band" (Ref. 4) as well as the ASSC (Ref. 17) and ASDE-X (Ref. 16) subsystem level specifications. For any Mode S squitter or multilateration subsystem-elicited Mode S reply, the probability of computing a valid plot report in any one second shall be at least 93% averaged over the coverage area. Out of all the ATCRBS replies that may be elicited by the multilateration subsystem from a particular target during a one second interval, the probability of computing at least one valid plot report shall be at least 93% averaged over the coverage volume, unless there are more than 25 ATCRBS targets in the coverage area, in which case the probability shall be at least 74%.

A target report is created if either three (update to a track) or four (initiation of a track) Remote Units (RUs) receive the same message from an aircraft. Failure to receive a message at an RU depends upon transponder unavailability (uplink) and failure to detect an aircraft due to synchronous FRUIT (downlink). A grid of possible aircraft locations on the airport surface will be chosen. P_d will be calculated for each location and the average P_d over the coverage area will be considered as the predicted P_d for the MLAT system.

Interference Environments — The FAA SBS Essential Services System Specification Document (SSD), FAA-E-3006 (Ref. 14), specifies that vendors shall provide surveillance services in four different interference environments (low, medium, high, and very high) that correspond to service volumes that have varying densities of aircraft and ground-based interrogators. The Volpe Simulator will be used to determine present and future interference environments seen at MLAT receivers for the baseline and UPX-41(C) scenarios. From this, a determination of the interference impact of the UPX-41(C) interrogators, relative to the specification for the interference environments in which vendor equipment must operate, can be made.

Simulated Configurations — Using the Simulator, the impact to DCA ASDE-X by the four AN/UPX-41(C) sites will be confirmed. Assuming a minimal impact in this configuration, the

AN/UPX-41(C) test configuration being simulated will be moved closer to DCA (in ten mile increments) to assess changes in P_d. While FRUIT rates will increase as the interrogators move closer to the victim system, the SME hypothesis is that transponder availability will be the bigger factor in changes in possible changes to Pd. Therefore, the meaningful test is one that focuses on dramatic increases in transponder occupancy (interrogator closer to victim) as opposed to small changes in transponder occupancy and changes to FRUIT (more interrogators at the Stage-4 buffer distance). This type of test also aligns with the Navy's objectives of investigating restriction relaxations that will help them meet their mission goals with operational and logistical efficiency.

If an AN/UPX-41(C) interrogator configuration that is close to DCA ASDE-X does not considerably decrease P_d, more interrogators will be added to determine how much interference would be needed to "break" the ASDE-X system. It should be noted, however, that the assessment of AN/UPX-41(C) interference to MLAT does not take into account the impact on other ASCAS systems and IFF systems. If, for example, DCA ASDE-X can withstand many interrogators next to the airport, but the SSR can only withstand them at a larger buffer zone, the most degraded ASCAS will determine the configuration that the FAA will allow while still leaving a spectrum margin for other IFF systems and the addition of new systems.

5.6. Wide Area Multilateration (WAM) (Not Tested)

System: Messages transmitted by aircraft transponders and received by three or more multilateration subsystem remote units are used to generate surveillance information concerning airborne aircraft. Aircraft identification and altitude are obtained by decoding transponder messages; aircraft horizontal position is derived from the time-differences-of-arrival of a transponder message at different ground stations. For FAA WAM systems, this information is provided to air traffic controllers. Reference 18 is the FAA WAM specification.

Parameter: Change (reduction) in target report rate.

Comments:

- The AN/UPX-41(C) can degrade WAM target report (plot update) rate by causing FRUIT, which results in the reception of the transponder message being disrupted by another aircraft's reply to an AN/UPX-41(C) interrogation.
- This test plan does not include measurements of AN/UPX-41(C) effects on an WAM installation.

5.7. TCAS

The WJHTC flight test engineering group will determine the impact to TCAS from the AN/UPX-41(C) by utilizing measurement data collected by the WJHTC measurement aircraft. These analyses will address

- 1030 and 1090 MHz TCAS surveillance interrogations and replies, and
- 1030 MHz TCAS air-to-air coordination interrogations and broadcast interrogations

The data analysis will address the impact of AN/UPX-41(C) operations on the reliability of these communications as a function of the traffic level.

The metric for evaluating TCAS performance is the probability that a track exists at Traffic Advisory (TA) time and at Resolution Advisory (RA) time. The TCAS II MOPS, DO-185B, Section 2.2.2.2.1.1, Probability of Track, specify that the probability that a target is in track is 90%.

Comment: It is recognized that there are special DoD TCAS-like systems (MILACAS and E-TCAS) operating in the NAS. There are no plans to collect measurements from aircraft equipped with these systems. However, we will investigate the potential for modeling the impact of AN/UPX-41(C) interrogators on these collision avoidance systems.

5.8. Flight Test Aircraft

System: Aircraft operated by the William J. Hughes Technical Center and equipped with test equipment that performs detailed measurements of the 1030/1090 MHz RF environment will be utilized (see Section 9.5). The aircraft measurement capability shall include the ability to determine and record the times when the transponder (a) replies to a radar interrogation, by mode; (b) is suppressed; and (c) broadcasts an ADS-B message. These measurements will be recorded for post-test data analysis. The aircraft will fly trajectories that foster accomplishment of the evaluation objectives (see Section 3.7).

Parameters: Post-test analysis will utilize parameters presented in Section 5.1 thru Section 5.5. These will include:

- Increase in the fraction of time the aircraft transponder is occupied and unable to respond to an interrogation.
- Increase in the transponder reply rate, by mode.
- Reduction in probability of message reception throughout the required surveillance volume.
- Impact of AN/UPX-41(C) sidelobes (Section 8.5.2)

Rationale: Largely as a result of the introduction of TCAS, transponder occupancy and reply rate have become part of the accepted methodology for assessing the impact of a new 1030 MHz interrogators on existing ASCAS systems.

6. Safety Risk Management

Testing will be conducted subject to FAA Order JO 7610.4 – Special Operations (Ref. 19), tailored as appropriate. Risk mitigation measures will be implemented, including:

1. The Volpe Center will appoint an representative who will provide overall coordination and focus on achievement of the test objectives. ("Volpe Center Test Controller").
2. The FAA will appoint a representative who is responsible for the monitoring of NAS systems and has the authority to request that the Volpe Center Test Controller issue a CEASE BUZZER if the AN/UPX-41(C) interrogators are operating ("FAA NAS Monitor").
3. The Navy will appoint a representative who is responsible for the monitoring of AN/UPX-41(C) Interrogators and has the authority to request that the Volpe Center Test Controller issue a directive of OFF or ON for the interrogators ("Navy AN/UPX-41(C) Controller").
4. There will be a continuously available communications link between the Volpe Center Test Controller, FAA NAS Monitor, and the Navy AN/UPX-41(C) Controller (e.g., telephone land line) and a continuously available backup link (e.g., each person carries a mobile phone).
5. Alternates will be appointed for the Volpe Center Test Controller, FAA NAS Monitor and the Navy AN/UPX-41(C) Controller, and the alternates shall have a common, continuously available communication link (e.g., mobile phone)
6. Testing will commence under low-risk (Green) conditions, based on the:
   - implementation of any required testing safety risk mitigations
   - number of AN/UPX-41(C) interrogators radiating,
   - number of aircraft within range of the AN/UPX-41(C) interrogators, and
   - distance between the AN/UPX-41(C) interrogators and US&P shore.
7. If unacceptable degradation of any NAS system is observed by the FAA NAS Monitor, the FAA NAS Monitor has the authority to request that the Volpe Center Test Controller issue a CEASE BUZZER if the AN/UPX-41(C) interrogators are operating and will inform the Navy AN/UPX-41(C) Controller "CEASE BUZZER ON AN/UPX-41(C) INTERROGATIONS".
8. If the unacceptable degradation observed by the FAA NAS Monitor has ceased and the FAA NAS Monitor judges that the risk has been mitigated, the FAA NAS Monitor has the authority to request that the Volpe Center Test Controller issue a RESUME BUZZER and will inform the Navy AN/UPX-41(C) Controller "RESUME BUZZER ON AN/UPX-41(C) INTERROGATIONS".
9. The decision to cease or commence operations of any/all AN/UPX-14(C) will be at the sole discretion of the Volpe Center Test Controller.

Consistent with the above communications requirements, the following defines the express communications structure for the test. The communications plan establishes three independent organizational enclaves: Senior Event Controllers; FAA Controllers, including the FAA aircraft; and Navy Controllers.

The primary event controllers are the: (1) the Volpe Test Controller, who is senior control agent; (2) FAA NAS Monitor, who is the senior FAA control agent; and (3) Navy UPX-41 Controller, who is the senior Navy control agent. Their communications structure is shown in Figure 6.

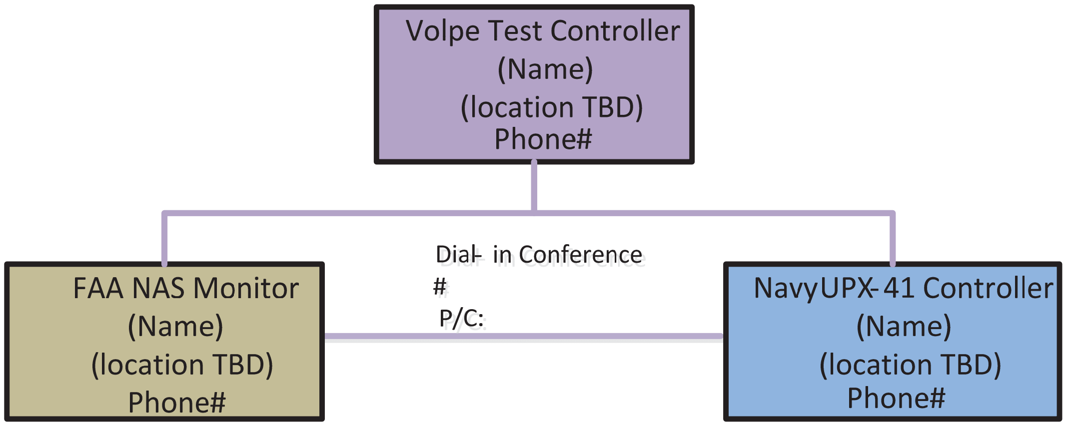


Figure 6 Senior Level Communications Enclave Structure

The purple line indicates that the senior event controllers have a dedicated conference line for isolating their conversation from the rest of the event members. This line allows the leaders to hold private conversations about the conduct of the event and to make decisions without interference from other event participants.

Each FAA and Navy Controller will, likewise have independent dedicated conference lines established to support private conversations within their individual organizations. Figure 7 and Figure 8 show communications structure of each organization.

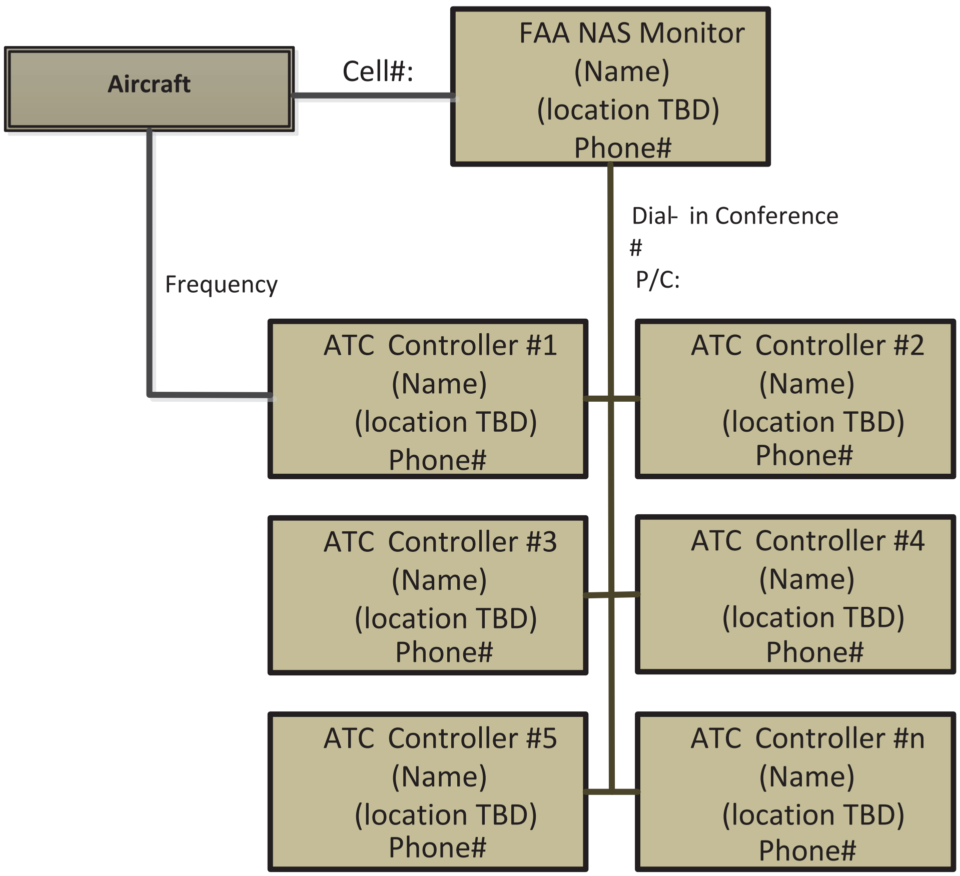


Figure 7 FAA Communications Enclave Structure

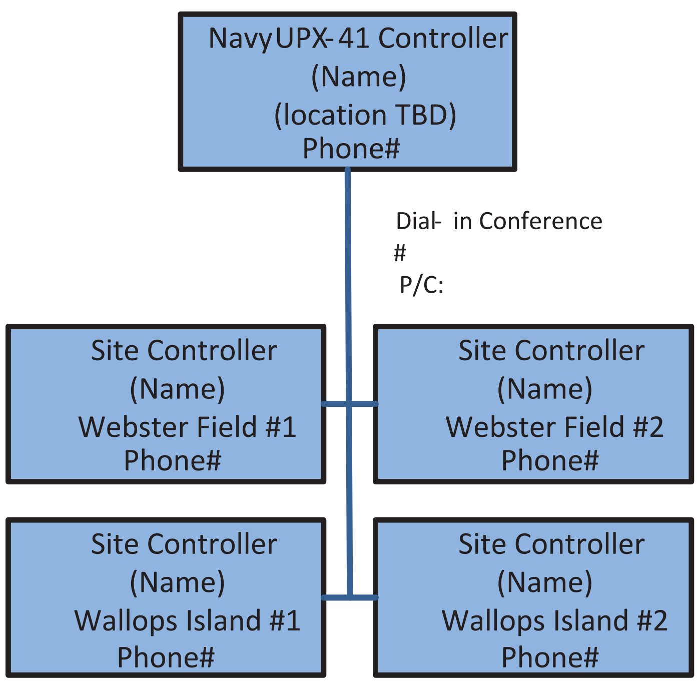


Figure 8 Navy Communications Enclave Structure

The FAA shall designate one of the ATC Controllers as the primary aircraft controller, and maintain a separate cellular telephone connection between the event controller in the FAA aircraft and the FAA NAS Monitor. If any ATC Controller observes an UPX-41(C) related anomaly or another IFF related anomaly, that ATC Controller is to report it to the FAA NAS Monitor for determination if the event is sufficient to issue a CEASE BUZZER call. Conversely, if the anomaly resolves after the CEASE BUZZER, the ATC controller who observed the anomaly shall inform the FAA NAS Controller so that a determination can be made to resuming the event or delaying until the next day.

The FAA NAS Monitor shall establish and maintain cellular telephone communications with the Aircraft event controller to ensure proper execution of the exercise, which could include deviation from that specified flight path.

The Navy UPX-41 Controller shall establish and maintain a conference line for communications with the Site Controllers. Should the primary communication path between the Test Controller and Site Controller(s) fail, this conference line can be used to relay the directions to keep the Test going until the primary communication line is re-established.

Figure 9 shows the overall communications plan.

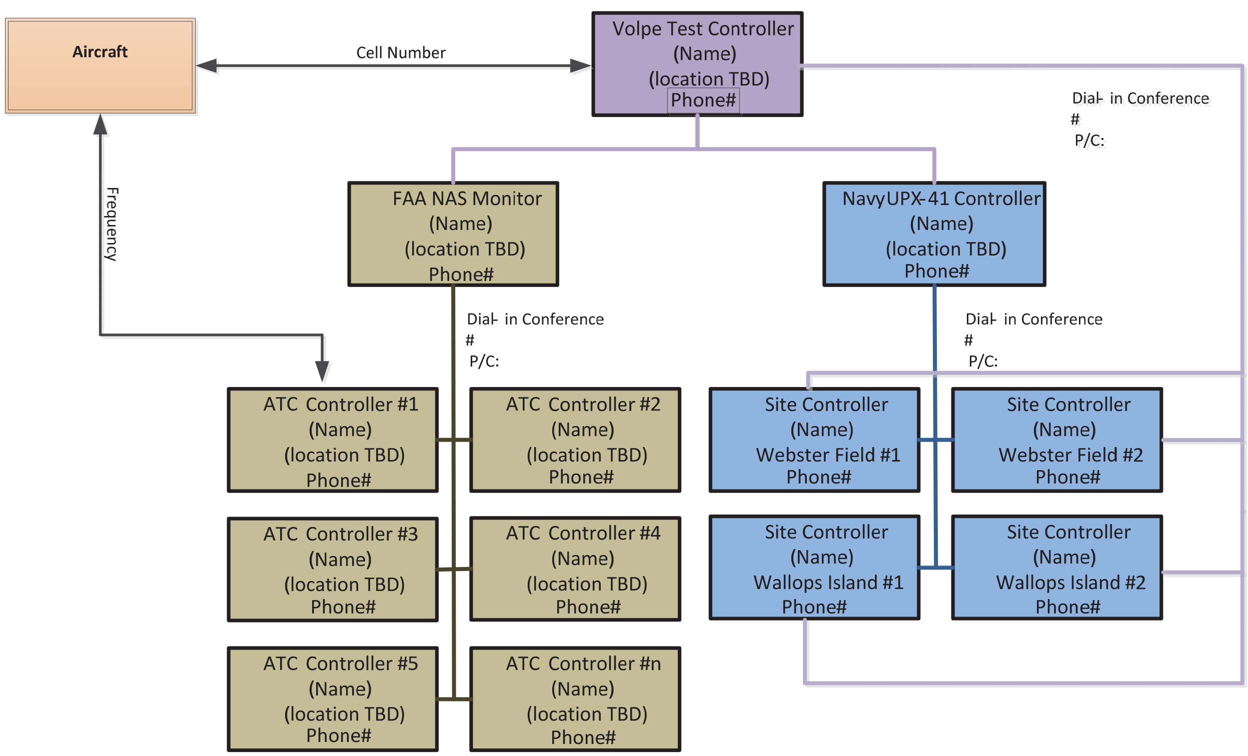


Figure 9 Top Level Communications Structure

7. Controlling and Monitoring the Test Environment

7.1. Controlling the Environment

In order to obtain meaningful measurement data, the use of systems transmitting on 1030 and 1090 MHz must be known and controlled during the test period.

