ALTERNATIVE SURVEILLANCE TECHNOLOGY FOR THE GULF OF MEXICO

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Abstract

In the Gulf of Mexico, there are two major operating aviation users: low altitude offshore and high altitude. The low altitude offshore operators are primarily helicopter fleets supporting the oil and gas exploration efforts; their traffic typically consists of 5,000 to 6,000 flights per day, most under one hour in duration. In the high altitude regime, over 300 oceanic flights pass through the Gulf of Mexico. Offshore surveillance coverage in the Gulf of Mexico is currently limited due to remote, over-water operations. Implementation of primary or secondary radar to support surveillance coverage in the Gulf of Mexico is technically and economically difficult. Air traffic between the United States and destinations in the Caribbean, Mexico, and Central America has grown at a rate of over 8% per year over the last 12 years. Currently, flights that transit the Central Gulf of Mexico are subjected to oceanic separation standards in part because of a lack of direct pilot-controller communications, standardized aircraft navigation requirements, and limitations to radar surveillance. Air traffic traversing the Gulf of Mexico often must choose between accepting a ground delay, a re-route, or a less fuel-efficient altitude. An estimated 40% of the traffic in the non-radar airspace may not receive their requested altitude or route. However, if seamless surveillance and communication coverage were implemented in the Gulf of Mexico, aircraft separation standards may be reduced from the current oceanic standards to domestic EnRoute standards, thus reducing delays and improving aircraft safety.

To improve surveillance coverage in the Gulf of Mexico for both the low altitude and high altitude users, the National Aeronautics and Space Administration (NASA) has initiated activities leading to deployment of alternative surveillance technology in the offshore area of the Gulf of Mexico. These technologies, multilateration and ADS-B, have significant potential to fill the lack of surveillance in the Gulf of Mexico. NASA conducted previous evaluations of multilateration and ADS-B for the low altitude offshore users recently. These evaluations demonstrated the feasibility of ADS-B and multilateration.

NASA, along with the Federal Aviation Administration's (FAA) Safe Flight 21 Program Office are conducting evaluations to determine ADS-B, as well as wide area multilateration, performance over US controlled high altitude airspace in the Gulf of Mexico. To support this evaluation, a network of eight ground stations (Mode S extended squitter) has been installed from Texas to Florida with the Central Processing System located at the Houston ARTCC in Houston, TX. As part of this network, three ground stations have been installed approximately 200 NMI offshore in the Gulf of Mexico. This network provides almost entire coverage of US oceanic airspace in the Gulf of Mexico. Also as part of this evaluation, the network of ground stations provides wide area multilateration coverage as well (where 3 or more ground stations receive an aircraft's transponder reply). The multilateration coverage area provides surveillance for aircraft at FL240 and above.

Three flight tests, using the FAA Tech Center's B727 and the NASA Gulfstream III aircraft, were conducted from January to March 2004. The results from these flight tests will be presented in this paper, assessing the performance of ADS-B and wide area multilateration in the Gulf of Mexico.

Introduction

In an earlier demonstration conducted by the Government not discussed in this paper, the Petroleum Exploration Terminal WAM and ADS-B and the Intracoastal City Terminal WAM systems assessed the non-radar surveillance technology, wide area multilateration and ADS-B, for terminal areas only. While these evaluations demonstrated the capabilities and potential of WAM and ADS-B as terminal applications as well as maturing the surveillance technology, the evaluations did not generate the support amongst the helicopter transport service providers. However, a surveillance need was identified for high altitude air traffic traversing the Gulf of Mexico to and from US and Mexican Airspace.

The Houston Air Route Traffic Control Center (ARTCC) is responsible for the air traffic control within the Houston Oceanic Control Area (CTA)/Flight Information Region (FIR) in the Gulf of Mexico. The CTA/FIR airspace is divided into two en route sectors (east and west) resulting in an area approximately 600 miles wide and 225 miles longitudinally. Controllers in these sectors handle air traffic crossing the Gulf of Mexico between the United States and Mexico, Central America, and South America. The CTA/FIR airspace lacks continuous surveillance coverage throughout the control of the Houston ARTCC, as shown in Figure 1.

