Assessing Wide Area Multilateration and ADS-B as Alternative Surveillance Technology

Anastasios C. Daskalakis and Patrick J. Martone
US DOT Volpe Center, Cambridge, MA, 02142

Charles M. Buntin
Federal Aviation Administration, Washington, D.C., 20591

Abstract

The Helicopter In-Flight Tracking System (HITS) program evaluated both Wide Area Multilateration (WAM) and Automatic Dependent Surveillance – Broadcast (ADS-B) as alternative surveillance technologies for both the terminal and en route domains in the Gulf of Mexico against the FAA's secondary radar. From 2001 to 2003, a network of ground stations, provided by the Sensis Corporation, was implemented to provide and demonstrate terminal services at Intracoastal City, LA. Flight tests were conducted using aircraft from both NASA Ames Research Center and the FAA Technical Center evaluating the performance of WAM and ADS-B against FAA secondary radar. In 2004, a network of ground stations were implemented from Galveston, TX to Pinellas Park, FL as well as the deep waters of the Gulf of Mexico to demonstrate seamless high altitude surveillance coverage within the US Flight Information Region (FIR) for aircraft at FL 280 and above using ADS-B. WAM for high altitude aircraft in the en route area was demonstrated for areas that had coverage from three or more ground stations. The flight tests were completed in March 2004. Finally, a proof of concept activity was conducted at the FAA Technical Center demonstrating the ability to process and display ADS-B targets on the Host Computer System. This proof of concept demonstrated the capability to convert Asterix Cat 10 surveillance data from both ADS-B and WAM derived targets to existing Common Digitizer –2 data format to interface with the Host Computer System, the automation platform currently utilized at Houston Center.

1 Introduction

Figure 1 depicts the Gulf of Mexico region airspace, including existing radar coverage at 18,000 ft. Two distinct regions (and corresponding user groups) of Gulf airspace are of interest to this effort—high-altitude Oceanic Sectors and low-altitude Offshore Sectors. Oceanic Flight Information Regions (FIRs) are assigned to the U.S. by international agreements. They begin approximately 75 NMI south of the U.S. coastline, and extend southward to boundaries with FIRs assigned to Mexico and Cuba, 300–350 NMI from the U.S. coast. High-altitude Oceanic Sectors extend upward from Flight Level 180 (FL180) to Flight Level 600 (FL600). Large fixed-wing aircraft, including scheduled/chartered air carriers, are the predominant users.