Aircraft using 1030/1090 MHz equipment will be monitored by the NAS systems detailed in Section 3, including recording their locations and altitudes. As described below, the tests will begin when flight activity is minimal and continue into a period when flight activity is at a peak level. It is expected that any degradation of ASCAS performance (e.g., reduction in round reliability) caused by AN/UPX-41(C) systems will increase with the number of aircraft within range of the ASCAS. Therefore, the tests will begin when flight activity is minimal, a low interference period, and continue into a period when flight activity is at a peak level.

During the test period, the military platforms using 1030/1090 MHz must be restricted to those facility/ships equipped with AN/UPX-41(C) systems participating in the test itself (i.e., no other tactical interrogators within the test area – at least 250 NM from the test aircraft data collection track). The Navy will issue a directive to all non-FAA IFF units that may be operating in the area to restrict the use of their IFF interrogators, and to notify the Mid-Atlantic Frequency Coordinator prior to changing the operating status of their IFF interrogators. This restriction is necessary because the basic purpose of the tests is to measure, as accurately as possible, the degradation of NAS systems caused by the AN/UPX-41(C). If other military platforms utilizing 1030/1090 MHz, potentially greater in number than the number of AN/UPX-41(C) ships participating in the test, are transmitting and/or entering and leaving the test area at unknown times, the findings of this test can be rendered useless.

7.2. Real-Time Test Monitoring

While conducting the Chesapeake Bay AN/UPX-41(C) test, the status of the SSRs of interest will be monitored at the FAA William J. Hughes Technical Center (WJHTC) using the Real-Time version of RBAT (RT-RBAT) running on multiple computers. The FAA Technical Center receives real-time data feeds from all of the SSRs of interest. RT-RBAT considers this data in segments, and computes performance statistics on those segments. The segment length can be set by the user but typically is set to 2-minutes (120-seconds).

For the Chesapeake Bay test, one of the RT-RBAT versions monitoring the test will be specially adapted for the test configuration. This special version will monitor two circular regions, each 40 NM in radius, informally termed “hot spots”. One region will be centered on the AN/UPX-41(C) installations at Wallops Island, and the other will be centered on the AN/UPX-41(C) installations at Webster Field. The intent is that monitoring these regions will enable changes in transponder occupancy and P_d due to the AN/UPX-41(C) to be detected in near real time as the Navy interrogators are toggled on and off.

The most important statistic to be monitored is the probability of detection, P_d, which will be used to determine the overall impact of the AN/UPX-41(C) interrogators and whether or not that impact is sufficient to trigger the CEASE BUZZER. Probability of detection is a less-sensitive measure of interference to an SSR than other metrics such as round reliability (Section 5.1). Thus, not causing a significant degradation of P_d is a necessary, but not sufficient, condition for the AN/UPX-41(C) interrogators to be permitted to operate in the NAS.

RBAT (the version used for post-test analysis of SSR data) has the capability to sort the data based on the location of the aircraft and to provide summary statistics for each “sort box”. Specifically, RBAT can sort data based on aircraft range (16 bins), azimuth (16 angular sectors, each 22.5 deg) and altitude (16 bins), and compute statistics for each combination of bins (total of 4,096). For real-time monitoring, it is not necessary to have statistics for all combinations. However, in addition to monitoring the entire service volume of an SSR, it is desirable to be able to monitor one or a few bins or bin groupings where the impact of the AN/UPX-41(C) interrogators is likely to be the greatest.

Based on the dry run activities, the original cease buzzer methodology, presented in Appendix: Pre-Dry Run CEASE BUZZER Methodology, was deemed unsuitable for this test. The new CEASE BUZZER methodology is summarized in the following paragraphs and an explanation is presented in Appendix: Post-Dry Run CEASE BUZZER Methodology.

Based on the discussion in Appendix: Post-Dry Run CEASE BUZZER Methodology, there are now two protocols that may be used during suspected interference situations:

> CEASE BUZZER – When called, all AN/UPX-41(C) interrogators that are currently radiating will stop radiating. FAA ATC will indicate when it is appropriate for the AN/UPX-41(C) interrogators to begin radiating again.
>
> DEGRADED BUZZER – When called, the AN/UPX-41(C) interrogator closest to the affected area will be asked to stop radiating. If P_d does not return to levels above the baseline minimum, this process will be repeated for the next closest AN/UPX-41(C) until P_d returns to the baseline minimum or all of the AN/UPX-41(C) interrogators have been turned off.

The standard ATC CEASE BUZZER process says that when air traffic controllers see missed target updates, they call CEASE BUZZER and all transmitters in the test cease radiation immediately. This process was modified in this test plan to turn off AN/UPX-41(C) interrogators, one at a time, starting with the interrogator closest to the problem area and moving to interrogators further away if the problem did not resolve itself, as a way to determine if the Navy interrogators were the source of the interference of the missed track update. During the dry run, it was requested that this process return to the standard CEASE BUZZER whereby all interrogators are immediately turned off when ATC identifies suspected anomalies, for both safety and standardization reasons. Returning to the standard CEASE BUZZER process was determined to be beneficial, not only to provide ATC a margin of confidence in the CEASE BUZZER process for safety reasons, but to also provide the test and data analysis community with the ability for the analysts to identify the anomaly in both real time, and after the test, comparing the data from all Navy interrogators ON to all OFF with minimal transition time.

Besides the operational concerns of the pre-dry run CEASE BUZZER discussed above, there were flaws to the mathematical nature of the pre-dry run CEASE BUZZER procedure. To give a real-time update of P_d using a reasonable statistical sample size, FAA SMEs suggest that P_d should be calculated by RBAT over a 20 scan interval. This equates to updates over approximately 1.5 minutes for a terminal radar (scan time = 4.6 sec) and updates over approximately 4 minutes for an en-route radar (scan time = 12 sec). The pre-dry run CEASE BUZZER methodology in the test plan gives P_d = 96% (Ref. 21) calculated by QARS as a threshold below which remedial action by maintenance personnel is mandatory. Comparing the calculated QARS P_d, however, to the RT-RBAT P_d is unfair because 30 minutes of data is fed into QARS versus 20 scans for RT-RBAT. Furthermore, QARS filters out Non-Discrete Mode 3/A codes while this method will not be used in RT-RBAT.

CEASE BUZZER and DEGRADED BUZZER decisions will now be made when P_d drops below the minimum P_d observed during the baseline week. Changes in hotspot activity or track counts can be used as indicators for greater analyst vigilance, but cannot be used exclusively to make calls for a CEASE BUZZER or DEGRADED BUZZER.

8. Test Procedure

8.1. Navy IFF System Grooming

“Grooming" of the Navy systems is required before the test, to ensure that they are operating to specification and aligned properly.

8.2. Dry Run

A “dry run” is currently scheduled for July 16-18, 2014, approximately one month before the scheduled live test. Except for the WJHTC data collection aircraft, the dry run will involve the same personnel, systems and procedures that will be involved in the live test. The dry run is planned for two days, with a third day reserved for contingencies.

More specifically, the dry run will include:

- Involvement of the Volpe Test Controller, FAA NAS Monitor and Navy UPX-41 Controller, and FAA System and Navy Site personnel, who will participate in the live test.
- Coordination with FAA Air Traffic Operations personnel prior to the test.
- Concurrent open communications lines with FAA Air Traffic Control (ATC) facilities that may be impacted.
- Cycling of the radiation (ON / OFF) by all four of AN/UPX-41(C) interrogators that will be involved in the live test. Only one interrogator at each location (St. Inigoes and Wallops) will radiate at one time; radiation by the two sites will not be coordinated.
- Communications between the Volpe Test Controller and Navy UPX-41 Controller and/or Navy Site Controllers regarding the ON/OFF status of the AN/UPX-41(C) interrogators.
- Collection of data from all ASCAS ground systems planned for participation in the live test.
- Monitoring of the status of FAA ASCAS systems at the WJHTC using Real-Time RBAT (Radar Beacon Analysis Tool).

8.3. Post Dry Run

Four activities are to be performed after the dry run but before the live test:

- Processing of the dry run data collected, to ensure that the processing software operates as intended and to familiarize the processing staff with the software.
- Evaluate P_d methodology and observed ranges
- Finalize AN/UPX-41(C) cycle periods for both airborne and non-airborne data recording periods
- Apply lessons learned to test procedures

8.4. Live Test: AN/UPX-41(C) Interrogator Schedule

8.4.1. Overview

It is planned to perform four days of test data collection with a fifth day as backup. Data collected on the first day establish the baseline 1030/1090 MHz environment in the test region, and will not involve radiation by any of the four AN/UPX-41(C) interrogators or other non-FAA IFF interrogators. Testing on the second date will utilize the least disruptive set of interrogators (two at WAL). The third day will add the two interrogators at NUI. The intent is that, by incrementally adding interrogators, the effect of each interrogator can be determined. The fourth day will repeat the configuration of the third day, as this is the interrogator configuration that best matches the Stage-4 conditions specified in Ref. 2. The fifth day will be used, if necessary, to accommodate schedule delays caused, e.g., by weather conditions or equipment issues.

The test is scheduled for August 18-22, 2014. The following week, August 25-29, 2014, will be utilized if additional time is needed. Testing during high-ceiling/good-visibility conditions is preferred, as those foster the ability of the WJHTC aircraft to maneuver and also generally coincide with desired air traffic levels.

During some testing, the AN/UPX-41(C) interrogator(s) will alternately radiate (ON condition) and not-radiate (OFF condition) for the same amount of time. When radiation is alternated, the ON / OFF interval length may vary from day to day, or within a day, to achieve test goals and for logistical reasons. Interval lengths may also vary based on the outcome of the dry run.

8.4.2. Establish Baseline Environment (Day 1)

The AN/UPX-41(C) interrogators will not transmit during this test day except for 5 minutes after the measurement aircraft departs ACY. This time will be used to identify the measurement aircraft by Wallops Island to give situational awareness to the VHF communication technician.

8.4.3. Sidelobe Testing at WAL and NUI (Day 2)

This test day will assess the effect of the fixed-base AN/UPX-41(C) interrogator systems at Wallops Island on the NAS systems cited in Section 2. One full day of testing is planned. Testing will commence at 5:30 AM local time, when there is little flight activity and continue for 12 hours, to 5:00 PM local time.

- During the period from 5:30 AM to 2:00 PM, one interrogator will be utilized.
  - From 5:30 AM to 10:00 AM, one interrogator at WAL will be cycled ON (for 30 min) and OFF (for 30 min).
  - From 10:00 AM to 3:00 PM, one interrogator will be ON either at WAL or NUI, to support sidelobe testing.
- During the period from 3:00 PM to 5:00 PM, two interrogators at WAL will be cycled ON (for 30 min) and OFF (for 30 min).

8.4.4. Effect of Two Interrogators at WAL and Two Interrogators at NUI (Day 3)

This sub-test will assess the effect of the two fixed-base AN/UPX-41(C) interrogator systems at Wallops Island and two fixed-base AN/UPX-41(C) interrogator system at St. Inigoes on the NAS systems cited in Section 2. One full day of testing is planned. Testing will commence at 5:30 AM local time, when there is little flight activity and continue for 12 hours, until 5:00 PM local time.

- From 5:30 AM to 10:00 AM, two interrogators at WAL and one interrogator at NUI will be cycled ON (for 30 min) and OFF (for 30 min).
- From 10:00 AM to 2:00 PM, two interrogators at WAL and two interrogators at NUI will be cycled ON (for 5 min) and OFF (for 5 min) to support airborne data collection.
- From 2:00 PM to 5:00 PM, two interrogators at WAL and two interrogators at NUI will be cycled ON (for 30 min) and OFF (for 30 min).

8.4.5. Effect of Two Interrogators at WAL and Two Interrogators at NUI (Day 4)

This sub-test will assess the effect of the two fixed-base AN/UPX-41(C) interrogator systems at Wallops Island and two fixed-base AN/UPX-41(C) interrogator systems at St. Inigoes on the NAS systems cited in Section 2. One full day of testing is planned. Testing will commence at 5:30 AM local time, when there is little flight activity and continue for 12 hours, until 5:00 PM local time.

- From 5:30 AM to 10:00 AM, two interrogators at WAL and two interrogators at NUI will be cycled ON (for 30 min) and OFF (for 30 min).
- From 10:00 AM to 3:00 PM, two interrogators at WAL and two interrogators at NUI will be cycled ON (for 5 min) and OFF (for 5 min) to support airborne data collection.
- During the period from 3:00 PM to 5:00 PM, two interrogators at WAL and two interrogators at NUI will be cycled ON (for 30 min) and OFF (for 30 min).

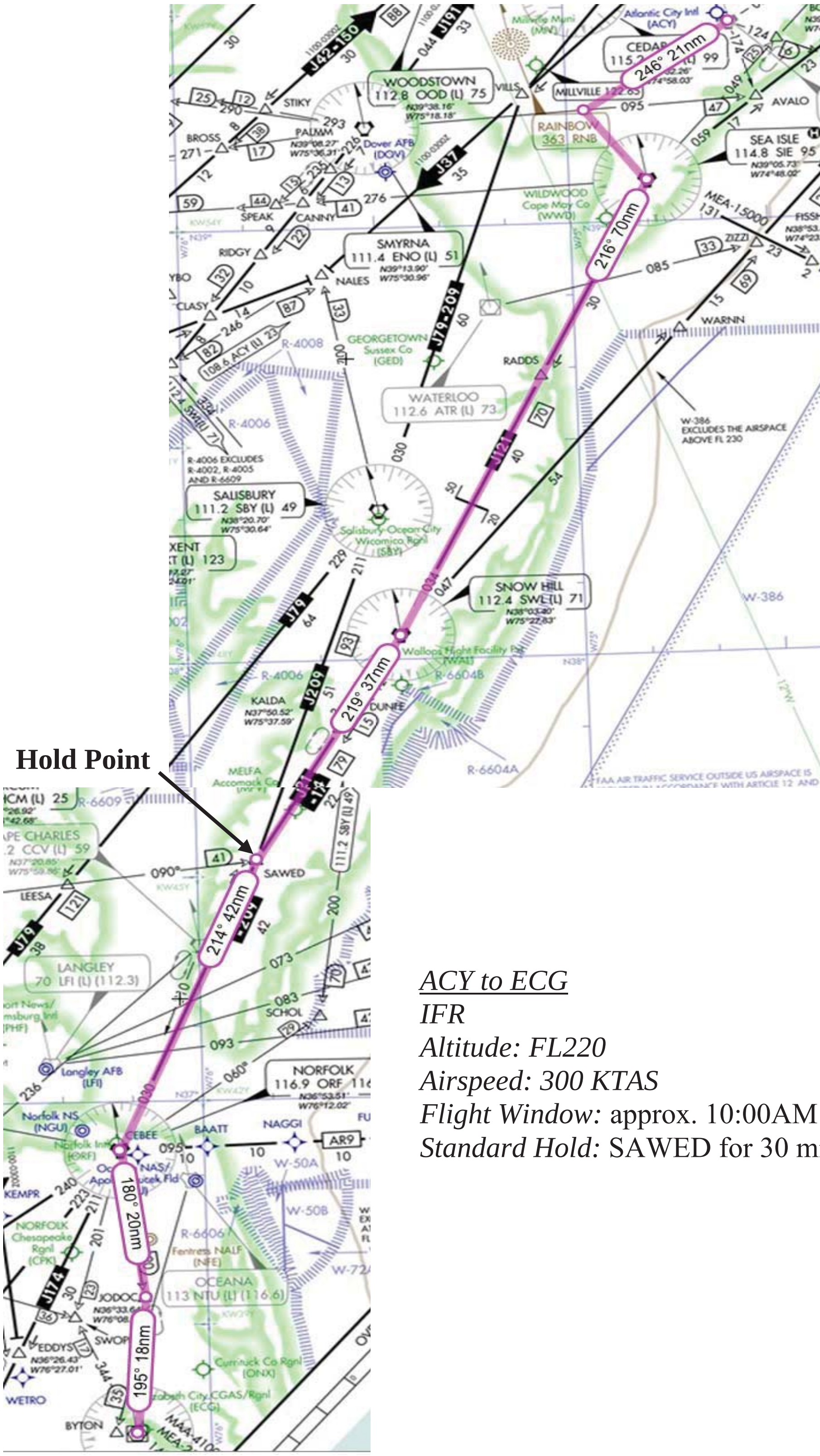
8.5. Live Test: Measurement Aircraft Schedule

It is anticipated that the measurement aircraft will be one of two Convair 580s operated by the FAA Technical Center. The low-level minimum airspeed for these aircraft is approximately 150 knots; the maximum speed is about 210 knots.

The flight information herein is subject to change based on several factors, including air traffic considerations and evolving test priorities.