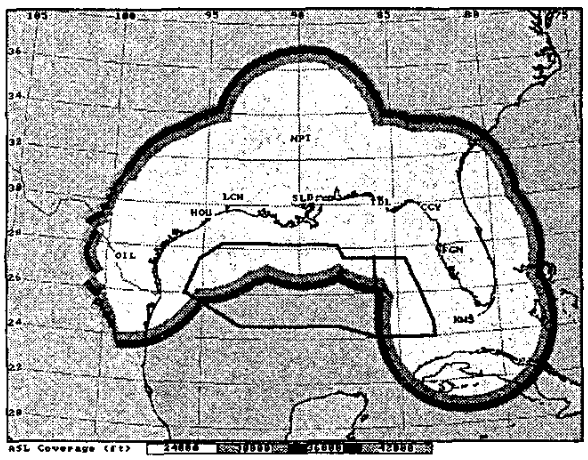

Figure 1. Gulf of Mexico Surveillance Coverage

Figure 1 shows the surveillance coverage at various altitudes provided by the FAA's long-range radar in the Gulf of Mexico. As shown in Figure 1, the long-range radars do not provide continuous surveillance coverage in the US FIR. Aircraft traveling in the US FIR in non-radar airspace maintain legal separation using oceanic standards. Air traffic controllers, using oceanic separation, maintain between 10 to 15 minutes in – trail separation between aircraft, depending on aircraft location in the US FIR. Once aircraft are within long-range radar coverage, air traffic controllers can maintain domestic standard separation of 5 NMI.

The Gulf of Mexico Wide Area Surveillance provided an opportunity to demonstrate the capability to provide surveillance coverage throughout the entire US FIR in the Gulf of Mexico. Previous evaluations demonstrated the feasibility to locate ground stations on offshore platforms and transport data onshore. This ability to locate ground stations on offshore platforms enables ADS-B surveillance coverage to extend further south than FAA long – range radar in the US FIR provided offshore platform locations exist in optimal locations.

The Gulf of Mexico Wide Area Surveillance system also provided an opportunity to evaluate wide area multilateration as an en route surveillance system. For an en route application, the minimum altitude coverage, at least for this evaluation, was FL240. To meet the minimum altitude coverage for the Gulf of Mexico Surveillance system, the Ground stations was spaced nominally 100 NMI. This required a different means to synchronize the ground stations to compute the time of arrival difference. The wide area multilateration component of the Gulf of Mexico Wide Area Surveillance evaluation was conducted to assess an alternative surveillance technology to ADS-B in the Gulf of Mexico. As part of this assessment, wide area multilateration may be able to provide a backup surveillance technology to ADS-B for those aircraft not equipped as well as a surveillance technology capable of validating the ADS-B position reports emitted by an aircraft transponder.

Surveillance Architecture

The Gulf of Mexico Wide Area Surveillance was designed to provide ADS-B surveillance coverage across the US FIR in the Gulf of Mexico at FL240. To accomplish the ADS-B surveillance coverage in the Gulf of Mexico, 8 ground stations were sited, 5 on shore and 3 deep-water platforms. The sites selected consisted of places located on a network backbone serviced by the telecommunications service provider, Stratos Global Corporation from Texas to Florida. By locating the Ground stations on the Stratos Global Corporation network backbone, telecommunication costs were minimized and no additional installation of network equipment was necessary. Each of the

Ground stations consisted of the following equipment:

1. a 1090 receiver capable of receiving and decoding Mode A/C, Mode S and extended Mode S squitter replies,
2. an FAA DME Model 5100A that also has omni-directional azimuthal coverage,
3. an uninterruptible power supply, and
4. a router, providing the interface to the microwave communications system that links the RU with the CPS, located at the Houston Center facility.