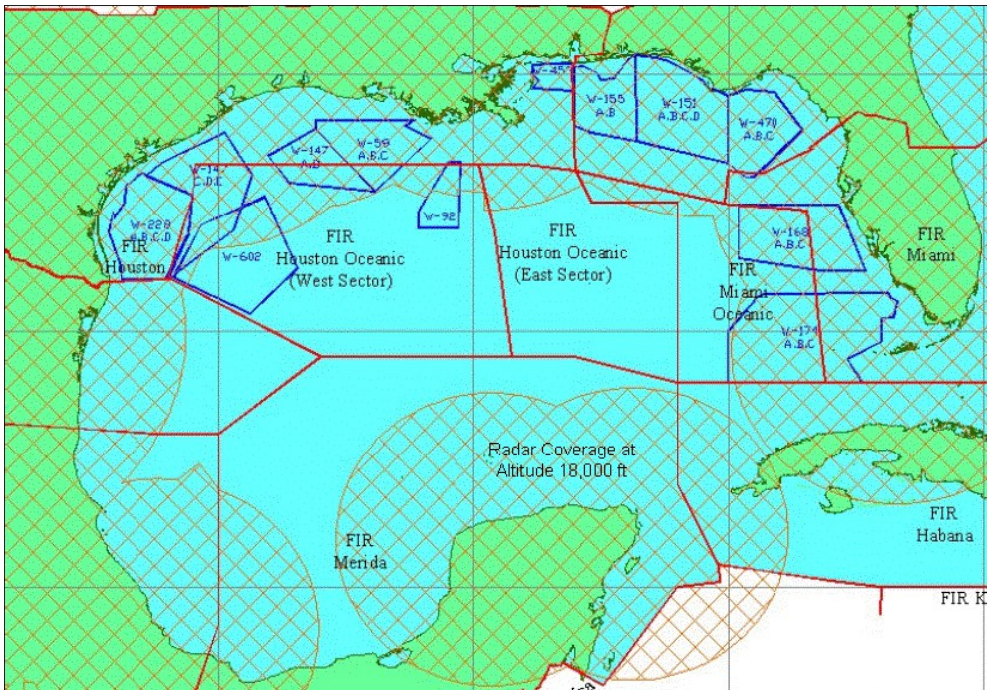

Figure 1 Gulf of Mexico Airspace

In contrast, Offshore Sectors (not explicitly indicated in Figure 1) lie within 100 NMI of the coast, and between 1500 and 7000 ft in altitude. Helicopters and small fixed-wing aircraft are the predominant users, with helicopters servicing petroleum platforms being an important component. The regions contiguous to these two are of less interest to this effort, because (1) airspace above the Offshore Sector is well-covered by radar, and (2) low-altitude Oceanic Sectors have little instrument flight rules (IFR) traffic. Surveillance coverage of the two airspace regions of interest herein is limited, because of (a) the low altitude nature of the Offshore Sectors, and (b) the remoteness of the Oceanic Sectors. Much of the Oceanic Sectors lies beyond the line of sight of shore-based radars. In effect, this airspace is physically unreachable, because placement of radars on platforms is considered to be economically infeasible. Moreover, an unavoidable consequence of the spherical shape of the Earth is that coverage of low-altitude airspace requires a relatively large number of line-of-sight sensors e.g., approximately 24 are needed to cover the Offshore Sectors at 2000 ft. Thus continuous radar surveillance of Gulf airspace, as is done throughout the National Airspace System (NAS), has not been achievable because of a combination of economic and physical factors. The lack of continuous surveillance significantly restricts the capacity of both types of Gulf airspace of interest herein when IFR are in effect. Aircraft in the Offshore Sectors operate primarily, and satisfactorily, under visual flight rules (VFR). The Houston Air Route Traffic Control Center (Houston ARTCC, the cognizant air traffic control facility) does not provide traffic advisories to the VFR traffic. When conditions require IFR operations in the Offshore Sector, responsibility for aircraft-to-aircraft separation shifts from the aircraft to the Houston ARTCC, which must employ inefficient, nonradar procedures to ensure safe separations. An example is the one-in, one-out" rule governing actual instrument approaches and departures to many airports/heliports lacking a radar: If an aircraft is executing an approach under IFR, then all other IFR aircraft are separated from that traffic, by being either held on the ground, or provided with appropriate lateral and vertical separation in the air, until the first aircraft has landed and informed air traffic control of that fact. In contrast, the high-altitude Oceanic Sectors operate under IFR at all times. Aircraft separation standards are time-based, but are equivalent to approximately 50 to 100 NMI much greater than the 5-NMI standard for domestic airspace.

1.1 Objectives of the HITS Deployment and Evaluation

The FY01 National Aeronautics and Space Administration (NASA) budget included funds for deployment of multilateration and Mode-S-based Automatic Dependent Surveillance-Broadcast sensors for the Helicopter In-Flight Tracking System. The FY02 budget legislation included language directing that funding from the NASA budget be expended for additional HITS deployment. Multilateration and automatic dependent surveillance broadcast (ADS-B) are new technologies that appear to have the potential to provide surveillance performance at least equivalent to that for secondary radar, without some of the latter's limitations such as relatively high cost and large size/weight ground equipment. However, both require that aircraft be transponder-equipped, and thus are not alternatives to primary radar. The HITS deployment directed by the FY01 and FY02 legislation provided the opportunity to evaluate these new technologies in the Gulf environment. Moreover, the Federal Aviation Administration (FAA) requested that NASA conduct such an assessment. Thus the objectives of this effort were to (1) deploy the HITS, and (2) conduct a technical and (to a lesser extent) operational evaluation of the capabilities of multilateration and ADS-B relative to those of secondary radar.

1.2 Deployment Overview

The HITS effort was sponsored by the Advanced Air Transportation Technologies (AATT) Project at NASA Ames Research Center. The U.S. Department of Transportation (DOT) Volpe National Transportation Systems Center (Volpe Center) supported the AATT Project by managing HITS installation and operation, and assessing its effectiveness. Sensis Corporation (Sensis) was responsible for the design, installation, operation, and maintenance of the HITS ground infrastructure. At NASA's invitation, the FAA actively monitored deployment and evaluation activities, and contributed aircraft for flight tests.

The HITS deployment and evaluation (Figure 2) comprised three phases:

- Phase I involved the deployment and testing of a WAM/ADS-B system in the offshore area immediately south of Intracoastal City, Louisiana. A 21-sensor array provided WAM coverage extending upward from approximately 100 ft above sea level (ASL) over a 7000-NMI^2 footprint, and upward from 1000 ft over 8725-NMI^2 footprint; a region 50-percent larger than the coverage area for an airport surveillance radar.