8.5.1. Establish Baseline Environment (Day 1)

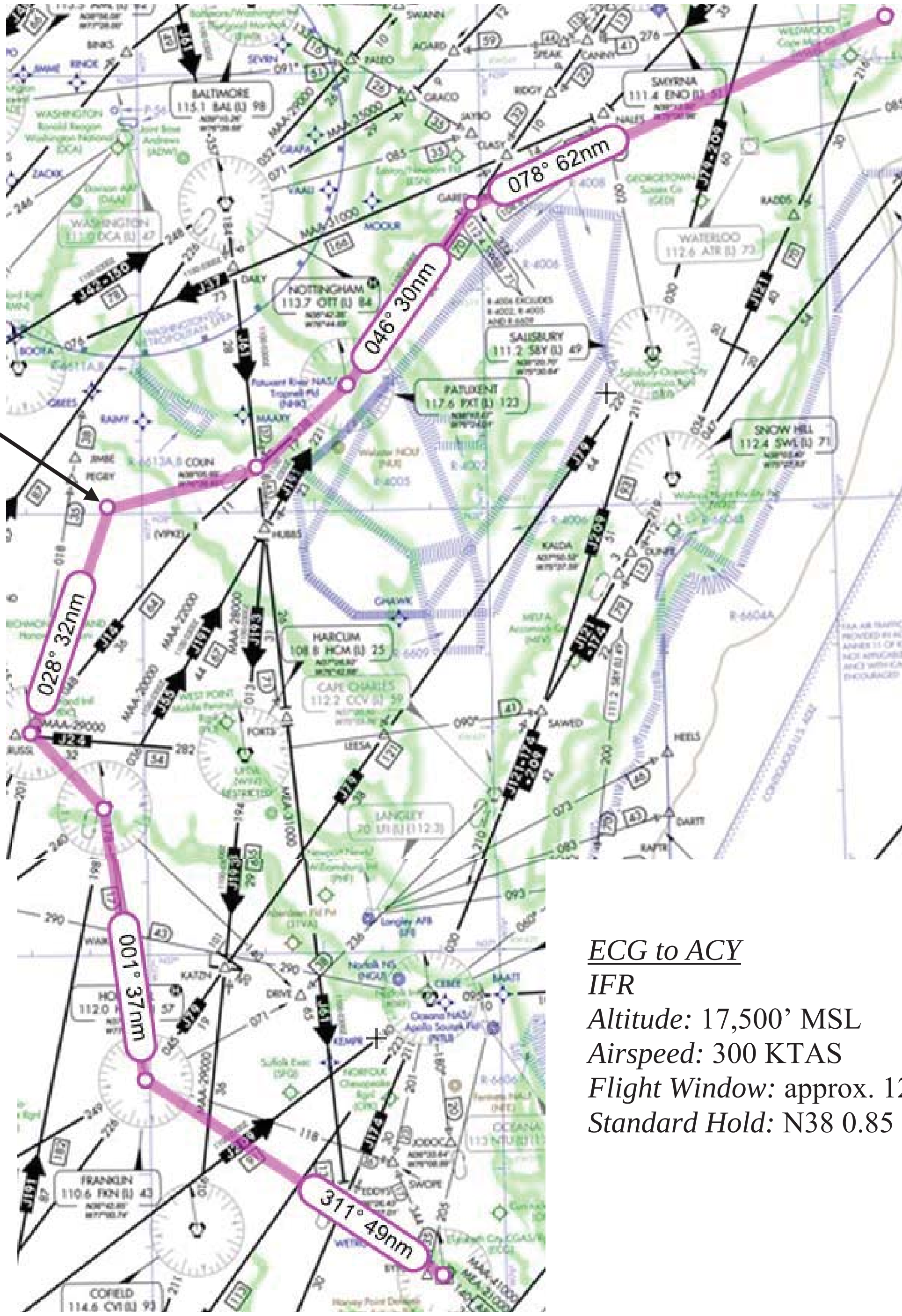
The FAA Flight Test Aircraft will fly from and return to the William J. Hughes Technical Center Technical (WJHTC), making a stop in Elizabeth City, NC. The aircraft will fly the flight plans shown in Figure 10 and Figure 11..



<u>ACY to ECG</u>
IFR
Altitude: FL220
Airspeed: 300 KTAS
Flight Window: approx. 10:00AM – 11:30 AM
Standard Hold: SAWED for 30 mins

Figure 10 Planned Flight Tracks, Leg 1: Day 1, Aug. 18 (Monday) and Day 3, Aug. 20 (Wed.)

Hold Point



<u>ECG to ACY</u>
IFR
Altitude: 17,500’ MSL
Airspeed: 300 KTAS
Flight Window: approx. 12:30pm-2:00pm
Standard Hold: N38 0.85 W077 06.75

Figure 11 Planned Flight Tracks, Leg 2: Day 1, Aug. 18 (Monday) and Day 3, Aug. 20 (Wed.)

8.5.2. Side Lobe Airborne Measurement Test (Day 2)

The measurement aircraft will fly in support of determining the impact of one AN/UPX-41(C) and the combination of two closely-spaced AN/UPX-41(C) interrogators' side lobes on transponder occupancy. Measurements will be collected while the aircraft is flying toward, directly over, and away from the AN/UPX-41(C) interrogators. It is desirable that the aircraft altitude be low, in order to minimize the impact of other interrogators.

Figure 12 depicts the planned tracks over the AN/UPX-41(C) interrogators at the Wallops Flight Facility, Figure 13 depicts the planned tracks over the interrogators at Webster Field, and Figure 14 depicts the sequencing of the flights over the interrogators. The sequence in Figure 14 will first be executed with all legs, turning each AN/UPX-41(C) interrogator on one at a time. The sequence that flies over buildings V-10 and V-24 will then be executed again, turning on both V-10 and V-24 at the same time. Note that the measurement aircraft has the endurance to fly the full sequence in Figure 14 twice. Based on flight and AN/UPX-41(C) interrogator conditions, the Volpe Center Test Controller reserves the right to re-execute any of the legs.

VFR
Altitude: 5,500' MSL
Airspeed: 180 KTAS

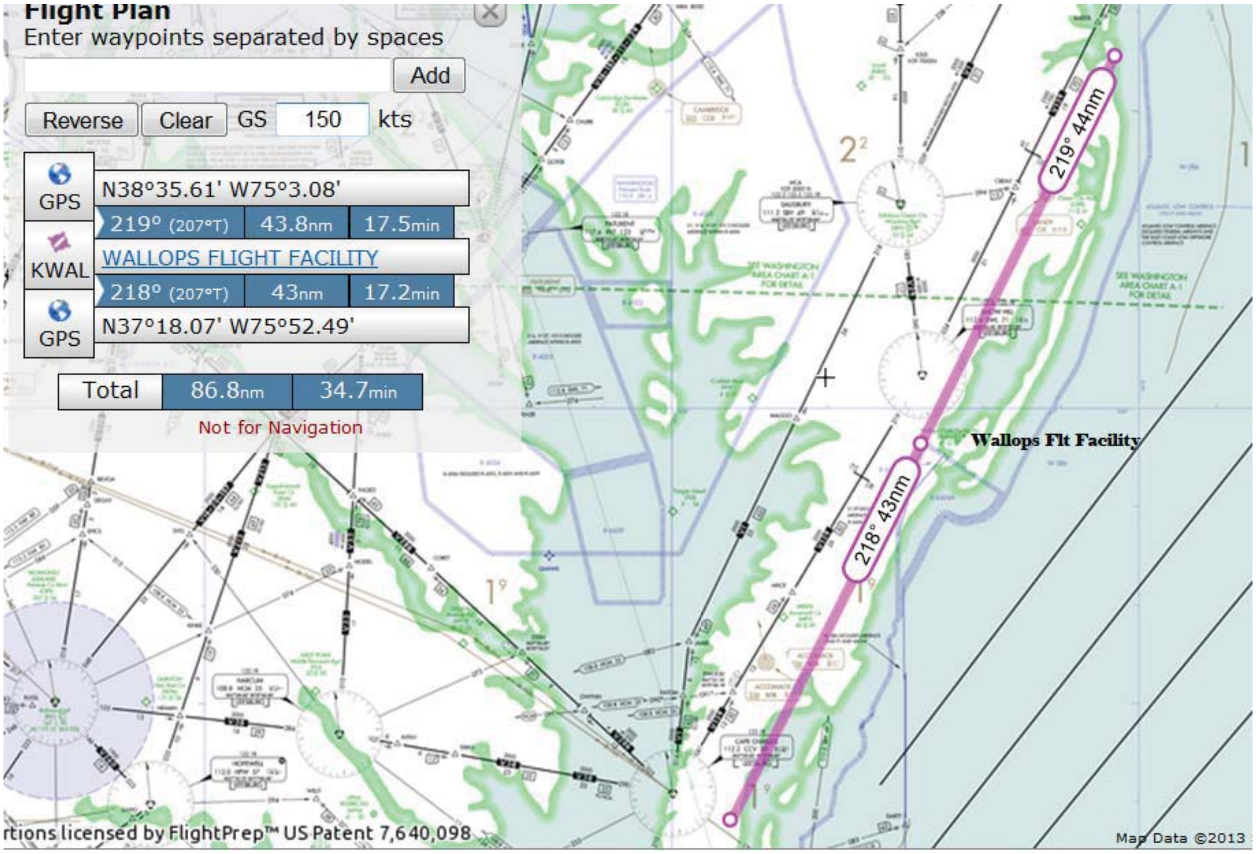


Figure 12 Planned Tracks over Wallops AN/UPX-41(C) Interrogators on Day 2

VFR
Altitude: 5,500' MSL
Airspeed: 180 KTAS

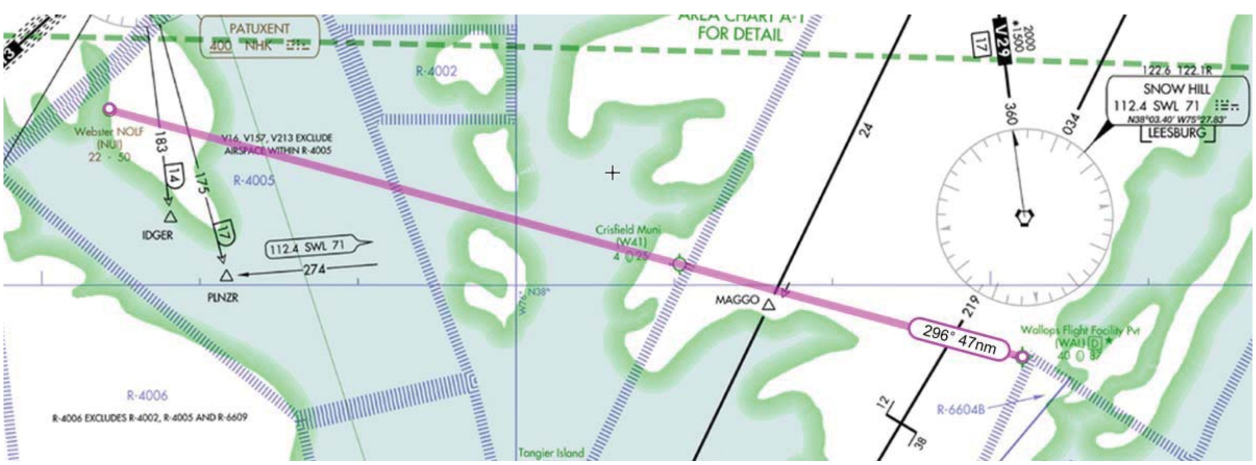


Figure 13 Planned Tracks over Webster Field AN/UPX-41(C) Interrogators on Day 2

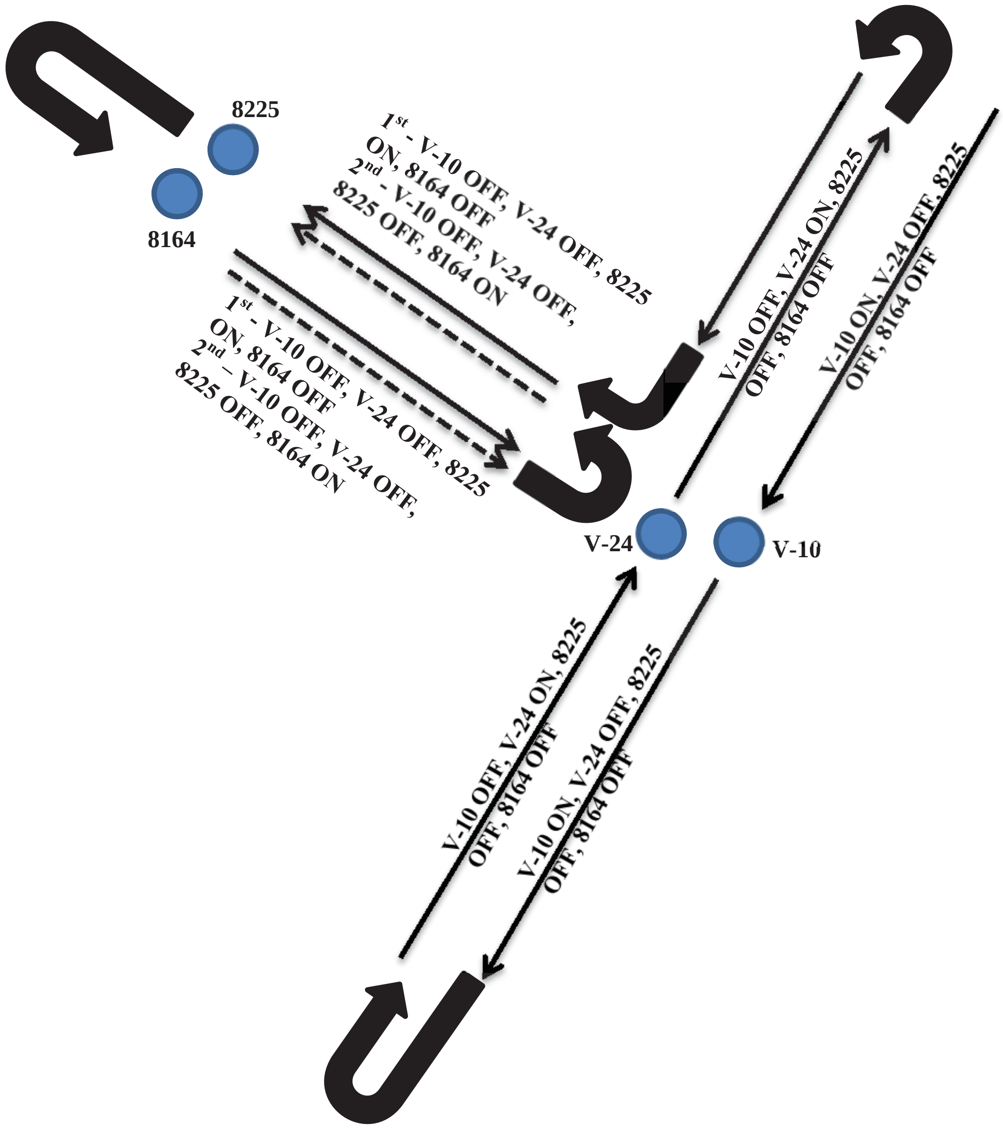


Figure 14 Sequencing of Tracks over AN/UPX-41(C) Interrogators on Day 2

8.5.3. <u>En Route Airborne Testing (Day 3)</u>

On Day 3 the FAA Flight Test Aircraft will fly from the William J. Hughes Technical Center Technical (WJHTC) over the same route as on Day 1 (see Figure 10).

8.5.4. <u>Terminal Area Airborne Testing (Day 4)</u>

On Day 4, the aircraft will overfly as many ground facilities — e.g., SSRs (Table 1), ADS-B sites (Table 3) and ASDE-X (DCA) sites — as possible. The trajectory and schedule must be coordinated with FAA Air Traffic Managers, and flexibility in terms of schedule may be required.

Figure 15 shows the planned track.

IFR

VFR for SFRA portion

Altitude: 9000' MSL

Airspeed: 300 KTAS

Flight Window: approx. 10:00AM – 3:00PM

Standard Hold: SAWED for 30 mins

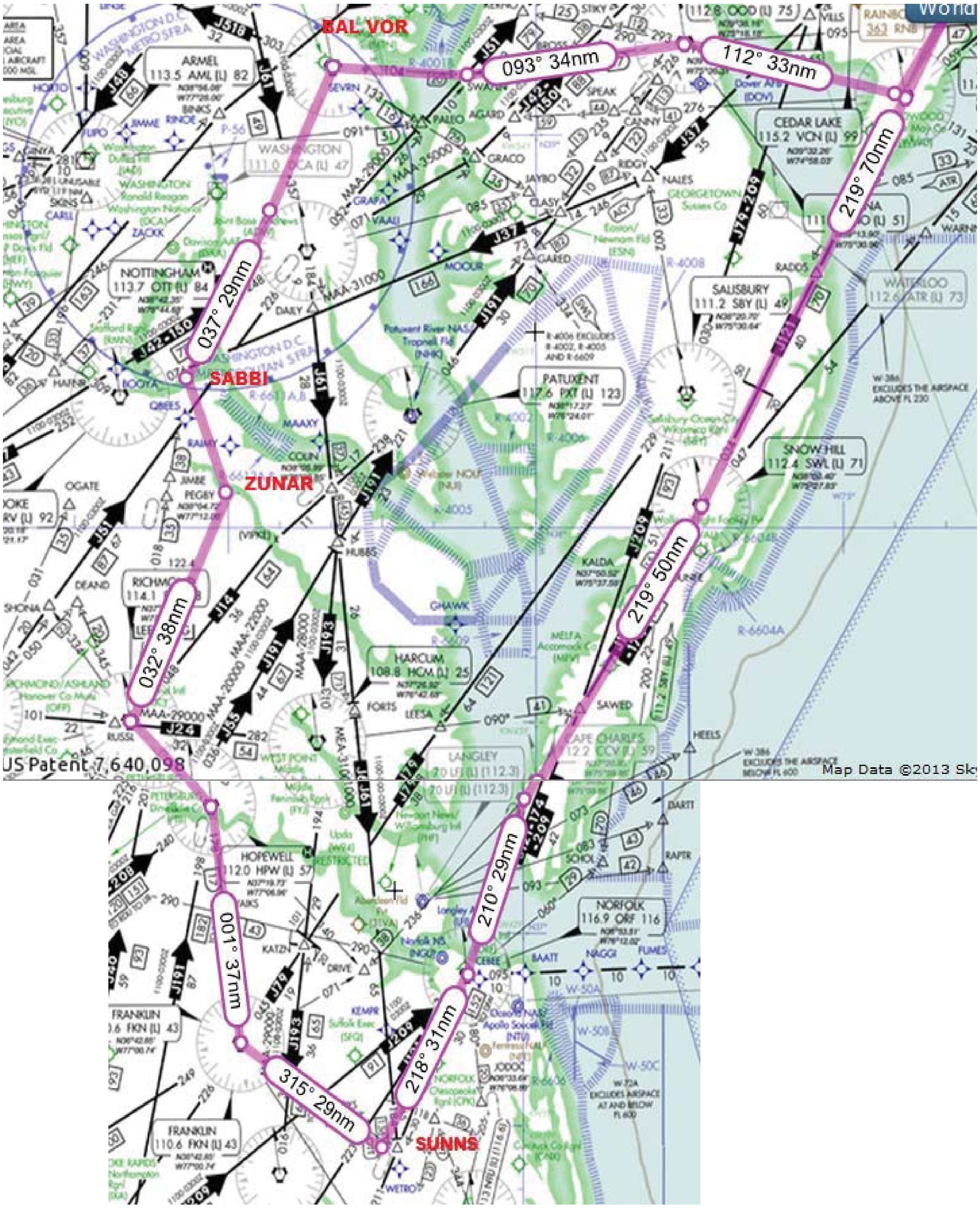


Figure 15 Planned Flight Tracks: Day 4, Aug. 21 (Thursday)

9. Appendix: System Characterizations

This section contains descriptions of the ASCAS systems in the NAS. The following section consists of a table of the key parameters for these systems.