Figure 2 shows the site locations and the predicted ADS-B surveillance coverage across the Gulf of Mexico at various altitudes. As can be seen in Figure 2, the sites provided optimal coverage with the exception of the boundary separating Houston and Miami Oceanic airspace. An additional ground station could have been located in Key West, FL to extend the coverage, however a coverage gap would remain in the Houston Oceanic sector.

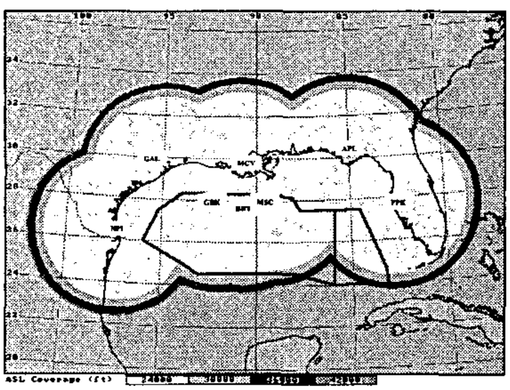

Figure 2. Predicted ADS-B Surveillance Coverage

Figure 3 shows wide area multilateration coverage provided by the Gulf of Mexico Wide Area Surveillance system for receiving an aircraft's transponder message. In this coverage area, aircraft operating with the Mode S transponder were tracked using the TCAS squitter (DF 11) that is broadcast once per second. However, to determine a multilateration position for an aircraft equipped with the Mode A/C transponder as well as receiving the beacon and altitude information for an aircraft equipped with a Mode S transponder, a transmitter interrogating on the 1030 MHz frequency was implemented.

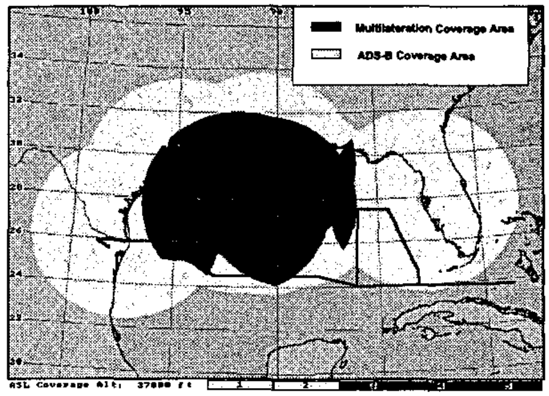

Figure 3. Wide Area Multilateration Coverage

Previous wide area multilateration testing in the Gulf of Mexico included the use of transmitters capable of interrogating both Mode A/C and Mode S transponders for their beacon and barometric altitude data. However, the range of the interrogators used in previous evaluations was approximately 65 NMI. This range was validated from assessments conducted during the Intracoastal City Multilateration system flight tests. For the Gulf of Mexico, the use of the interrogators implemented during the previous assessments, because of their interrogation range, became impractical. To implement wide area multilateration as an en route system, the range performance of the interrogators needed to increase from 65 NMI to 200 NMI to minimize the number of transmitters needed for implementation. The range of the transmitter was increased to 200 NMI by integrating a high-powered amplifier to increase the power to nearly 3 kilowatts and using a DME antenna with 12 dB gain. The high-powered transmitter was installed at Morgan City, LA and utilized for the flight-testing conducted. Morgan City, LA was selected for the high-powered transmitter for two reasons: 1. it provided sufficient overlapping coverage with the multilateration receive only coverage and 2. it was a land based site which enabled for easy access to the transmitter. Figure 4 shows the high-powered transmitter coverage area.