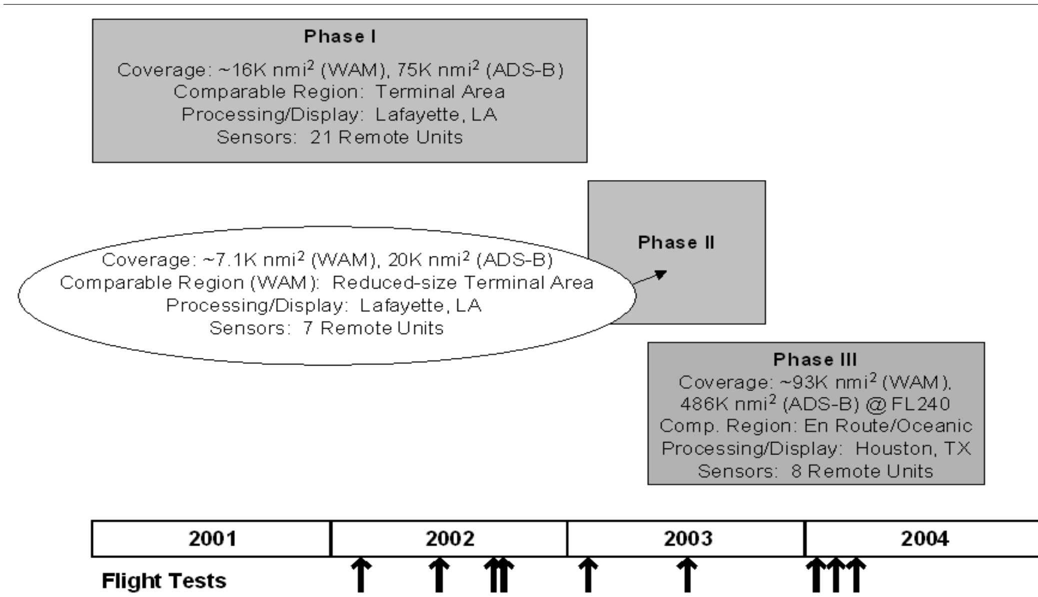

Figure 2 HITS Deployment and Evaluation Phases

• Phase II constituted redeployment of a subset of the Phase I sensors around the high-intensity helicopter operating area at Intracoastal City. This phase evaluated the effectiveness of HITS WAM capability to provide surveillance services to a small airport that could benefit from them.

• Phase III shifted primary focus from offshore to oceanic airspace, and from WAM to ADS-B. This phase used a redesigned set of eight sensors that were deployed to provide ADS-B coverage of most of the U.S.-managed FIRs a region comparable to several domestic en route sectors. A long range WAM capability was also implemented in a smaller, sub-area of the Gulf. This was the first U.S. WAM system configured and tested for operation in en route-like or oceanic airspace and likely the first anywhere.

The HITS ground infrastructure was a modified version of the FAA's ASDE-X subsystem that uses multilateration and ADS-B to track aircraft on the surface. ASDE-X and HITS multilateration use signals from all three types of currently deployed aircraft transponders Air Traffic Control Radar Beacon System (ATCRBS), Mode S short squitter, and Mode S extended squitter.* Ground stations, termed remote units (RUs), measure the time of arrival (TOA) of the same transponder message at one or more locations. Aircraft horizontal position is determined by processing three or more TOA measurements at a central location. Only a single message needs to be received in an update interval for accurate position determination, because signal variability (noise) is sufficiently small that it is not necessary to average multiple measurements. Aircraft identify (Mode A code, and Mode S code when available) and barometric altitude (Mode C code) are determined from information in transponder messages. HITS ADS-B functionality requires signals from ADS-B Mode S extended squitter transponders that became available in this decade. When ADS-B signals are received at one or more ground sensor(s), HITS develops a target report by decoding the message, which contains aircraft identity, and position and velocity, derived from an onboard Global Positioning System (GPS) receiver. When an ADS-B message is received at three or more ground stations, a WAM target report is also generated.

1.3 HITS Evaluation Overview

Evaluation of the HITS was based on extensive flight testing. Targets of opportunity (existing air traffic) were employed to address narrow objectives. The Phase I configuration was flight tested during five periods, enabling Sensis to identify and implement system improvements, and Volpe to determine ("score") HITS performance for most combinations of (i) tracking methodology (WAM or ADS-B), (ii) aircraft transponder type, and (iii) aircraft altitude regime. Tests were conducted for three altitude regimes: above 20,000 ft (high), approximately 10,000 ft ("medium"), and less than 7000 ft (low). The single Phase II test period was targeted at the low-altitude, ATCRBS transponder, WAM tracking performance of a reduced and relocated sensor matrix from Phase I. The three Phase III flight-test periods were restricted to high-altitude flights, but involved all possible combinations of tracking methodology and transponder type.