9.1. ATCRBS and Mode S SSRs

SSRs interrogate aircraft equipped with transponders on 1030 MHz and receive replies from those aircraft that contain identity and aircraft-supplied barometric altitude data on 1090 MHz Aircraft range relative to the SSR is determined by the time from interrogation to receipt of a reply; azimuth positioning is determined from the azimuth position of the radar antenna when the reply is received. While an aircraft is within the main lobe of the SSR antenna, the SSR may interrogate an aircraft multiple times, and may receive one or more replies. However, each time an SSR scans a target (target enters and leaves the SSR main beam) the SSR creates a single target report (sometimes called target message or plot report), which is sent to the Automation system(s) that are interfaced with the SSR. The Automation systems perform processing and generate information (in form of target icon and a data block) that an air traffic controller uses to safely separate air traffic.

There are three basic types of SSRs in the NAS: (a) ATC Radar Beacon System (ATCRBS) with traditional (non-monopulse) antennas and sliding window processing; (b) ATCRBS with monopulse antenna; and (c) Mode Select (Mode S) capable[*]. Sliding window ATCRBS SSRs interrogate aircraft using multiple Mode A/C interrogations (usually involving three pulses) while within the beamwidth of the antenna, so that the azimuth position can be determined. For ATCRBS sliding-window systems, a series of successive 12-pulse replies (nominally about 18 for terminal SSRs) received in the antenna beamwidth are used to determine the azimuth position of the aircraft; for monopulse ATCRBS and Mode S systems, the azimuth position can theoretically be determined from a single reply, although in most cases more than one reply is used (nominally about 6 for ATCRBS, 2 for Mode S). ATCRBS SSRs do not selectively interrogate individual aircraft; all aircraft within the antenna beamwidth that decode the same Mode A/C interrogations will reply, resulting in numerous 1090 MHz replies for every interrogation.

Mode S-capable SSRs selectively interrogate each tracked aircraft equipped with a Mode S transponder using a separate Mode S interrogation for each aircraft, while also interrogating ATCRBS transponders with Mode A/C interrogations. These systems also provide monopulse capability for determining azimuth position, versus the sliding window method of older ATCRBS SSRs. The selective interrogations of Mode S SSRs are intended to limit the number of

[*]A possible source of confusion is that the term “Mode S” has two meanings: (a) Mode S refers to a SSR concept, involving 56-bit (and, in some cases, 128-bit) messages, sent by aircraft and ground equipment; (b) Mode S refers to the first SSR to be procured by the FAA which implements this concept.

transponder replies by preventing all other Mode S aircraft from replying to a an interrogation. However, until the TERRA* fix is removed, Mode S transponders are also replying to every Mode A/C interrogation. Mode S transponder-equipped aircraft are acquired using All-Call interrogations that every Mode S transponder in the beam replies to, similar to the way ATCRBS interrogations function. However, Mode S transponders can be locked out from replying to All-Call interrogations once there is a track established, limiting the number of replies. ATCRBS transponders do not support the selective interrogation feature. Therefore, Mode S SSRs use multiple Mode A/C interrogations to detect ATCRBS-equipped aircraft, which results in multiple ATCRBS-equipped aircraft replying to every Mode A/C interrogation.

The anticipated inventory of FAA and DoD fixed SSR assets that will be operating in the baseline NAS environment for the analysis timeframe (approximately 300 SSRs total) will include a mix of monopulse Mode S-capable (40%), monopulse ATCRBS (35%), and sliding-window ATCRBS (25%) SSRs. With ADS-B becoming the primary means of ATC surveillance in the future, FAA SSRs will then provide a backup surveillance capability, but would be needed in the event of an ADS-B outage (e.g., if GPS is unavailable). A reduced network of FAA SSRs will be sufficient to provide this backup capability, with the current complement of en route SSRs, and terminal SSRs at high density airports (42 systems), remaining operational in the NAS. All remaining FAA SSRs (approximately 50% of the total SSR inventory) will be monopulse systems, with approximately 80% of these operating as Mode S SSRs, and the balance operating as monopulse ATCRBS SSRs. All Mode S SSRs will have the "Terra Fix" removed, and their interrogation sequence modified, as recommended in the SBS Program Office's 2009 report (Ref. 4).

Based on feedback received from the DoD, the team assumes that, for the Interim Analysis phase, DoD-owned SSRs currently in operation will remain in the NAS with no significant increase in numbers. Of these systems, it is also assumed that approximately 50% of these will be monopulse ATCRBS SSRs, with the remaining systems being sliding-window ATCRBS SSRs. DoD has also reported to the team that they have operational requirements to interrogate with Mode S, although the specific methods by which this might be accomplished by platforms that are not part of the NAS are currently being studied.

9.2. Automatic Dependent Surveillance – Broadcast (ADS-B):

ADS-B is an advanced surveillance technology that allows avionics to broadcast an aircraft's identification, position, altitude, velocity, and other information. Since the aircraft's position is normally derived from the Global Positioning System (GPS) and transmitted at least once or twice per second (depending on the link used), the broadcasted position information is normally more accurate and timely than most current radar-based position information. Additionally, the

* TERRA was the manufacturer of transponders that, while they met MOPS specifications, had an unintended response to the ATCRBS suppression pulse. Until such transponders are out of service, Mode S SSRs have stopped transmitting the ATCRBS suppression pulse.

avionics provides specific flight parameter information with the broadcast of its surveillance position.

In the NAS, there are two ADS-B equipage types:

- 1090 Extended Squitter (1090ES): an extension of Mode-S technology in which 1090ES avionics periodically broadcast messages at 1090 MHz that provide their identity (24-Bit Address), target state vector (position, velocity) and other aircraft status information.
- Universal Access Transceiver (UAT): a new technology in which UAT avionics periodically broadcast messages at 978 MHz that provide their identity, target state vector and other status information.

Each of these equipage types may support only ADS-B-OUT services, or may be more comprehensive and support ADS-B-IN services as well. Table 9 contains high-level descriptions of the ADS-B-OUT and -IN services that are provided to aircraft with the different equipage types. It also describes the ADS-B air to air surveillance, which is complementary to, but independent of the broadcast services provided by the FAA.

Table 9 Summary of ADS-B Services

Category	Service	Description
ADS-B-OUT Service (to Air Traffic Control)	ADS-B Surveillance (Air to Ground)	A service to FAA Air Traffic Control (ATC) that receives, formats, and forwards the received broadcast information of 1090ES and UAT ADS-B-OUT equipped aircraft
ADS-B-IN Services (to aircraft equipped with ADS-B-IN in addition to ADS-B-OUT)	ADS-B Surveillance (Air to Air)	An 'in cockpit' service to 1090ES/UAT ADS-B-IN equipped aircraft that captures 1090ES/UAT squitters of proximate aircraft
	ADS-B Rebroadcast (ADS- R)	A service to the cockpit of 1090ES/UAT ADS- B-IN equipped aircraft that supports ADS-B message translation and rebroadcast of the identity and state of proximate aircraft with UAT/1090ES ADS-B equipage
	Traffic Information Services - Broadcast (TIS-B)	A service to the cockpit of 1090 and UAT ADS-B-IN equipped aircraft that broadcasts the state of proximate aircraft that are not ADS-B equipped
	Flight Information Service – Broadcast (FIS-B)	A service to the cockpit of UAT ADS-B-IN equipped aircraft that provides Meteorological and Aeronautical Information

The accuracy and broadcast characteristics of ADS-B supports numerous cockpit-based and air traffic control (ATC) applications. ADS-B-equipped aircraft with cockpit displays can receive ADS-B messages (i.e. ADS-B IN) from other suitably equipped aircraft within the reception range resulting in an air-to-air and airport surface surveillance capability. ADS-B surveillance broadcasts (i.e. ADS-B OUT) can also be received by ground-based transceivers to provide surveillance information for air traffic services and other functions such as traffic flow management and fleet operations management.

In the United States, two different data links have been adopted for ADS-B use: 1090 MHz Extended Squitter (1090ES) and the Universal Access Transceiver (UAT) on 978 MHz. The 1090ES link is intended for transport aircraft, and is required when operating above flight level 180; the UAT link is intended for general aviation aircraft. Broadcasts on one link are received on the ground and re-broadcast on the other link via Automatic Dependent Surveillance - Rebroadcast (ADS-R), to support cockpit-based ADS-B applications between aircraft using dissimilar links. Based on the projection of air traffic growth in the Northeast corridor, this analysis assumes that beyond 2020, 80% of the aircraft operating at any given time in this airspace will be broadcasting ADS-B messages using the 1090ES link, with the remaining 20% using the UAT link.

State vector and other information for aircraft that are not equipped with ADS-B, or are without a functioning system, are determined by ground-based surveillance systems (e.g., SSRs) when available. This information is broadcast to aircraft equipped with ADS-B IN via Traffic Information Services - Broadcast (TIS-B), which uses the same ADS-B links and protocols, to support cockpit situational awareness. The use of TIS-B is expected to decrease as aircraft equip with ADS-B to meet the equipage rule requirements for ADS-B by 2020.

ADS-B is planned to become the primary means of ATC surveillance in the NAS starting in 2020. The ADS-B service, currently being implemented by the SBS Program Office, will be used to provide ADS-B data to ATC. This capability will be available for all areas currently being provided radar services, with additional non-radar areas being included to expand NAS capabilities (e.g., Gulf of Mexico, selected secondary airports). Ground-based backup FAA SSR surveillance capabilities will be retained beyond 2020, but will only cover en route airspace and the most congested (approximately 44) terminal areas.

9.3. Multilateration Systems

Similar to SSRs, multilateration surveillance systems interrogate aircraft transponders on 1030 MHz and receives replies on 1090 MHz. Unlike SSRs, however, multilateration systems determine aircraft position using the time difference of arrival of replies at multiple ground stations that have synchronized clocks. Multilateration systems use Mode S selective interrogations of aircraft equipped with Mode S transponders to minimize the number of replies from these aircraft. To minimize the number of replies from aircraft equipped with ATCRBS transponders, a whisper-shout Mode A/C interrogation scheme is used so that all ATCRBS transponders do not reply to each interrogation.

Multilateration systems can also use ADS-B broadcasts to determine position using the time difference of arrival technique. The ability to passively multilaterate on ADS-B broadcasts will also allow a reduction in Mode S and ATCRBS interrogation/reply sequences for ADS-B-equipped aircraft.

Multilateration systems are implemented in three forms:

- as part of the ASDE-X or ASSC surface surveillance systems at selected larger airports,
- as a Wide-Area Multilateration (WAM) capability used as an alternative to traditional SSR surveillance in selected environments (typically which are not favorable for the operation of an SSR)
- as a Precision Runway Monitor – Alternate (PRM-A), in lieu of a conventional PRM radar, for monitoring aircraft approaching closely-spaced parallel runways

For the purposes of this analysis, surface multilateration systems are implemented in all locations that currently have Airport Surface Detection Equipment (ASDE) systems installed, including ASDE-3, ASDE-X and ASSC system locations. WAM capabilities are installed in mountainous regions of Colorado and Alaska and military installations at 29 Palms, CA, Patuxent River, MD.

9.4. TCAS

TCAS performs the collision avoidance function by actively interrogating nearby transponder-equipped aircraft with Mode S and ATCRBS Mode C altitude interrogations, using existing ATCRBS and Mode S signal formats on 1090 MHz. TCAS tracks ATCRBS-equipped aircraft in its vicinity via a “whisper-shout” power management technique, and Mode S-equipped aircraft using the Mode S squitter for acquisition and discretely addressed interrogations. TCAS also interrogates Mode S-equipped aircraft at different rates based on their collision threat potential.

TCAS determines which transponder-equipped aircraft are a threat based on proximity and direction of flight. Depending on the class of TCAS equipment, the system will issue traffic warnings, up/down maneuver instructions, and/or coordinated advisories. TCAS-issued warnings can be in the form of traffic advisories (TAs) for potential threats, or resolution advisories (RAs) for imminent threats of collision. The pilot is to maneuver only after receiving an RA.

A basic performance characteristic of TCAS is called the Risk Ratio, which is defined in terms of the probability of a Near Mid-Air Collision (NMAC) with and without TCAS:

$$\text{Risk Ratio} = \frac{\text{Probability of NMAC with TCAS}}{\text{Probability of NMAC without TCAS}}$$

The widely accepted goal for the TCAS Risk Ratio is a value of 0.1 or smaller. The risk ratio is comprehensive of all effects, including a surveillance component and a logic component.

To achieve a risk ratio of 0.1, TCAS is designed to issue an RA when an intruding aircraft's tau value (time to Closest Point of Approach) falls below a defined threshold, dependent on the ownship aircraft's altitude, as shown in Table 10:

Table 10 Tau Threshold versus Ownship Altitude

Ownship Altitude (AGL)	Tau
< 1,000 ft	N/A
1,000 – 2,350 ft	15 seconds
2,350 – 5,000 ft	20 seconds
5,000 – 10,000 ft	25 seconds
10,000 – 20,000 ft	30 seconds
20,000 – 42,000 ft	35 seconds
> 42,000 ft	35 seconds

To support these threshold values, TCAS is designed to provide a reliable surveillance range of 14 NM when the ownship aircraft's altitude is greater than 10,000 ft, where aircraft closure rates can be as high as 1200 kt. Due to airspeed restrictions in the United States, TCAS is also designed to provide a reliable surveillance range of at least 4 NM when the ownship aircraft's altitude is less than 10,000 ft., where closure rates can be as high as 600 kt. A probability of 90% or higher of having an intruder successfully in track by the time an RA needs to be issued is consistent with the overall goal of providing a risk ratio of 0.1 or smaller.

All aircraft that are currently required to carry TCAS will continue to be required to do so in 2020 and beyond. No changes in TCAS operational requirements are anticipated by the analysis timeframe. Based on the projection of air traffic growth in the Northeast corridor, this analysis assumes that beyond 2020 (before any proposed mitigations are put in place), 80% of Mode S equipped aircraft (i.e., 64% of all aircraft) operating at any given time in the airspace will be equipped with TCAS II v7.0 or later.

9.5. WJHTC Airborne Measurement Suite

The WJH FAA Technical Center developed test equipment to provide detailed measurements of the 1030/1090 MHz RF environment that includes signals from SSR, TCAS, ADS-B and other systems that utilize the ASCAS frequency band. The equipment has been installed on aircraft for airborne measurements. It has also been installed on ground vehicles or structures for surface measurements.

Figure 16 shows the basic system configuration used for airborne measurements. It consists of two 1030 MHz receivers and two 1090 MHz receivers each for top and bottom antenna recording. Each receiver provides a log video signal output that is sampled and recorded digitally for post processing and analysis. The 1030 receivers also supply a synchronized Differential Phase-Shift Keying (DPSK) signal for recording as well. (DPSK is the waveform used for Mode S interrogations.) A surface measurement configuration is similar but typically only uses one antenna for each frequency.

Because the log-video signal is continuously recorded and post-processed, the ability to re-process the data after modifying the analysis tool is available. This has proven to be a valuable asset when certain anomalies are detected or there is interest in additional decode types. This is the case for both frequencies.

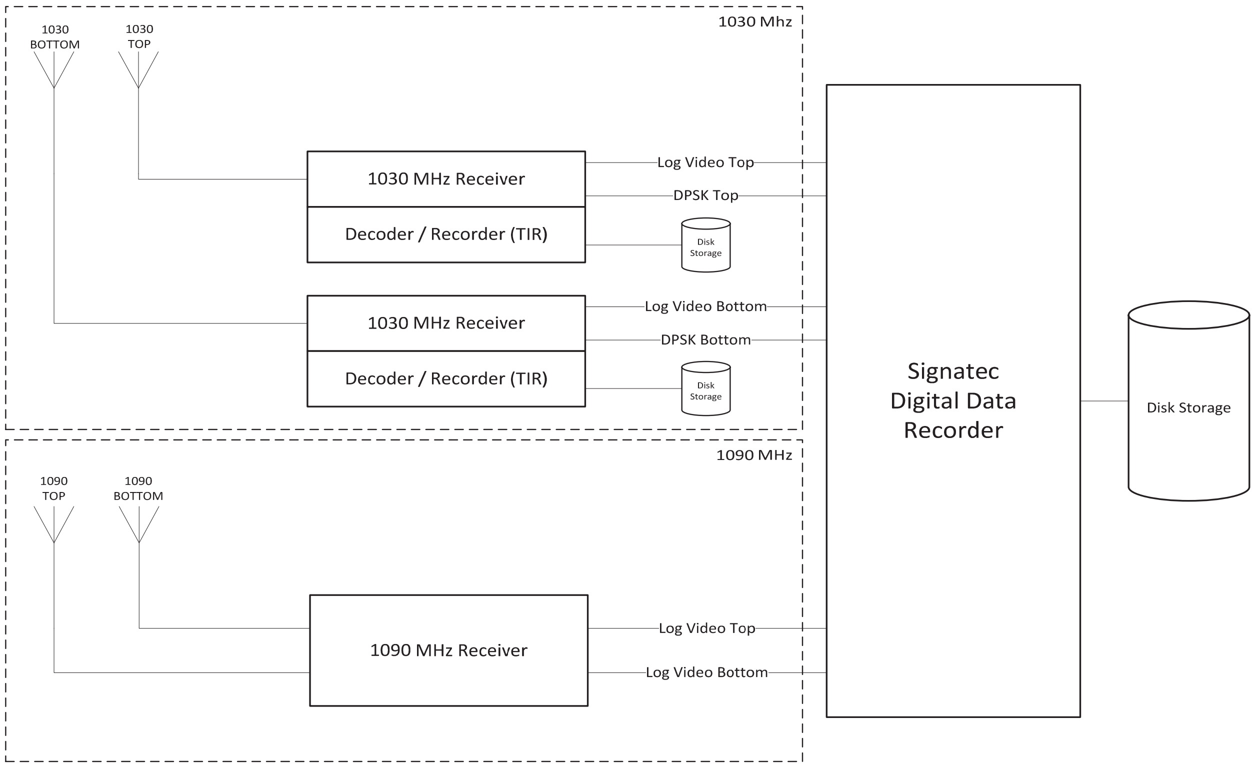


Figure 16 WJHTC Basic 1090/1030 MHz RF Measurement and Recording Configuration

1090 MHz Post-Processing Specifications:

- Decode time accuracy is to the nearest 100 nanoseconds GPS time-tagged
- Amplitude dynamic range from approximately -85 dBm to -30 dBm
- Utilizes an enhanced decoding process and applies error detection and correction
- Stores decoded as well as unsuccessfully decoded data to measure all signals in space independent of signal quality
- Decode types:
  - ATCRBS Modes A & C
  - Mode S Short or Long Replies
  - Acquisition Squitters
  - ADS-B Extended Squitters
  - TCAS Replies

1030 MHz Post-Processing Specifications (Signatec Data):

- The decode time accuracy is to the nearest 100 nanoseconds GPS time-tagged
- Amplitude dynamic range from approximately -77 dBm to -30 dBm
- Decode types:

  - Mode A, suppressed and non-suppressed
  - Mode C, suppressed and non-suppressed
  - Inter-mode A, suppressed and non-suppressed
  - Inter-mode C, suppressed and non-suppressed
  - ATCRBS-Only Mode A, suppressed and non-suppressed
  - ATCRBS-Only Mode C, suppressed and non-suppressed
  - Whisper-Shout Mode A, suppressed and non-suppressed
  - Whisper-Shout Mode C, suppressed and non-suppressed
  - Mode S short, suppressed and non-suppressed
  - Mode S long, suppressed and non-suppressed
  - Mode 1, suppressed and non-suppressed
  - Mode 2, suppressed and non-suppressed
  - Mode 4
  - TACAN - DME
- The process detects sub-MTL (Minimum Trigger Level) Mode S interrogations and detects other decode types that may be caused by them. (Sub [but near] -MTL Mode S data blocks that partially break receiver threshold can cause spontaneous replies such as Mode A. Some transponder designs are more susceptible to this than others.)
- Other decode types can be added and previously recorded data can be re-processed.