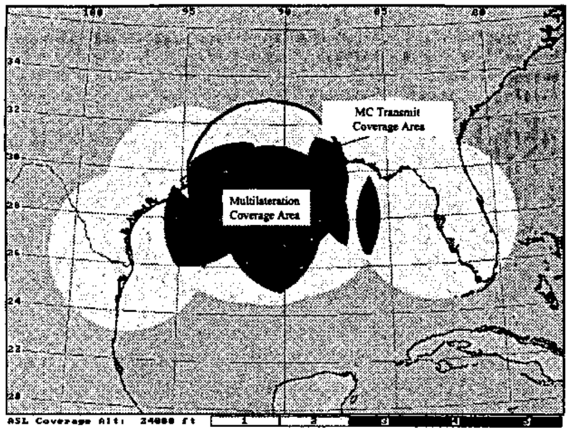

Figure 4. WAM Transmitter Coverage Area

Test Aircraft

Two test aircraft were used for the assessment of the Gulf of Mexico Wide Area Surveillance system as shown above:

- NASA Gulf Stream III,
- FAA Tech Center B-727

The NASA Gulf Stream III aircraft was equipped with the Honeywell KT73 Mode S extended squitter transponder. The KT73 Mode S extended squitter utilized the Honeywell KLN 94 Navigator as the GPS input for the Mode S extended squitters reports. The KT73 Mode S extended squitter transponder RF peak power was measured by the NASA operations engineer and recorded to be 315 Watts prior to flight-testing.

The FAA Tech Center B-727 was equipped with the Rockwell CollinsXS-950 Mode S extended squitter transponder using WAAS corrected GPS navigation data as its input source for the Mode S extended squitter messages. The Rockwell Collins XS-950 performance was verified prior to flight-testing and its peak RF power was measured at 480 Watts for the upper antenna and 417 Watts for the lower antenna on the airframe.

The FAA Tech Center was also equipped with a Narco model AT 155 Mode A/C transponder that was used to assess the wide area multilateration performance of the Gulf of Mexico Wide Surveillance system. The Mode A/C transponder was also verified prior to flight-testing and its peak RF power was measured at 140-Watts upper antenna only. To validate the position computation of the wide area multilateration system, the FAA Tech Center B-727 was equipped with an independent GPS receiver, the Z-Xtreme GPS receiver. The Z-Xtreme GPS receiver recorded non-differentially corrected GPS position reports.

Evaluation Criteria

These criteria were developed expressly for this evaluation. They are not Sensis contractual requirements for this effort, nor are they necessary for the HITS to perform satisfactorily as a flight following system. Moreover, these criteria are not appropriate for use as the entire requirements portion of a future multilateration/ADS-B system specification. Non-performance topics are omitted, as are some detailed performance-related topics contained in the ATCBI-6 and ASDE-X specifications. Conversely, some criteria found herein are not specifically in the ATCBI-6 or ASDE-X specifications.

Approach to Deriving Evaluation Criteria

The baseline radar standards upon which the HITS evaluation was based are primarily those for the Air Traffic Control Beacon Interrogator, Model 6 (ATCBI-6), as documented in [1]. In order to perform a complete evaluation, every criterion listed in the ATCBI-6 specification is extracted and corresponding criteria are developed for the HITS multilateration and ADS-B capabilities, Ref 4. In many cases, the parameters have been transformed to account for the technology differences among the three technologies. In brief:

- SSR measures aircraft range and azimuth relative to a single ground location; a ground-interrogation/aircraft-transponder-response methodology is employed; and ground sites have mechanically-scanned high-gain directional antennas.
- Multilateration measures the times-of-arrival at three or more ground stations of both un-elicited (squittered) or elicited transponder signals; aircraft location is computed in rectangular

coordinates with respect to the geographic reference system used to define the ground station locations; and ground sites have omni-directional low-gain stationary antennas.

- ADS-B avionics obtain aircraft position and velocity from an onboard GPS receiver, and squitter this information to one or more ground stations over a digital data link; and ground sites have omni-directional low-gain stationary antennas.