9.6. AN/UPX-41(C) Digital Interrogator System (Shipboard)

The NTIA certified Stage-4 spectrum support (shown in Section 11) for the AN/UPX-41(C) Digital Interrogator System (Shipboard) when configured as follows:

- OE-120 electronically steered antenna (ESA) group
- AN/UPX-29(V) Air Traffic Control Radar Beacon System, Identification Friend or Foe, Mark XII/Mark XIIA, Systems (AIMS) Mark XII Interrogator (Section 9.7 contains a description)
- AN/UPX-24 interface, Version 2.1.2
- Controlled by the Cooperative Engagement Capability (CEC, Section 9.8 contains a description), and
- Interrogation strategy of no more than one 360 degree Mode 4 scan out of every seven scans.

The AN/UPX-41(C) has detection range of approximately 280 NM. When operating in the full-scan mode, it has a scan period of 4.096 seconds, which involves 1,024 interrogations at a rate of 250 per second (Ref. 20). Thus it has a scan rate similar to (but faster than) a FAA terminal radar and a detection range similar to (but longer than) a FAA en route radar. The interrogation rate is comparable to that of FAA SSRs, which have interrogation rates of 100 to 400 per second.

When controlled by the CEC (as approved by Ref. 2), the AN/UPX-41(C) has the interrogation pattern shown in Table 11. During six consecutive scans, only the Selective Identification Feature (SIF) modes (1, 2, 3 and C) are interrogated. Mode 4 is only interrogated every 7th scan, when it is interlaced with the SIF modes — e.g., Mode 1, Mode 4, Mode 2, Mode 4, Mode 3, Mode 4, Mode C, Mode 4, etc.

The AN/UPX-41(C) / AN/UPX-29(V) are capable of two additional scan modes that are not addressed by Ref. 2 — Sector and Pop up. These are possible because the OE-120 antenna is steered electronically. Pop up scans can be triggered in three ways: from the host ship Combat System (CS), from the Cooperative Engagement Capability (CEC) and from operators manually through the AN/UPX-24(V) Control Indicators (CIs). CEC is the only ship system which requests Sector scans.

Table 11 AN/UPX-41(C) Interrogation Pattern

Mode	Scan 1 0-4 sec	Scan 2 4-8 sec	Scan 3 8-12 sec	Scan 4 12-16 sec	Scan 5 16-20 sec	Scan 6 20-24 sec	Scan 7 24-28 sec
Mode 1	256	256	256	256	256	256	128
Mode 2	256	256	256	256	256	256	128
Mode 3	256	256	256	256	256	256	128
Mode C	256	256	256	256	256	256	128
Mode 4	0	0	0	0	0	0	512

The AN/UPX-41(C) OE-120 electronically-steered antenna (ESA, Figure 17) is independent of a primary radar antenna. Being electronically-steered enables it to have a rapid scan rate and to respond quickly to interrogate pop-up targets.

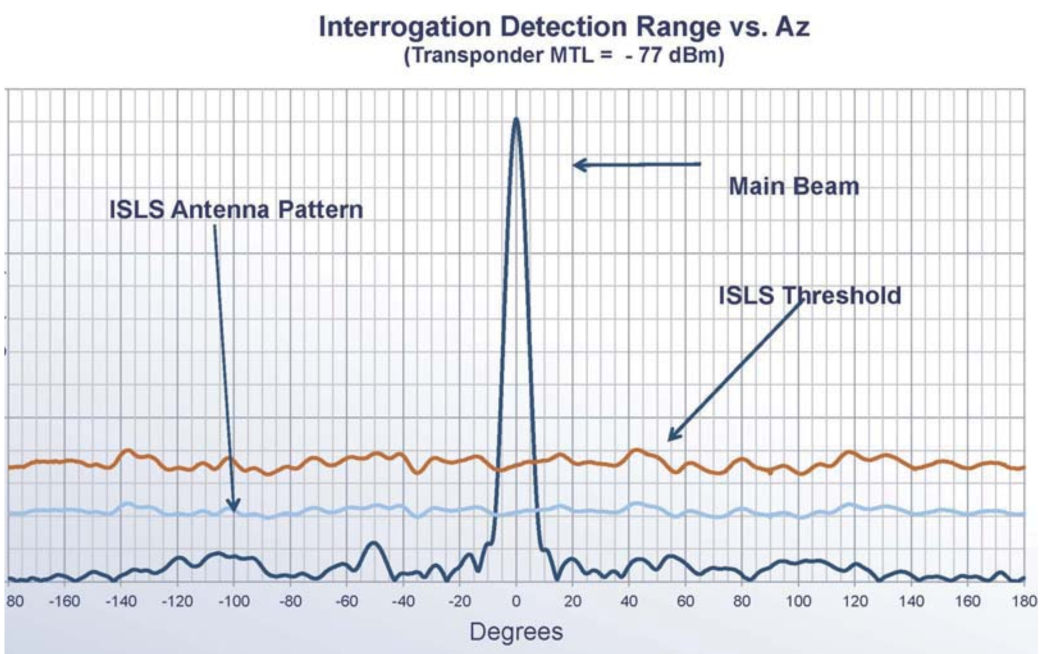


Figure 17 AN/UPX-41(C) Detection Range vs. Antenna Azimuth

9.7. AN/UPX-29(V) Interrogator System

The Interrogator System AN/UPX-29(V) is a centralized AIMS MK XII IFF system that employs a challenge and reply technique to distinguish friendly platforms in a multi-target environment. This is accomplished by generating identity queries on specific or general targets and processing target responses to obtain identification. An electronically-steered antenna (ESA), which is independent of a radar antenna, is employed to provide for near immediate pop-up interrogations of targets without antenna rotation delays. Since an ESA is used, the AN/UPX-29(V) is not dedicated to be used with any one particular radar system. The AN/UPX-29(V) is used with any radar system(s) that provides trigger and antenna bearing signals for synchronization of IFF target data with radar track data.

The AN/UPX-29(V) acts as a standalone IFF system, performing all AIMS MK XIIA functions. In addition, the AN/UPX-29(V) can convert analog data from conventional IFF operation into digital data, process and store up to 400 targets, provide instantaneous interrogation on a target within 25 microseconds, provide electronic evaluation of Mode 4 replies, provide operator-designated target information from data storage, provide simultaneous display of IFF targets synchronized with up to four radars at 22 displays, provide sector interrogation capability, and interface with shipboard computer control systems.

The AN/UPX-29(V) can be controlled from up to 22 manually operated display positions, one semi-automatic operating position, and one shipboard computer controlled interface. These positions can function simultaneously, and AIMS functions are available at each position independent of the functions selected at other positions.

The primary operating mode of the AN/UPX-29(V) uses the processor controller main unit and the ESA. In the event of a failure in the main processor or a failure of the ESA antenna, a backup (Bypass) processor is provided along with a backup rotating antenna. The main and backup systems are independent of each other, allowing for up to four possible operating configurations. When the AN/UPX-29(V) backup processor is used, the interface with the shipboard computer control system will be disabled, and the system will be slaved and limited to displaying IFF video with one radar. If the rotating antenna is used, the AN/UPX-29(V) will be unable to perform instantaneous popups or redirects on targets.

9.8. CEC - Cooperative Engagement Capability

9.8.1. Overview

Cooperative Engagement Capability (CEC) is a real-time sensor netting system that enables high quality situational awareness and integrated fire control capability. CEC is designed to enhance the Anti-Air Warfare (AAW) capability of ships and aircraft by the netting of battle force sensors to provide a single, distributed AAW defense capability. CEC enables Integrated Fire Control to counter increasingly capable cruise missiles and manned aircraft.

9.8.2. Features

CEC is a system of hardware and software that allows the sharing of radar and weapons systems data on air targets among U.S. Navy ships, U.S. Navy aircraft, and USMC Composite Tracking Network (CTN) Units. Sensor data from individual units is transmitted to other units in the group via a real-time high quality, anti-jam capable line-of-sight, Data Distribution System (DDS). Each Cooperating Unit (CU) platform uses identical data processing algorithms resident in its Cooperative Engagement Processor (CEP), resulting in each having the same display of air track information. This gives an individual ship the added capability to launch anti-air weapons at threat aircraft or missiles within its engagement envelope based on remote sensor data provided by the CEC sensor network. The CEC system makes it possible for multiple surface ships and aircraft to form an air defense network by sharing radar target measurements in real-time.

CEC's two major system functions consist of a Cooperative Engagement Processor for sensor networking and a Data Distribution System for real-time communications. The system interfaces with the platform sensors and combat systems. CEC's Common Equipment Set (CES) provides for shared hardware components among the different CEC equipped platforms. The basic CEC equipment set consists of an antenna subsystem, a signal data processor, a backup battery, and technician control interfaces. The AN/USG-2 CEC system variant is designed for Navy surface ships, the AN/USG-3 CEC system variant is designed for Navy E-2 aircraft, the AN/USG-4 CEC system variant is designed for the USMC CTN and the AN/USG-4 is designated for the Army JLENS.

9.9. AN/UPX-41(C) Test Site Configurations

9.9.1. All Sites

All 4 sites will be operating with Interrogator System AN/UPX-29(V), comprised of CP-1273/UPX-24(V) Mode 5 Processor Controller Part Number 54301-1, AN/UPX-24(V) Part Number 54300, Software Version 2.1.3 and 2.1.3E, and Interrogator Set AN/UPX-41(C) Part Number 1001734G-71, Software Version 5.5 and Antenna Group OE-120/UPX.

9.9.2. Webster Field Buildings 8225 and 8164

Emulate CEC control (6 SIF scans followed by one Mode 4/SIF interlaced Scan) AN/UPX-24(V) SW version 2.1.3E will be used at one or both Webster Field sites (2.1.3E enables an external Ethernet interface for both CEC emulation and enhanced data collection).

9.9.3. Wallops Island Building V-10

AEGIS Baseline 8.1.2 with CEC running 2.1.9.9_4.21 (6 SIF scans followed by Mode 4/SIF interlaced scan).

9.9.4. Wallops Island Building V-24

SSDS 6.06.03 with EU 1 and with CEC 2.1.7.4 (all SSDS / CEC baselines are same for IFF), (6 SIF scans followed by Mode 4/SIF interlaced scan).

10. Appendix: NAS ASCAS Systems Summary Table

Parameter	Mode S	ASR-11	Condor MK2D	ATCBI-5	ATCBI-6	ATCBI-6M	PRM	PRM-A	ASDE-X MLAT	WAM	TCAS	ADS-B A/C	ADS-B Gnd	ADS-R	AN/UPX-41(C)
Usual Domain	Terminal & En Route	Terminal	Terminal	Terminal & En Route	En Route	En Route	Approach	Approach	Airport Surface	En Route	Terminal & En Route	N/A	Both	Both	En Route
Scan Period (sec)	4.8 or 12	4.8	4.8	4.8 or 12	12	12	1	1	N/A	N/A	N/A	N/A	N/A	N/A	4.096
Interrogations/sec	Variable			300	120	120	450 maximum	Mode S: 50/sec max; 27/W-S RT/sec	Mode S: 50/sec max; ATCRBS: 24/W-S RT/sec	Mode S: 50/sec max; ATCRBS: 14/W-S RT/sec		5.2	Variable	Variable	250
Transmit Freq. (MHz)	1030	1030	1030	1030	1030	1030	1030	1030	1030	1030	1030	1090	N/A	1090	1030
Receive Freq. (MHz)	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	N/A	1090	1090	1090
Antenna Type	Monopulse	Monopulse	Monopulse	Conventional	Monopulse	Monopulse	E-Scan	Folded, Omni	Folded, Omni	Folded, Omni	Omni	Omni			OE-120
Number in NAS	144	~100	16	~25	~87	42	6		35	3	N/A	N/A	794 by 2015	794 by 2015	
Waveform(s)	ATCRBS & Mode-S	ATCRBS	ATCRBS	ATCRBS	ATCRBS & Mode-S	ATCRBS, Mode-S & Mode-4	ATCRBS		ATCRBS & Mode-S	ATCRBS & Mode-S	ATCRBS & Mode-S	Mode S Ext.	Mode S Ext.	Mode S Ext.	ATCRBS, Mode-4
Interlace	If on a coast, it's a joint use Radar with Mode 2	If on a coast, it's a joint use Radar with Mode 2	If on the coast it's a joint use Radar with Mode 2	If on the coast it's a joint use Radar with Mode 2	If on the coast it's a joint use Radar with Mode 2	If on the coast it's a joint use Radar with Mode 2	Modes A,C	Modes A, C, S	Modes A,C,S	Modes A,C,S	Modes A,C,S	N/A	N/A	N/A	(1,2,A,C) 6 revs (1,4,2,4,A,4,C,4) 1 rev
Transmit Power (W)		160W to 1500W	160 - 1500 W												2000 W
DoD Name	—	FAA version of DoD DASR or AN/GPN-30	SSR with AN/GPN-30 or DASR												
Primary Radar	ASR-8, ASR-9 or BOS	ASR-11 primary	AN/GPN-30	ARSR-1,2,3 & ASR-9 or BOS	ARSR-1,2,3 or BOS	ARSR-4	none	none	ASDE-3 or SMR	none	N/A	none	none	none	AN/SPY-1
Specifications	RTCA DO-181 FAA Order 6365.1A	RTCA DO-181	RTCA DO-181	RTCA DO-181	RTCA DO-181 FAA-E-2923B	RTCA DO-181 FAA-E-2923B	FAA-E-2887	FAA-E-2942	FAA-E-2942	ICAO Doc 9924, Appendix M FAA-E-3024	RTCA DO-185	RTCA DO-260	RTCA DO-260	RTCA DO-260	AIMS-03-1000

*BOS = Beacon Only System

11. Appendix: AN/UPX-41(C) Stage-4 Certification (SPS-18778/1)

The following two pages are images of the PDF file of Ref. 2, SPS-18778/1, *AN/UPX-41(C) Digital Interrogator System, S/W V5.5, with Mode 5 (Shipboard)*, NTIA Certification, June 22, 2012.

FOR INFORMATION Doc. 29339/1

FORM NTIA-44 (3/91) U.S. DEPARTMENT OF COMMERCE NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION CERTIFICATION OF SPECTRUM SUPPORT	Classification UNCLASSIFIED	Control Number SPS-18778/1 ERP-1247
Recipient Agency Navy	System AN/UPX-41(C) Digital Interrogator System, S/W V5.5, with Mode 5 (Shipboard)	Stage of Review 4 – Operational

Section 1: OPERATING CHARACTERISTICS FOR WHICH SUPPORT IS CERTIFIED

Frequency (MHz)	Emissions	Peak Power (W)	Station Class	Operating Location
1030 (Transmit)	10M0V1D 18M0V1D 20M0V1D	2000	NR	US&P

Section 2: SOURCE DOCUMENTS

Docket Number	Description of Document	Dated
SPS-17890/1	FAA Memorandum: AN/UPX-41(C) Digital Interrogator System Mark XII with software version 5.4 (shipboard), Stage 3	Mar 2, 2011
SPS-18408/2	Navy Replacement Request for Stage 4 Spectrum Support	Feb 16, 2012
SPS-18521/1	Navy Memorandum: Detailed Response to FAA letter, SPS-17890/1	Feb 16, 2012
SPS-18692/1	FAA Memorandum: Designated High and Medium Aircraft Density Areas	May 5, 2012

Section 3: SPS RECOMMENDATIONS

The Spectrum Planning Subcommittee has reviewed this system under the provisions of Chapter 10 of the NTIA Manual, noting that the receiver of the subject system is tuned to center frequency 1090 MHz and the UPX-41(C) has the capability to transmit at 4000 watts peak power, recommends that:

1. NTIA certify Stage 4 spectrum support for the AN/UPX-41(C) Digital Interrogator System (Shipboard), as specified in Section 1 when operated in conjunction with the OE-120 antenna, the AN/UPX-29(V), the AN/UPX-24 interface Version 2.1.2., controlled by the CEC, and the interrogation strategy of no more than one 360 degree Mode 4 interrogation scan out of every seven scans. It is recognized that this system has a back-up antenna that will only be used in emergencies and the Navy acknowledge that no more than one back-up antenna will be in operation in the National Airspace System (NAS).
2. Navy be aware that use of the AN/UPX-41 Digital Interrogator System in a standalone mode or in conjunction with any other system not listed in Recommendation 1 will require the submission to the SPS with additional antenna information and the associated Platform Level Certification from the DoD AIMS Program Office.
3. Navy coordinate operations of this system with the FAS Aeronautical Assignment Group (AAG) and the FAA Regional Coordinators in accordance with Sections 1.3.2 and 8.3.16 of the NTIA manual, respectively.
4. Navy be aware that when operating the Shipboard AN/UPX-41(C) Digital Interrogator within 100 NM of the US&P ship configurations operating under this certification can be granted frequency assignments to operate without changing the base PRF of 250 Hz in the US&P under the aggregate operating conditions in paragraph 5.
5. Navy be aware that the FAA is conducting 1090 MHz congestion and IFF implementation studies to assess the future viability of the 1090 MHz spectrum environment and the performance of NAS aeronautical surveillance and collision avoidance systems. The results of these studies will determine the limitations of future non-NAS interrogator operations in the US&P. The Navy agrees to begin operations of the UPX-41(C) digital interrogator under the following conditions when operating within 100 NM of the US&P. Ships shall maintain the following separation when operating 4 ship interrogators at the same time within the same geographic area, as defined as 250 NM from the next closest ship interrogator:
   a. 50 NM from the center point of FAA designated High Aircraft Density Areas as provided in SPS-18692/1.
   b. 30 NM from the center point of FAA designated Low and Medium Aircraft Density Areas as provided in SPS-18692/1.

Downgrading Instructions	Classification	Page Number
	UNCLASSIFIED	1 of 1 pages

Form NTIA-44 (3/91) CONTINUATION PAGE	Classification UNCLASSIFIED	System AN/UPX-41 (C) Digital Interrogator System, Mode 5 (Software 5.5) (Shipboard)

6. Navy, when operating less than 4 ship interrogators at the same time within the same geographic area, as defined as 250 NM from the next closest ship interrogator when operating within 100 NM of the US&P., ships must maintain a 30 NM separation from the US&P coast.

7. Navy be aware that the addition of Mode Select (Mode S) interrogation capability requires equipment modifications for proper operation in the NAS.

8. The FAA and the Navy agree to conduct joint testing to validate the initial operations conditions within a target of three to six months of the date of this signed spectrum certification.

9. Navy ensure that personnel are protected from radiation levels that exceed generally accepted exposure criteria.

Name/Title of Recommending Official	Signature	Date
Stephen J. Butcher SPS Chairman	Stephen J. Butcher	JUN 2 2 2012

Section 4: NTIA CERTIFICATION

The Office of Spectrum Management certifies Stage 4 spectrum support for this system.
This office concurs with the SPS recommendations in Section 3.

Name/Title of Certifying Official	Signature	Date
Edward M. Davison Deputy Associate Administrator	Edward M. Davison	JUN 2 2 2012
Distribution	**Classification**	**Page Number**
IRAC, SPS, FAS, EPS	UNCLASSIFIED	2 of 2 pages

12. Appendix: RBAT Capabilities

12.1. Analysis Programs Available

- Beacon and Radar Coverage – calculates the beacon and radar coverage for the cell. The coverage is defined as the minimum altitude and elevation angle for the cell. A cell is defined as a region of the airspace.
- Beacon False Target Summary – identifies false targets and groups them into the split, ring-a-round, downlink reflection, PRF, uplink reflection, ATCRBS/Mode S, and other categories. The uplink reflections are used to calculate the location and orientation of the reflectors.
- Conflict Analysis – analyzes conflicts. Two tracks are in conflict if they are in each other's user specified range, azimuth, and altitude (optional) windows. The same statistics that are given by Surveillance Analysis are provided for each conflict. Plots of the conflicts are also provided.
- Duplicate Search Analysis – identifies duplicate search message pairs. A search message is a duplicate if it has the same height, range, and azimuth as another search message or if is has the same height and its range and azimuth is within the user specified windows around a radar reinforced beacon message.
- Enhanced Surveillance – determines the GICB registers that are used by Mode S transponders. This program requires an ASTERIX input extraction file.
- Filter – filters the input extraction file and creates an output extraction file that contains all the messages that pass the filter. Time, range, azimuth, altitude, elevation angle, ATCRBS ID, Mode S ID, track number, surveillance file number, Mode 2, channel, ATCRBS/Mode S, message type, and bit field filters are available.
- Fixed Transponder Accuracy – calculates the range and azimuth accuracy using the beacon messages for a specified fixed transponder. The range and azimuth of the fixed transponder are input by the user.
- KML Plot – produces a KML plot file that can be displayed in Google Earth. The colors and symbols for the individual point are selectable.
- Moving Track Plot – plots the messages that are in a user specified range and azimuth interval around the selected track. This is done repetitively as long as the user keeps entering tracks. This program is used to examine the environment of problem tracks.
- Moving Track Filter – filters the messages on the input extraction file and creates an output extraction file that contains all the messages that pass the moving track filter. This is a user specified range and azimuth interval around the user specified track. The track numbers are those that are assigned by Surveillance Analysis.
- Multi Site Plot – plots the global tracks. A global track consists of correlating local tracks. A local track contains beacon, search, or AIMS messages from a single site. The messages from each site are plotted in a separate color. The messages are plotted with respect to an origin whose latitude and longitude is specified by the user.
- Multi Site Registration – calculates the registration errors using the beacon messages with high confidence altitude. The local range, azimuth, and altitude are converted to a central x, y, and z coordinate system. The reference x, y, and z are calculated using a quadratic

fit centered on the beacon message. The quadratic fit only uses those beacon messages from sites other than that of the centered beacon message.

- Nine Points Accuracy – calculates the range and azimuth accuracy using the beacon messages for all the Mode S targets and for ATCRBS targets with discrete ATCRBS IDs. The reference range and azimuth positions are calculated using a nine points least squares curve fit centered on the beacon message.
- Peak Loading – determines the wedges, sectors, and quadrants that contain target counts in excess of their thresholds.
- Playback – plays back the extraction file on a PPI type display.
- Scan Interval Plot – plots a user specified number of scans of messages per plot. The user can also specify the number of scans between successive plots.
- Scan Summary – counts the messages by category each scan. It also gives the initial system status and any changes in status, gives counts of quality versus confidence for search messages, and plots the number of beacon and search messages per scan.
- Surveillance Analysis – analyzes beacon and search performance using an integrated beacon and search tracker. Statistics are given by track, position, and overall.
- Surveillance Print and Plot – prints, plots, and counts the messages. Time, range, azimuth, altitude, elevation angle, ATCRBS ID, Mode S ID, surveillance file number, Mode 2, channel, ATCRBS/Mode S, and message type filters are available.
- Terra Analysis – lists and plots the Terra global tracks. A global track consists of correlating local tracks. A local track contains beacon, search, or AIMS messages from a single site. The messages from each site are plotted in a separate color. The messages are plotted with respect to an origin whose latitude and longitude is specified by the user.
- Three Dimensional Height Accuracy – calculates the height accuracy using the beacon messages that have height and that have high confidence altitude. The estimate of the height is the altitude. The height is only available for radar reinforced beacon messages.
- Throughput – calculates beacon and search delay times. Statistics and plot are given as a function of target loading.
- Transponder Register Accuracy – calculates the accuracy of the data in certain transponder registers versus the values computed using the RBAT tracker.

12.2. Example RBAT's Output Text Information

Table 12 Example RBAT Surveillance Analysis Program Summary Output

Radar type	: CD2 En Route, ATCBI4/5, ARSR1/2 or FPS or BOS
Radar format	: CD2
Mode S mode	: False
Timing message	: Search RTQC
Mode 2 field	: Mode 2
Use adjusted time-of-day?	: Yes
Is beacon delay on?	: No
Elevation of antenna above MSL	: 103.0 (Ft)
Maximum range	: 250.0 (NMIs)
Antenna latitude in DD:MM:SS	: 024:35:05.60 N
Antenna longitude in DD:MM:SS	: 081:41:20.20 W
Antenna magnetic declination	: 0.0 (DEGs)

Target	Track	----- Prob. of Detection -----			--- Search PD ---		Target ID		Target Altitude		Mode 2		Number	ATCRBS	Radar	Search	Range	Azmth
Category	Life	Beacon	Search	Total	LogNml	Mti	Rel	Conf	Rel	Conf	Rel	Conf	Hits	Reinf	Reinf	Collim	Error	Error
DISCRETE	473,797	95.80	78.46	97.43	78.46		99.94	100.00	99.71	99.97	96.55	100.00	27.6		80.19	100.00	0.08	0.14
NON DISCRETE	37,707	95.18	50.37	96.10	50.37		99.28	100.00	99.72	99.19	65.00	100.00	25.1		51.95	99.99	0.09	0.40
ATCRBS	511,504	95.75	76.39	97.34	76.39		99.90	100.00	99.71	99.91	81.62	100.00	27.4		78.12	100.00	0.08	0.16
MODE 2	1,577	91.82	56.12	94.93	56.12				90.00	100.00	91.57	100.00	8.7		57.73	100.00	0.20	0.89
BEACON	513,081	95.74	76.32	97.33	75.06		99.90	100.00	99.71	99.91	87.28	100.00	27.4		78.06	100.00	0.08	0.16
SEARCH	8,631		73.06	73.06	73.06												0.16	0.38
TOTAL	521,712	95.74	76.27	96.93	76.27		99.90	100.00	99.71	99.91	87.28	100.00	27.4		78.06	100.00	0.08	0.16

Number of tracks included in the statistics = 6776

ATCRBS=6229 (91.93 %) Mode S=0 (0.00 %) Mode2=45 (0.66 %) Search=502 (7.41 %) Mode 4=0 (0.00 %)

Number of beacon tracks with Mode 2 capability: ATCRBS=20 (0.32 %) Mode S=0

Number of Mode 2 reports correlated to non-military beacon tracks: ATCRBS=8530 (1.7 %) Mode S=0

Number of scans = 4950

Uncorrelated reports: beacon = 5720 search = 33392 Mode 4 = 0

Coasted tracks: beacon = 21853 search = 2325 Mode 4 = 0

Uncorrelated reports per scan: beacon = 1.16 search = 6.75 Mode 4 = 0.00

Coasted tracks per scan: beacon = 4.41 search = 0.47 Mode 4 = 0.00

Uncorrelated reports plus immature track updates per scan: beacon = 3.69 search = 8.25 Mode 4 = 0.00

12.3. Example RBAT Output Plots

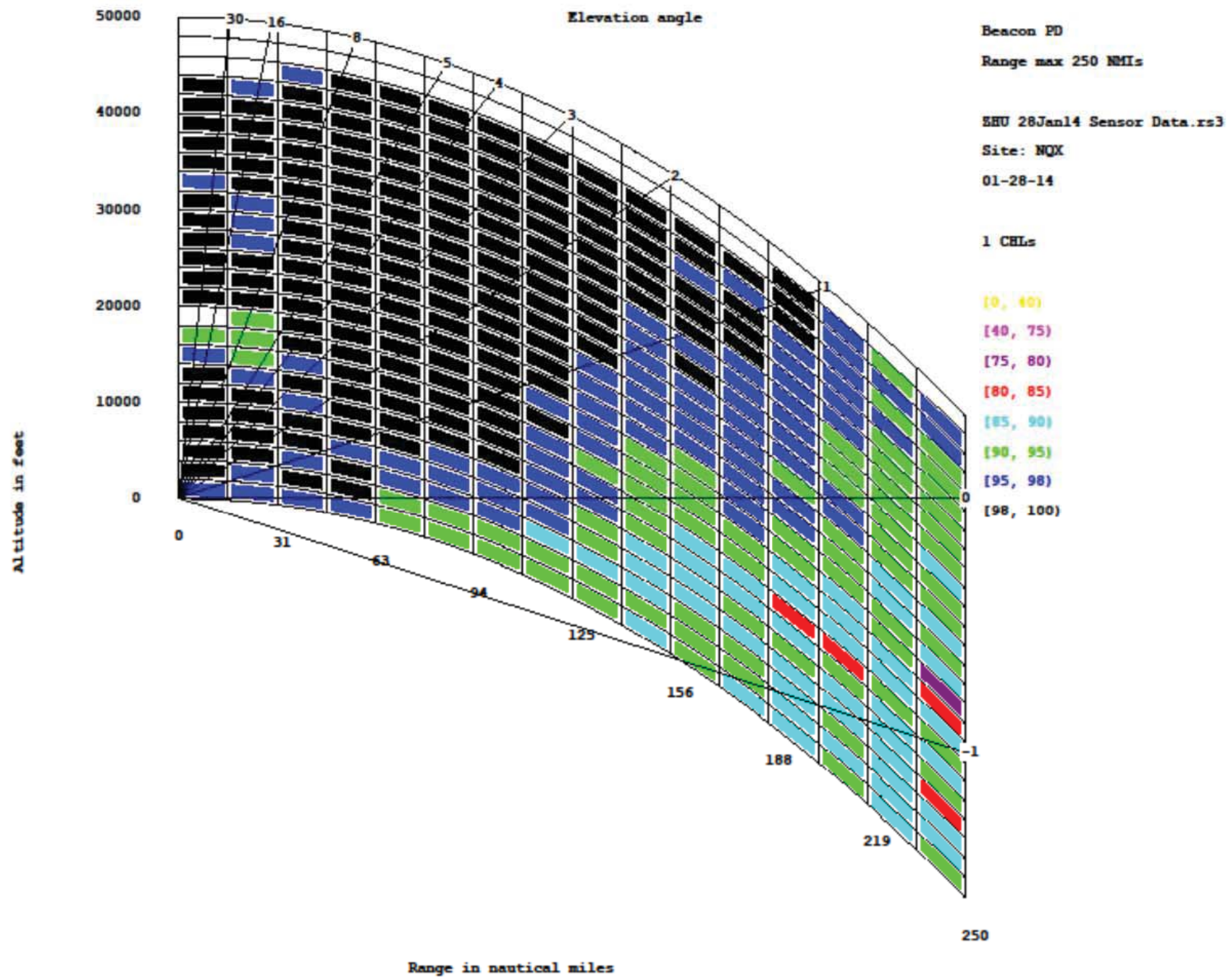


Figure 18 RBAT: SSR Probability of Detection as a function of target range and altitude; Key West Naval Air Station radar, Jan. 28, 2014

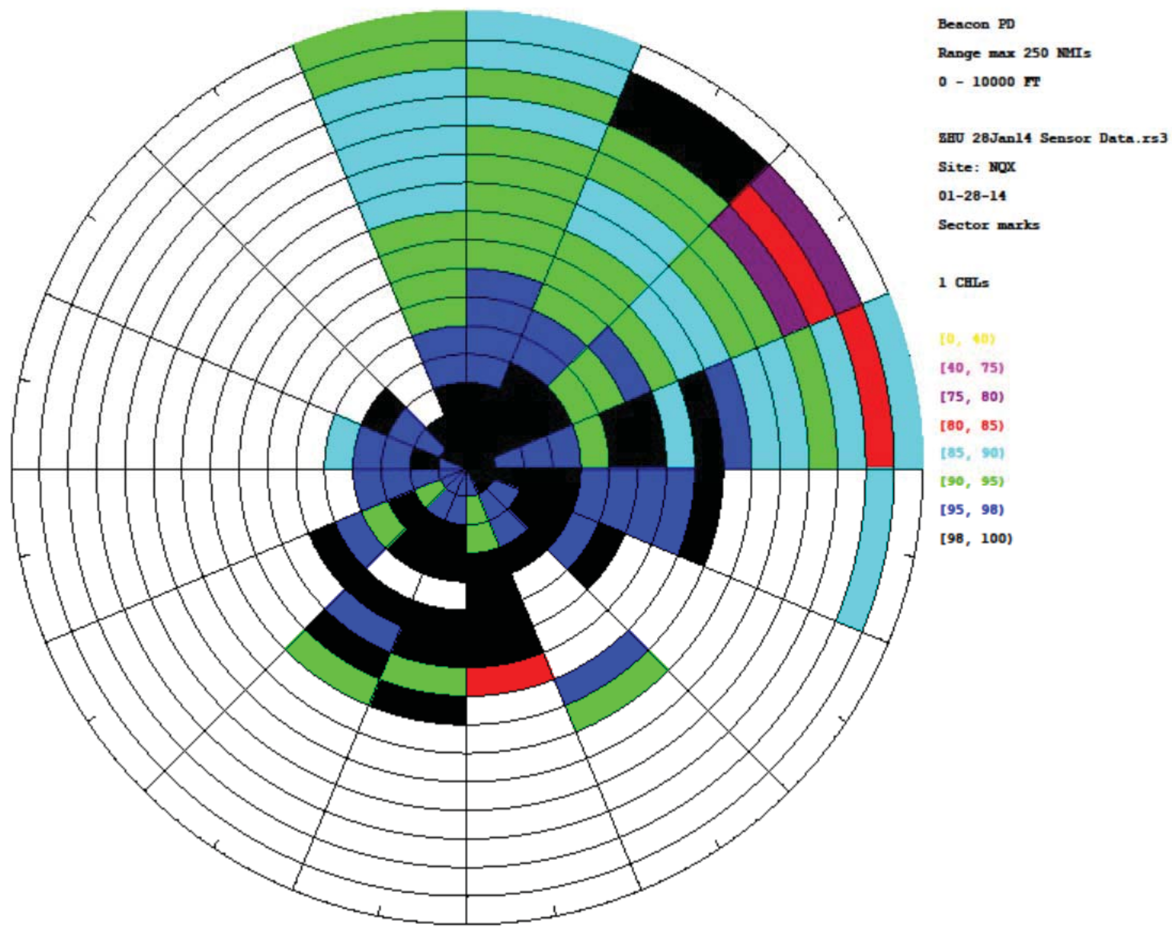


Figure 19 RBAT: SSR Probability of Detection as a function of target range and azimuth angle, for targets 0 to 10,000 feet; Key West Naval Air Station radar, Jan. 28, 2014