Fundamentally, radar is a station-referenced surveillance system; multilateration is an area surveillance system; and ADS-B is a digital data link combined with an area navigation system.[1]

In addition to the ATCBI-6 specification (Ref. 1), several documents were consulted in developing the criteria, here. The ASDE-X specification (Ref. 2) is the standard for multilateration/ ADS-B systems designed for airport surface surveillance. The primary standards by which all FAA beacon radars are designed against are FAA Order 1010.51.A (Ref. 3, developed for the IFF Mark X system), FAA Order 6365.1A (Ref. 4, developed for Mode S), and International Civil Aviation Organization (ICAO) Annex 10 (Ref. 7). ICAO Annex 10 has precedence over FAA Order 6365.1A when conflicts arise.

ADS-B Test and Evaluation

Current FAA long-range radars in the Gulf of Mexico do not provide surveillance coverage in the entire US FIR for the Houston Oceanic sector. Flight tests were flown to demonstrate the capability of ADS-B to provide surveillance data beyond the range of FAA long-range radars as well as identify areas in the US FIR Houston Oceanic sector where additional ADS-B ground stations need to be implemented. Providing seamless surveillance coverage in the US FIR Houston Oceanic sector would enable air traffic to maintain domestic longitudinal separation (5 NMI) throughout the Gulf of Mexico.

The NASA Gulf Stream III aircraft flew flight profiles in March 2004 to assess the performance of ADS-B and wide area multilateration. The flight test to assess ADS-B component of the Gulf of Mexico Wide Area Surveillance system determined the extent of the surveillance coverage along the US/Mexican FIR boundary and the performance of the Ground stations. An inbound and outbound leg from Houston Intercontinental Airport (IAH) to nearly the boundary of the Miami Oceanic region was flown at different flight levels. Figure 5 shows the NASA Gulf Stream flight profile at FL 390.

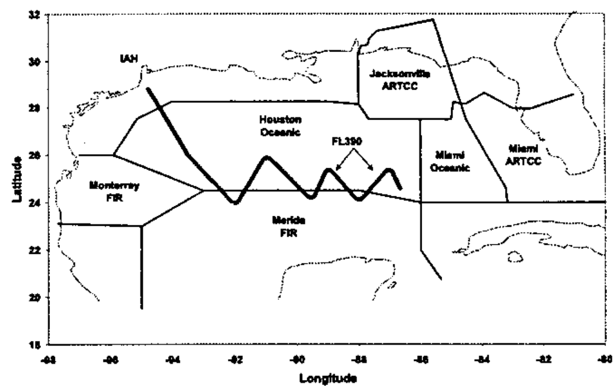

Figure 5. NASA Gulf Stream III ADS-B Flight Profile Inbound

The FAA Tech Center B-727 aircraft flew flight profiles in January, February, and March 2004. The flight profiles used to assess the ADS-B performance were flown on published Jet Airways traversing the Gulf of Mexico to and from US airspace, Figure 6. The flight test profiles not only assessed the ADS-B performance of the Gulf of Mexico Wide Area Surveillance system but also to demonstrate ADS-B coverage into Mexican controlled airspace.

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[1] The terms *station-referenced* and *area* surveillance system are adopted from the navigation field, where similar terms were introduced approximately 10 years ago to emphasize the fundamental differences between traditional station-referenced systems (e.g., NDB, VOR, DME, and ILS) and the then emerging area navigation systems (e.g., GPS, Loran-C and DME/DME).

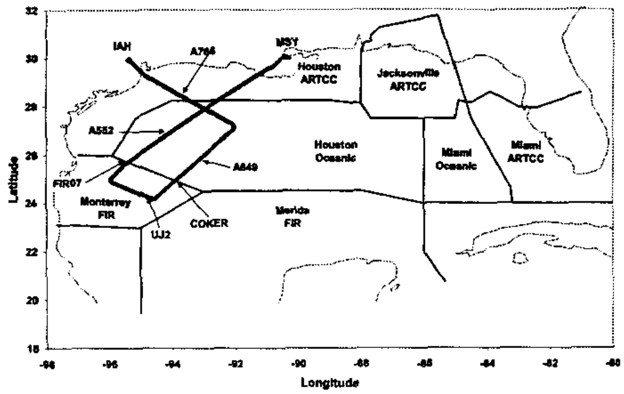

Figure 6. FAA Tech Center Aircraft Feb 10 ADS-B Flight Profile

ADS-B vs Long Range Radar

Long-range radar data was collected from the Houston Center facility for all the flight tests conducted to support the assessment of the Gulf of Mexico Wide Area Surveillance system. Long-range radar data, from 17 facilities, collected from Houston Center included the following data fields: beacon code, barometric altitude, latitude, longitude, and time stamp in Universal Time Coordinate (UTC). Surveillance data between the Gulf of Mexico Wide Area Surveillance system and the long range radars were correlated based on the aircraft's beacon code, barometric altitude, and time of flight. Figure 7 compares the ADS-B surveillance data and the long-range radar data for flight data along US FIR/Mexican FIR. The ADS-B flight data represents the received Mode S extended position squitter only. The flight track represented by the long-range radar represents a plot report received from any long-range radar responsible to Houston Center.

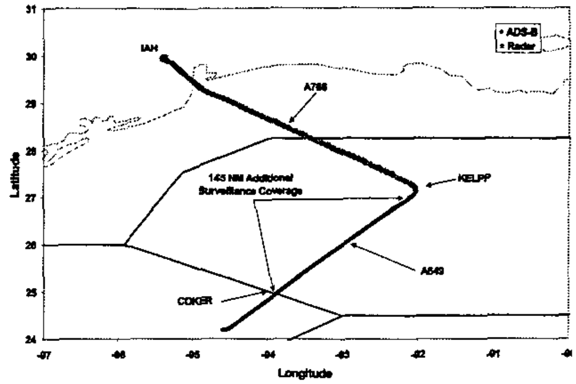

Figure 7. Feb 10 Flight Track ADS-B vs Long – Range Radar

ADS-B Performance Summary

The ADS-B performance of the Gulf of Mexico Wide Area Surveillance system demonstrated exceptional performance throughout the Government assessment. The Government was unable to independently verify the performance of the update interval for the Mode S extended velocity and flight id squitter during these flight tests because of the limitations of the Asterix Cat 10 message set. The ADS-B performance of the Gulf of Mexico Wide Area Surveillance system also demonstrated the capability of extending current long – range radar surveillance coverage into Mexican airspace. Complete coverage within the US FIR Houston Oceanic sector is possible with the inclusion of Ground stations in Mexico and in the Florida Keys.

WAM Test and Evaluation

The Gulf of Mexico Wide Area Surveillance system WAM component was configured and designed to provide multilateration surveillance for an enroute domain. All previous implementations and assessments with WAM were used in terminal applications. The use of WAM as an enroute surveillance system required 2 critical changes to the Contractor's terminal WAM architecture – 1. the timing synchronization for the ground stations changed from using a RefTran to using GPS time, 2. the range of the interrogator in the Receive/Transmit Remote Unit increased from approximately 60 NMI to 200 NMI, and 3. transitioning a terminal area application to an enroute application. Flight tests were flown in February 2004 for the Contractor and Government to evaluate the WAM performance and identify system improvements. One Mode A/C equipped aircraft (FAA Tech Center) flown on March 23, 2004 and one Mode S equipped aircraft (NASA Gulf Stream III) flown on March 24, 2004 were used to quantify the performance of the Gulf of Mexico Wide Area Surveillance system.

Also in March 2004, the NASA Gulf Stream III flew a flight test profile to assess the wide area multilateration coverage for the Gulf of Mexico Wide Area Surveillance system using a Mode S transponder without extended squitter capability, Figure 8. This was the first time in the Gulf of Mexico that an assessment of any wide area multilateration system was conducted using a Mode S transponder. Previous assessments of wide area multilateration in the Gulf of Mexico used the Mode S extended squitter transponder. The flight profile for the NASA Gulf Stream flew within the wide area multilateration receives only area as well as within the coverage area of the transmitter located in Morgan City, LA.