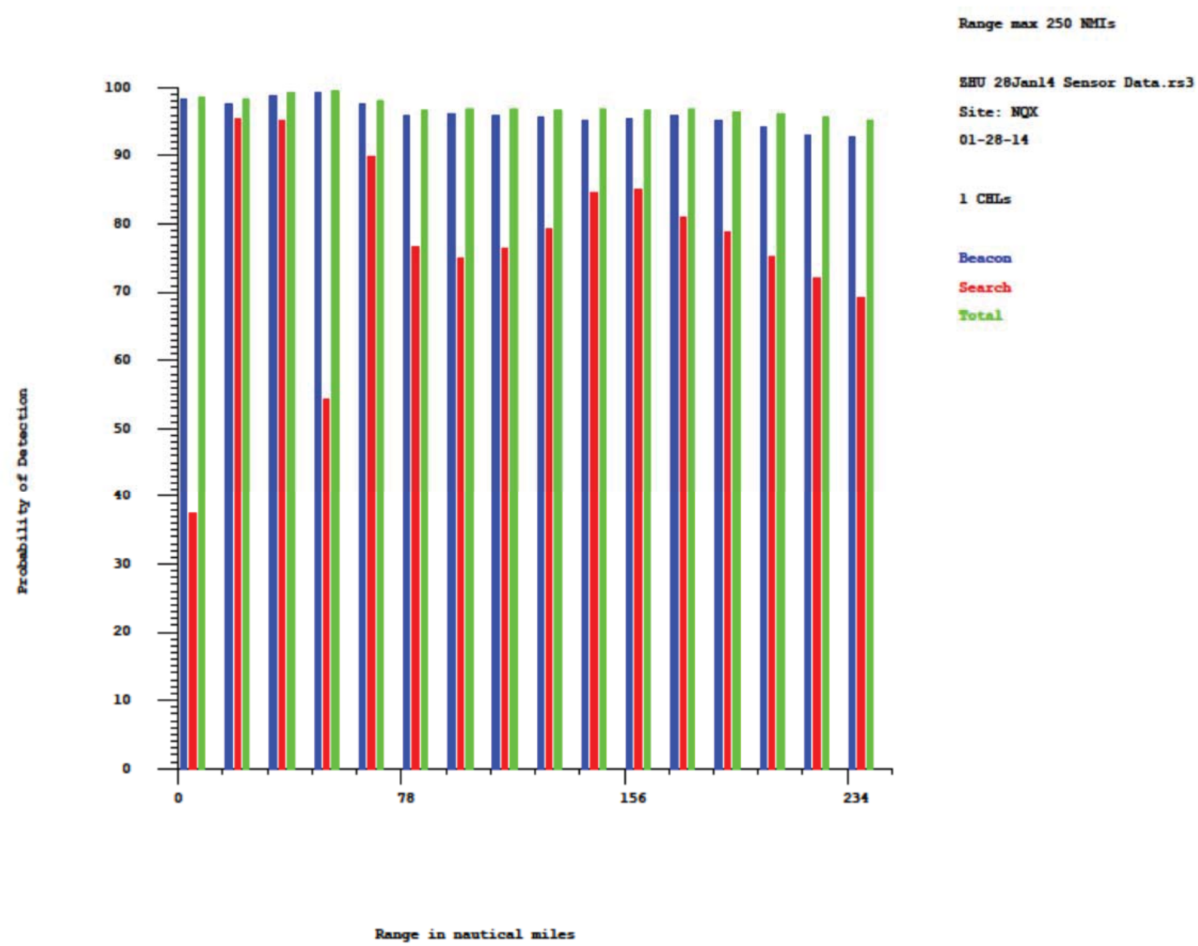


Figure 20 RBAT: Probability of Detection as a function of target range; for Beacon Radar (SSR), Search Radar, or either; Key West Naval Air Station radar, Jan. 28, 2014

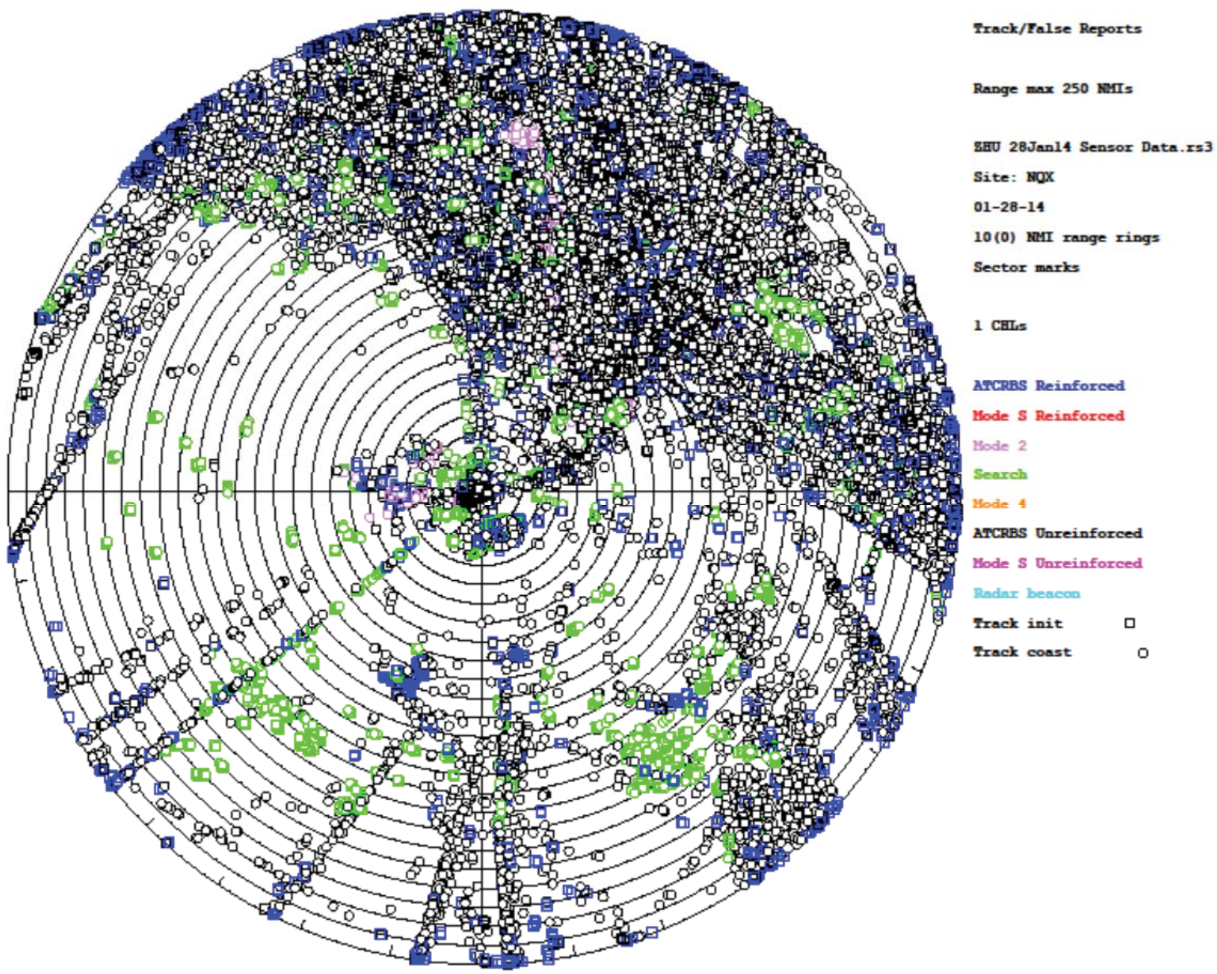


Figure 21 RBAT: Target Tracks; Key West Naval Air Station radar, Jan. 28, 2014

13. Appendix: Pre-Dry Run CEASE BUZZER Methodology

For each SSR's full service volume, P_d from RT-RBAT will be evaluated against a baseline P_d that will be determined from data recorded the week before the test. Based on recommendations from the FAA SMEs, if the P_d during the test drops by more than 1% — e.g., from 98.7% to 97.7% — as compared to the P_d during the same time of day as the baseline evaluation, a CEASE BUZZER may be initiated. In addition, a more sensitive P_d measurement can be made as the AN/UPX-41(C) are toggled on and off where a 1% change in P_d would be considered for initiating or clearing a CEASE BUZZER. Lastly, based on FAA recommendation, a CEASE BUZZER may be initiated if P_d falls below 96%. The P_d values used for monitoring the impact of the AN/UPX-41(C) interrogators are based on aircraft with IFR beacon codes (called DISCRETE codes in RBAT). The critical P_d values above are consistent with values in *Maintenance of NAS En Route Stage A - Air Traffic Control System* (Ref. [21], page 3-7), which specifies the following values for "beacon blip/scan ratio" (another term for P_d):

- Standard: 99% (the optimum value assigned to an essential parameter of the system).
- Initial tolerance: 99% minimum (the maximum deviation, from the standard value of the parameter, beyond which is permissible at the time of initial tune up or a major readjustment).
- Operating tolerance: 96% minimum (the maximum deviation, from the standard value of the parameter, beyond which remedial action by maintenance personnel is mandatory).

For at least two reasons, some judgment/discretion will be exercised in interpreting the results of RT-RBAT P_d calculations. First P_d can fluctuate during an operational day due to factors that are not related to the AN/UPX-41(C) interrogators. Second, the P_d calculations performed at NAS facilities and addressed in Ref. 21 utilize different software (including a different tracker and possibly different rules for excluding aircraft from the calculation) than RT-RBAT.

It is not the intent to cancel the test if ASCAS systems, at baseline, are already operating at these limits. If ASCAS systems are already operating within the above ranges, the FAA NAS monitor will make the determination on when a CEASE BUZZER will be initiated. Finally, if the POTOMAC TRACON or WASHINGTON ARTCC contacts the FAA NAS Monitor and reports degradation in ATC performance, a CEASE BUZZER will be initiated.

The CEASE BUZZER process will begin by turning off the closest AN/UPX-41(C) to the affected area. If P_d does not return to expected levels, this will be repeated for the next closest AN/UPX-41(C) until P_d returns to the expected level or all of the AN/UPX-41(C) have been turned off. The test may be able to continue once the impact has been evaluated and deemed unrelated to this test. If the test can be continued, the Test Director will incrementally request the AN/UPX-41(C) be turned on, beginning with the furthest but allowing time for sufficient evaluation of P_d. If the P_d does not return to expected levels, the affected facility will be contacted by the FAA NAS Monitor and internal FAA remediation steps initiated. If the remediation is unsuccessful, the test will continue and a note made to not include the affected sensor within the test analysis.

14. Appendix: Post-Dry Run CEASE BUZZER Methodology

Background

The standard ATC CEASE BUZZER process says that when air traffic controllers see missed target updates, they call CEASE BUZZER and all transmitters in the test cease radiation immediately. This process was modified in the CBAY AN/UPX-41(C) Test Plan to turn off Navy interrogators, one at a time, starting with the interrogator closest to the problem area and moving to interrogators further away if the problem did not resolve itself (henceforth referred to as DEGRADED BUZZER), as a way to determine if the Navy interrogators were the source of the interference of the missed track update. During the dry run, it was requested that this process return to the standard CEASE BUZZER whereby all interrogators are immediately turned off when ATC identifies suspected anomalies, for both safety and standardization reasons. Returning to the standard CEASE BUZZER process was determined to be beneficial, not only to provide ATC a margin of confidence in the CEASE BUZZER process for safety reasons, but to also provide the test and data analysis community with the ability for the analysts to identify the anomaly in both real time, and after the test, comparing the data from all Navy interrogators ON to all OFF with minimal transition time.

Besides the operational concerns of the original CEASE BUZZER discussed above, there are flaws to the mathematical nature of the original CEASE BUZZER procedure. To give a real-time update of P_d using a reasonable statistical sample size, FAA SMEs suggest that P_d should be calculated by RBAT over a 20 scan interval. This equates to updates over approximately 1.5 minutes for a terminal radar (scan time = 4.6 sec) and updates over approximately 4 minutes for an en-route radar (scan time = 12 sec). The agreed upon CEASE BUZZER methodology in the signed test plan gives P_d = 96% (Ref. 21) calculated by QARS as a threshold below which remedial action by maintenance personnel is mandatory. Comparing the calculated QARS P_d, however, to the RT-RBAT P_d is unfair because 30 minutes of data is fed into QARS versus 20 scans for RT-RBAT. Furthermore, QARS filters out Non-Discrete Mode 3/A codes while this method will not be used in RT-RBAT.

New CEASE BUZZER Nomenclature

CEASE BUZZER – When called, all AN/UPX-41(C) interrogators that are currently radiating will stop radiating. FAA ATC will indicate when it is appropriate for the AN/UPX-41(C) interrogators to begin radiating again.

DEGRADED BUZZER – When called, the AN/UPX-41(C) interrogator closest to the affected area will be asked to stop radiating. If P_d does not return to levels above the baseline minimum, this process will be repeated for the next closest AN/UPX-41(C) until P_d returns to the baseline minimum or all of the AN/UPX-41(C) interrogators have been turned off.

New DEGRADED BUZZER Methodology

Data recorded from the week prior to the test will be used exclusively to find lower and upper bounds of Beacon P_d and track counts for each radar site. Restricting baseline data collection to the week before the test allows for consistent comparison to P_d and track levels observed during the test. For each 20 scan update of RT-RBAT, the analyst will assess the Beacon P_d and Track Count as shown on the Summary screen accessed through the drop down menu Display > Summary. The assessment will follow the decision chart in
Figure 22.

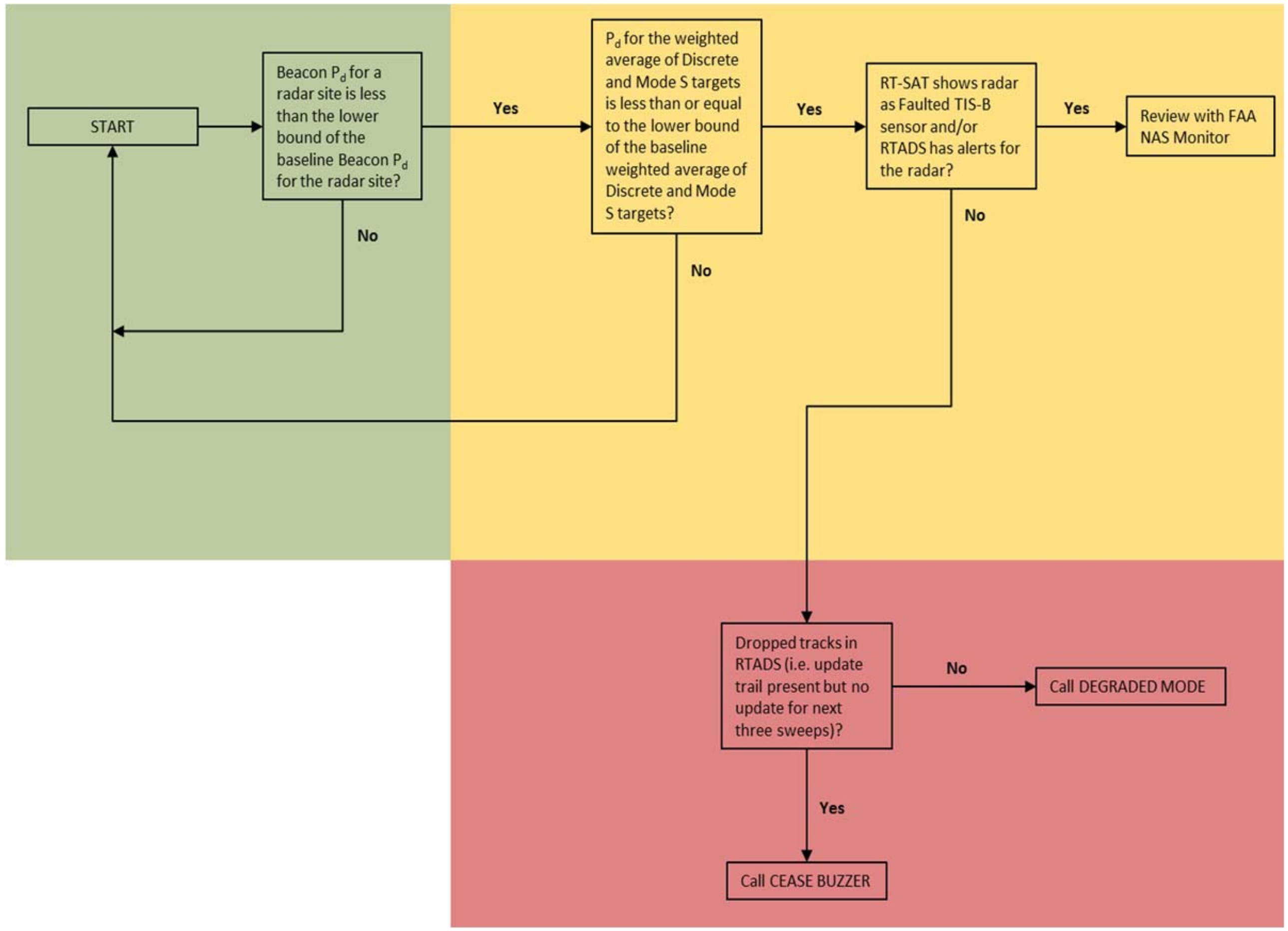


Figure 22 CEASE BUZZER/DEGRADED BUZZER Decision Chart

Understanding RBAT P_d

Unlike the theoretical calculation of P_d[*], RBAT uses a statistical method in which P_d for a track is "defined as the percent of times a beacon message correlates with an existing beacon track. A beacon message correlates with the beacon track if it is the best beacon message in the range and azimuth window around the track."[†] The P_d over a given surveillance volume will then be the weighted average of the P_d and track life for each track in that surveillance volume. While this method is not ideal for correlating loss of surveillance coverage with spectrum interference, it gives a reasonable estimate of P_d for the sake of monitoring a test in real-time.

RBAT gives five P_d summary statistics as shown in Table 13. Beacon, Discrete, and Mode S P_d will be used to make radar surveillance coverage impact decisions.

Table 13 P_d Types Reported in RBAT

P_d Types	Description
Discrete	ATCRBS-only 3/A codes NOT ending in 00
Non-Discrete	ATCRBS-only 3/A codes ending in 00 (e.g. 1200)
ATCRBS	Weighted average[‡] of Discrete and Non-Discrete
Mode S	Mode S targets
Beacon	Weighted average of Discrete, Non-Discrete, and Mode S tracks

Sample size plays a role in the RBAT P_d calculation. For example, 3 missed updates over 20 scans of 10 tracks will show a lower P_d than the same number of missed updates over 20 scans for 100 tracks. Therefore, for the hotspot area, we would expect a greater range between the maximum and minimum observed P_d than in the full coverage volume because there are fewer tracks in the hotspot area. The converse can also happen where P_d becomes artificially high if tracks are dropped due to interference – dropped tracks after a

[*] Probability of detection is dependent upon the transponder reply probability and the probability of receiving the minimum number of replies necessary to determine that a target exists. (Stevens, 1988)

[†] Track updates, and therefore, P_d, are limited by the sophistication of the tracker employed in RBAT. An explanation of the RBAT tracker can be found in the RBAT help files.

[‡] $$\frac{(\sum track\ life_{Discrete} * P_{d_{Non-Discrete}}) + (\sum track\ life_{Non-Discrete} * P_{d_{Non-Discrete}})}{\sum track\ life_{Discrete} + \sum track\ life_{Non-Discrete}}$$

user-specified number of scans are not counted against P_d; this method is employed by the RBAT tracker so as not to penalize a radar's P_d if aircraft are leaving the radar's surveillance volume. Therefore, in theory, the analyst must be simultaneously aware of changes in P_d and track count. If the track count drops below a baseline minimum count at a given time of day, this could be grounds for calling a CEASE BUZZER or DEGRADED BUZZER.