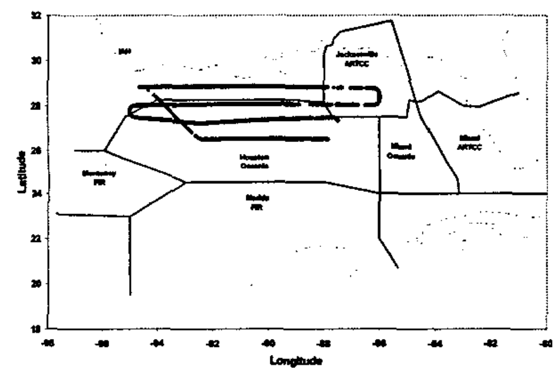

Figure 8. NASA Gulf Stream III WAM Flight Profile

WAM Performance Summary

The Gulf of Mexico Wide Area Surveillance system provided an opportunity to develop and mature WAM technology for an enroute application. Valuable lessons were learned that will improve the system performance for an enroute system. The WAM system demonstrated the capability to integrate GPS timing synchronization for its ground stations enabling application in the Gulf of Mexico as well as developing an interrogator capable of eliciting replies at distances greater than 200 NMI.

Program Summary

Configuration Description — The Phase III system comprised eight RUs — three on platforms located beyond 100 nmi from the coastline and five on on-shore arrayed in an arc from Texas to Florida. To improve reception, the ground stations' sensitivity was increased and omni directional 8-dBi gain RU antennas were deployed. The Central Processing System was located in the Houston Air Route Traffic Control Center (ARTCC). The configuration was designed to provide ADS-B coverage of most of the northern two-thirds of the Gulf, including the region in the center that lacks surveillance coverage. This region necessitates use of oceanic separation procedures for trans-Gulf operations, resulting in delays during peak traffic periods.

WAM was implemented where overlapping coverage from three or more RUs existed, with the expectation of surveilling approximately one-third of the ADS-B coverage region. Employing WAM technology over such a broad area required two significant technology enhancements: (1) GPS timing was introduced to synchronize the ground station clocks, and (2) an experimental high-power interrogator was employed to elicit aircraft transponder replies.

ADS-B Performance — The RUs demonstrated Mode S extended squitter message reception from targets up to 250 nmi away. ADS-B coverage was demonstrated within nearly the entire US FIR at FL280 and above, with the exception of the southeast corner of the Houston Oceanic East Sector area due to lack of installed platforms. Continuous surveillance by U.S. ADS-B and Mexican radar was demonstrated for flights between the U.S. southern coast and the Yucatan peninsular.

WAM Performance — Functionally, the system demonstrate the capability to provide WAM data for Mode S extended squitter equipped aircraft throughout much of the US FIR including some data samples within the Mexican FIR. The high-powered transmitter successfully interrogated Mode S equipped targets at distances greater than 200 nmi.

References

[1] Department of Transportation, Federal Aviation Administration, Specification for Air Traffic Control Beacon Interrogator Model 6 (ATCBI-6) System, Redlined Draft, February 23, 1999.

[2] Helicopter In-flight Tracking System (HITS): Test and Evaluation Plan, Draft, Volpe National Transportation Systems Center, December 2001

[3] Department of Transportation, Federal Aviation Administration, National Airspace System (NAS), Subsystem Level Specification for Airport Surface Detection Equipment – Model X (ASDE-X), FAA-E-2942, version 2.0, June 6, 2000.

[4] Federal Aviation Administration, U. S. National Standard for the IFF Mark X (SIF) Air Traffic Control Radar Beacon System (ATCRBS) Characteristics, FAA Order 1010.51A, March 8, 1971.

[5] International Civil Aviation Organization, International Standards, Recommended Practices and Procedures for Air Navigation Services Aeronautical Telecommunications (including Amendment 71), ICAO Annex 10, November 1996.