The Role of Track Counts

Practically speaking, in the context of this test, there is no expectation by FAA SMEs that the operation of all four AN/UPX-41(C) interrogators simultaneously will create enough spectrum interference for a continuous loss of track updates. If this situation did arise, the RT-RBAT analyst would likely not notice the issue before ATC because RT-RBAT only updates every 20 scans. Furthermore, basing CEASE BUZZER or DEGRADED BUZZER decisions on changes in track counts could prove spurious since the range between the minimum and maximum number of tracks observed at a given time can be quite large. For example, in Figure 23, the maximum number of tracks observed at 4:30PM is about 80. For the same time, the minimum number of tracks observed is about 45. If the analyst observes a track count of 80 during a period when the AN/UPX-41(C) interrogators are OFF and sees the track count drop to 75 when the AN/UPX-41(C) interrogators are ON, it is impossible to make a determination as to whether that occurred because of spectrum interference or because aircraft left the surveillance volume in question.

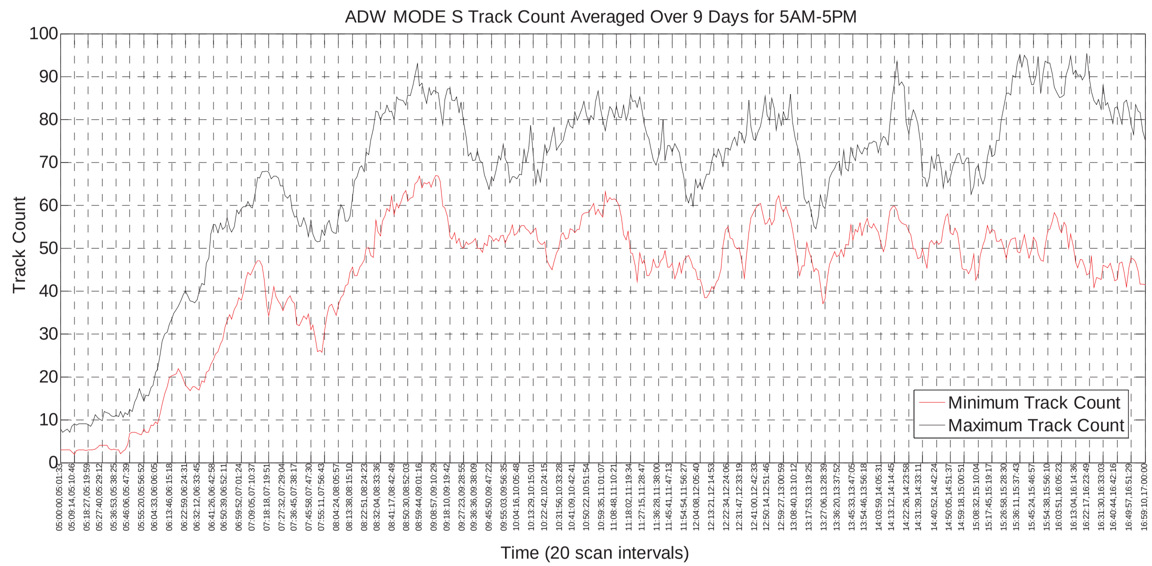


Figure 23 ADW Mode S Track Count Averaged Over 9 Days for 5AM-5PM

Based on observed track counts for the hotspot area (not shown here), it is possible that radars that have little overlap with the hotspot area (e.g. IAD, ORF) exhibit minimum track counts of zero. Therefore, calling a CEASE BUZZER or DEGRADED BUZZER based on track counts dropping below the baseline minimum track count would never happen when observing the hotspot areas because the baseline data makes the analyst believe that zero tracks is acceptable.

<u>The Role of the Hotspot</u>

During the test, the analyst will have two RT-RBAT versions running. One version will monitor each radar's full surveillance volume. The other version will monitor the "hotspot," or the area around the AN/UPX-41(C) interrogators where transponders see sidelobe energy. FAA SMEs expect surveillance coverage to degrade in this area first if there is spectrum interference from the AN/UPX-41(C) interrogators. The comparison of the P_d for radars given by these two versions gives the analyst additional situational awareness, but cannot be used solely to make a decision to call a CEASE BUZZER or DEGRADED BUZZER.

Consider the following three scenarios:

1) Hotspot P_d drops by more than non-hotspot P_d.
2) Hotspot and non-hotspot P_d drop equally.
3) Non-hotspot P_d drops by more than hotspot P_d.

Scenario 1 is a beginning indication that there may be spectrum interference from the AN/UPX-41(C) interrogators. Yet because of the nature of the statistical method for calculating P_d in RBAT, this event by itself does not provide conclusive evidence of spectrum interference. Scenario 2 could be an indication that there may be spectrum interference from the AN/UPX-41(C) interrogators for all of the surveillance volume, but it could also indicate a systemic problem with the radar itself[*]. Scenario 3 would not follow the hypothesis of the FAA SMEs yet the analyst should not rule out the possibility that this scenario could be a spectrum interference event. None of the scenarios give conclusive evidence on spectrum interference from the AN/UPX-41(C) interrogators, but the hotspot and non-hotspot versions should still be used as indicators for the analyst to be more vigilant of possible spectrum interference.

Summary

As depicted in

Figure 22, CEASE BUZZER or DEGRADED BUZZER decisions will derive directly from P_d dropping below the minimum observed during the baseline week. Changes in hotspot activity or track counts can be used as indicators for greater analyst vigilance, but cannot be used exclusively to make calls for a CEASE BUZZER or DEGRADED BUZZER.

[*] During the dry run, it was observed the P_d drops for the Richmond radar correlated with a Faulted TIS-B Sensor indicator in RT-SAT.

15. Test Personnel Roles and Contact Information

Table 14 Test Personnel Roles and Contact Information

Name	Role	Location	Email	Cell Phone
Allen Mackey	Volpe Test Controller	WJHTC	Allen.Mackey@dot.gov	(617) 921-7076
Michael Prata	FAA NAS Monitor	WJHTC	Michael.Prata@faa.gov	(609) 204-1498
Dan Trongone	Backup FAA NAS Monitor	WJHTC	Dan.Trongone@faa.gov	(609) 364-8058
Mark Cianflone	Navy Controller/Webster Field Coordinator	Webster Field	Mark.Cianflone@navy.mil	(301) 904-0204
James Jones	Webster Field Backup Coordinator	Webster Field	James.T.Jones1@navy.mil	(240) 577-5263
Mike Laney	Wallops Is. Coordinator	Wallops Is.	Mike.Laney@navy.mil	(301) 904-6784
Joe Caruso	Wallops Is. Backup Coordinator	Wallops Is.	Joseph.Caruso@navy.mil	(570) 267-8949
Miles Bellman	Analyst	WJHTC	Miles.Bellman@dot.gov	(617) 866-0330
Vaibhav Shah	Backup Analyst	WJHTC	Vaibhav.Shah@dot.gov	(732) 763-9386
Michael Geyer	Backup Test Controller/Analyst	WJHTC	Michael.Geyer@dot.gov	(617) 833-2292
Jim Falcone	Observer, Navy Test Lead	WJHTC	James.Falcone@navy.mil	
Richard Talbott	Observer	WJHTC	Richard.Talbott@jhuapl.edu	(301) 318-0581
Dan Spooner	Observer	WJHTC	Daniel.Spooner@lmco.com	
Darrell Lack	Observer	WJHTC	Darrell.Lack@navy.mil	
Steven Perchalski	Observer	WJHTC	Steven.Perchalski@navy.mil	
Tom Ahn	ATC Liaison	Washington ARTCC	Thomas.Ahn@faa.gov	
Bob Langan	ATC Observer	Washington ARTCC	Robert.Langan@navy.mil	(202) 607-8251
Adam Osborne	ATC Liaison	Washington ARTCC	Adam.Osborne@navy.mil	
Jim Marrs	FAA Flight Test Pilot	Aircraft	James.Marrs@faa.gov	(609) 485-6004
	FAA Flight Test Pilot	Aircraft		
John VanDongen	FAA Flight Engineer 1	Aircraft	John.Vandongen@faa.gov	(609) 485-6949
Tom Pagano	FAA Flight Engineer 2	Aircraft	Thomas.ctr.Pagano@faa.gov	
Eugene Fayn	Navy Flight Engineer	Aircraft	Eugene.Fayn.ctr@navy.mil	(215) 589-2272
Tim Mills	VHF Communications Technician	Wallops Is.	Tim.Mills.ctr@navy.mil	
Oscar Valle-Colon	Observer	Webster Field Bldg. 8225	Oscar.ctr.Valle-Colon@faa.gov	(202) 267-9739
Sandra Wright	Observer	Wallops Is. Bldg. V-10	Sandra.ctr.Wright@faa.gov	(202) 603-7094
Phil Ralph	AN/UPX-41(C) Controller	Webster Field Bldg. 8225	Phil.Ralph.ctr@navy.mil	
Bob Holden	AN/UPX-41(C) Backup Controller	Webster Field Bldg. 8225	Robert.Holden1.ctr@navy.mil	
Lloyd Walling	AN/UPX-41(C) Controller	Webster Field Bldg 8164	Lloyd.Walling.ctr@navy.mil	

Name	Role	Location	Email	Cell Phone
Glenn Landmann	AN/UPX-41(C) Backup Controller	Webster Field Bldg. 8164	Glenn.Landmann.ctr@navy.mil	
Philip Nalley	AN/UPX-41(C) Controller	Wallops Is. Bldg. V-10	Philip.Nalley.ctr@navy.mil	
Jim Phillips	AN/UPX-41(C) Backup Controller	Wallops Is. Bldg. V-10	Jim.Phillips.ctr@navy.mil	
Bob Badger	AN/UPX-41(C) Controller	Wallops Is. Bldg V-24	Robert.Badger1.ctr@navy.mil	
Mark Barnum	AN/UPX-41(C) Backup Controller	Wallops Is. Bldg V-24	Mark.Barnum.ctr@navy.mil	

16. Test Controllers and Contact Bridges

Table 15 Test Controllers and Contact Bridges

Name	Role	Location	Participant(s)	Line to Call	Time Duration	Phone Assignment
Allen Mackey	Volpe Test Controller	WJHTC	All Participants	***Primary:*** (877) 336-1831 Passcode: 7221159 Host passcode: 3936 ***Backup:*** (877) 336-1274 Passcode: 5194013 Host passcode: 5430	Opening brief: 0515 – 0530 Closing brief: 1700 - 1730	WJHTC1 (609) 485-9961
Allen Mackey	Volpe Test Controller	WJHTC	Navy Test Controller NAS Monitor	***Primary:*** (609) 485-9878 ***Backup:*** (877) 336-1831 Passcode: 7221159 Host passcode: 3936	0530 - 1700	WJHTC2 (609) 485-9878
Allen Mackey	Volpe Test Controller	WJHTC	As Required	***As required:*** (609) 485-9236	0530 - 1700	WJHTC3 (609) 485-9236

Name	Role	Location	Participant(s)	Line to Call	Time Duration	Phone Assignment
Allen Mackey	Volpe Test Controller	WJHTC	Navy Test Controller Navy AN/UPX-41(C) Controller Webster Field Bldg 8225 Navy AN/UPX-41(C) Controller Webster Field Bldg 8164 Navy AN/UPX-41(C) Controller SCSC Wallops Is. Bldg V-24 Navy AN/UPX-41(C) Controller SCSC Wallops Is. Bldg V-24	***Primary:*** (877) 336-1274 Passcode: 5194013 Host passcode: 5430 ***Backup:*** (301) 342-5802 Passcode: 4522623	0530 - 1700	WJHTC1 (609) 485-9961
Allen Mackey	Volpe Test Controller	WJHTC	Wallops Island VHF Communications Technician	***Primary:*** (609) 485-9236 ***Backup:*** (877) 336-1831 Passcode: 7221159 Host passcode: 3936	Day 2: 1000-1400	WJHTC3 (609) 485-9236
Mark Cianflone	Navy Controller	Webster Field	As Required	***As required:*** (301) 995-8211	0530 - 1700	

Name	Role	Location	Participant(s)	Line to Call	Time Duration	Phone Assignment
Mark Cianflone	Navy Controller/ Webster Field Lead	Webster Field	Navy AN/UPX-41(C) Controller Webster Field Bldg 8225 Navy AN/UPX-41(C) Controller Webster Field Bldg 8164 Navy AN/UPX-41(C) Controller SCSC Wallops Is. Bldg V-24 Navy AN/UPX-41(C) Controller SCSC Wallops Is. Bldg V-24	***Used as required and backup:*** (301) 342-5802 Passcode: 4522623	0530 - 1700	
Mike Prata	FAA NAS Facilities	WJHTC	POTOMAC TRACON WASHINGTON ARTCC Mode S Facilities	***As required:*** (609) 485-9960	0530 - 1700	WJHTC4 (609) 485-9960

17. List of Acronyms and Symbols

ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-R	Automatic Dependent Surveillance – Rebroadcast
AIMS	Air Traffic Control Radar Beacon System, Identification Friend or Foe, Mark XII/Mark XIIA, Systems
ASCAS	Aircraft Surveillance and Collision Avoidance Systems
ASDE-X	Airport Surface Detection Equipment, Model X
ASTERIX	All Purpose STructured Eurocontrol Radar Information EXchange
ATC	Air Traffic Control
ATCBI	Air Traffic Control Beacon Interrogator
ATCRBS	Air Traffic Control Radar Beacon System
BWI	Baltimore-Washington International Thurgood Marshall Airport
CEC	Cooperative Engagement Capability
CI	Control Indicator
CPR	Compact Position Reporting
CS	Combat System
CVN	Carrier Vessel Nuclear (*Ford* class and *Nimitz* class)
CG	Cruiser, Guided missile (*Ticonderoga* class)
DCA	Ronald Reagan Washington National Airport
DDG	Destroyer, Guided missile (*Burke* class)
deg	degree(s)
DME	Distance Measuring Equipment
DPSK	Differential Phase-Shift Keying
DoD	Department of Defense
FAA	Federal Aviation Administration
FIS-B	Flight Information Services – Broadcast
FRUIT	False Replies Unsynchronized In Time
IAD	Washington Dulles International Airport
IFF	Identification Friend or Foe
LBTS	Land Based Test Sites
LHA	Landing Helicopter Assault (*Tarawa* class)
LHD	Landing Helicopter Deck (*Wasp* class)
LPD	Landing Platform Dock (*San Antonio* class)
LSD	Landing Ship Dock (*Harpers Ferry* Class)
MDAS	Mode S Data Analysis Software
MOPS	Minimum Operational Performance Standards
MTL	Minimum Trigger Level

MSAT	Mode S Analysis Tool
MSSR	Monopulse Secondary Surveillance Radar
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NCP	NAS Change Proposal
NHK	Trapnell Field, Patuxent River Naval Air Station
NM	Nautical Miles
NTIA	National Telecommunications and Information Administration
ORF	Norfolk International Airport
QPL	The Plains, Virginia, ATCBI-6 SSR
QVR	Oceana, Virginia, ATCBI-6M SSR
PRM	Precision Runway Monitor
PRM-A	Precision Runway Monitor – Alternate
RBAT	Radar Beacon Analysis Tool
RIC	Richmond International Airport
RTCA	RTCA, Inc. (formerly Radio Technical Commission for Aeronautics)
sec	second(s)
SIF	Selective Identification Feature
SPS	Spectrum Planning Subcommittee
SSDS	Ships Self Defense System
SSR	Secondary Surveillance Radar
TACAN	TACtical Air Navigation
TCAS	Traffic Alert and Collision Avoidance System
TIS-B	Traffic Information Services – Broadcast
UAT	Universal Access Transceiver
US&P	United States and Possessions
V-PAT	Volpe Performance Analysis Tool
WAM	Wide Area Multilateration
WJHTC	William J. Hughes Technical Center Technical

18. References

1. SPS-17890/1, *AN/UPX-41(C) Digital Interrogator System Mark XII with software version 5.4 (shipboard), Stage 3*, FAA Memorandum, March 2, 2011.

2. SPS-18778/1, *AN/UPX-41(C) Digital Interrogator System, S/W V5.5, with Mode 5 (Shipboard)*, NTIA Certification, June 22, 2012.

3. SPS-18692/1, *AN/UPX-41(C) Digital Interrogator Set, S/W V5.5, with Mode 5 (Shipboard)*, FAA Memorandum, May 5, 2012.

4. FAA, *Final Report on 1090 MHz Spectrum Congestion in 2035 and Performance of Systems Operating in the Band*, Surveillance and Broadcast Services Program, August 28, 2009.

5. Volpe Center, *AWACS Interference Analysis Summary*, briefing to FAA Spectrum Management Office, December 16, 2008.

6. RTCA DO-260B, *Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B)*, Special Committee 186, December 13, 2011.

7. FAA E-2923A, *Specification for Air Traffic Control Beacon Interrogator Model 6 (ATCBI 6) System*, AND 450, February 14, 2002.

8. FAA E-2887a, *Specification, Electronic Scan Precision Runway Monitor (E-SCAN PRM)*, June 16, 1999.

9. Tourigny, Chris. ASP TSGWP15-11R1-Update on the Development of Typical Transponder Occupancy Characteristics. Paris, June 24-28, 2013.

10. FAA, *Radar Beacon Analysis Tool (RBAT)*, version 9.5, July 15, 2013. Available from: http://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/about/campus/faa_host/tnes/ATCSurveillance/software/rbat2/

11. FAA, *Mode S Analysis Tool (MSAT)*, version 2.2, April 25, 2011. Available from: http://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/about/campus/faa_host/tnes/ATCSurveillance/software/msat2/

12. FAA SRT-047, *Surveillance and Broadcast Services Description Document*, Office of Surveillance and Broadcast Services (SBS), October 24, 2011.

13. FAA, E-3011, *Automatic Dependent Surveillance – Broadcast (ADS-B) / ADS-B Rebroadcast (ADS-R) Critical Services Specification*, Office of Surveillance and Broadcast Services (SBS), June 17, 2010.

14. FAA, E-3006, *FAA SBS Traffic Information Services – Broadcast (TIS-B) / Flight Information Services – Broadcast (FIS-B) Essential Services System Specification Document (SSD)*, Office of Surveillance and Broadcast Services (SBS), February 9, 2010.

15. RTCA DO-242A, *Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B)*, Special Committee 186, June 25, 2002.

16. FAA E-2942, *Subsystem Level Specification for Airport Surface Detection Equipment – Model X (ASDE-X)*, August 27, 2009.

17. FAA, E-3021, *Subsystem Level Specification for Airport Surface Surveillance Capability (ASSC)*, November 10, 2010.

18. FAA, E-3010, *Specification for Wide Area Multilateration (WAM)*, February 2, 2009.

19. FAA Order JO 7610.4P CHG 3, *Special Operations*, March 7, 2013.

20. Navy, *Civil Transponder Occupancy*, Mark Cianflone, NAWCAD 4.5.9, November 20, 2012.

21. FAA Order JO 6100.1H, *Maintenance of NAS En Route Stage A - Air Traffic Control System*, En Route Services, February 09, 2009.