2 HITS Deployment Configurations

2.1 HITS Ground Equipment

The basic HITS equipment architecture involves:

• A set of RUs sited to receive transponder emissions from aircraft in the region under surveillance; some RUs are receive-only (RO) units, and some are RT units that elicit messages from aircraft transponders; and

• A central processing site (CPS) where data provided by the RUs are processed to derive aircraft positions; the CPS also displays aircraft positions and monitors the status of the system. Remotely located reference transponders (RXs, housed in separate electronics cabinets having the same size/shape as RU cabinets) were used in Phases I and II to synchronize the RU clocks. RU clock synchronization was necessary to ensure consistency of the TOA measurements used in multilateration calculations. Commercial telecommunications linked the RUs and CPS.

RU antennas were either a Navy AS-177B (omni directional azimuthal coverage with 2.8 dBi of mainbeam gain) or an FAA DME Model 5100A (omni directional azimuthal coverage with 8 dBi of mainbeam gain). Each RU also had an uninterruptible power supply and a router that provided the interface to the microwave communications system linking the RU with the CPS. The CPS for each phase included the TP computer, maintenance and display terminal (MDT), and communications equipment. The TP received decoded aircraft transponder messages and associated TOA timestamps over the commercial communications network. Functionally, the TP clustered transponder messages from different RUs i.e., determined whether all received messages candidate set were due to the same aircraft transmission. The TP also performed multilateration calculations on a set of TOAs associated with cluster messages to determine the aircraft horizontal position. These calculations required the geographical coordinates of the RUs, which were obtained from a survey during installation, and the aircraft altitude, which was determined by decoding transponder messages.

The output of the TP was interfaced with a MDT within the CPS via a local-area network. The MDT had a graphical user interface for interacting with the RUs and TP. It monitored the status of the RUs and TP, could reconfigure the RUs if needed, and provided a graphical display of the aircraft being tracked by HITS. Separate T1 lines linked the CPS with the Volpe Center in Cambridge, Massachusetts, and Sensis Corporation in DeWitt, New York. Remote MDTs were located at each of these sites, enabling remote operation and maintenance of the HITS, as required and continuous data recording for timely analyses.

2.2 Phase I Network Architecture

Flight following, as practiced in the Gulf of Mexico, is a process whereby helicopter transportation service providers track the location of their fleets, based on periodic position reports provided by their pilots. A Federal Aviation Administration (FAA)-approved flight-following process is a requirement for all offshore operations conducted under Federal Aviation Regulation Part 135, but not for those conducted under Part 91. Most offshore operators have some formalized means of monitoring the location of their aircraft, required or not, to enhance the safety and efficiency of their operations. Flight following in the Gulf has traditionally been accomplished by very-high-frequency (VHF) radio reports. Recently, some helicopter fleet operators have begun investing in a satellite communications capability that provides (a) automated position updates from helicopters to their operations centers, and (b) a data channel from the operations centers to the aircraft. The Phase I HITS system was implemented, in part, to evaluate WAM flight-following capability for the offshore service providers. Because virtually all Gulf helicopters are equipped with Air Traffic Control Radar Beacon System (ATCRBS) transponders, the intent was that WAM flight following would not require additional aircraft equipage. However, the practice in the Gulf is that, for VFR operations (which are used most of the time), each fleet operator is assigned one beacon code for its entire fleet, unique from the codes assigned to other operators. With WAM, this enables operators to distinguish their own aircraft from those in other fleets, but not to identify individual aircraft. This limitation strongly reduced fleet operators interest in WAM flight-following technology, and none requested a feed of the HITS-derived traffic information. Mode S transponder equipage would enable WAM surveillance to identify individual aircraft, but these avionics are just beginning to be installed on Gulf rotorcraft.

Phase I provided a valuable opportunity to assess WAM and ADS-B surveillance technologies as alternatives to secondary radar, including determining the impact of the harsh Gulf environment on their performance. Although multilateration had been developed and tested as a surface-surveillance technology, WAM had not been assessed in the U.S. as a potential airborne surveillance technology. The Gulf of Mexico environment, for both its weather and remoteness, provided unique challenges to assessing a potential future surveillance system, not only for the offshore operations but also for potential for high-altitude sectors. Challenges included: surveillance coverage of low-altitude offshore users, signal reflections off the sea surface, reliable telecommunications between offshore oil platforms and onshore facilities, and maintenance and repair of remote ground stations

The HITS ground-equipment architecture for Phase I is shown in figure 3. This configuration comprised 21 RUs, 11 ROs, and 10 RTs, and 7 RXs. The CPS was located at Petroleum Helicopters, Inc. (PHI) in Lafayette, Louisiana.

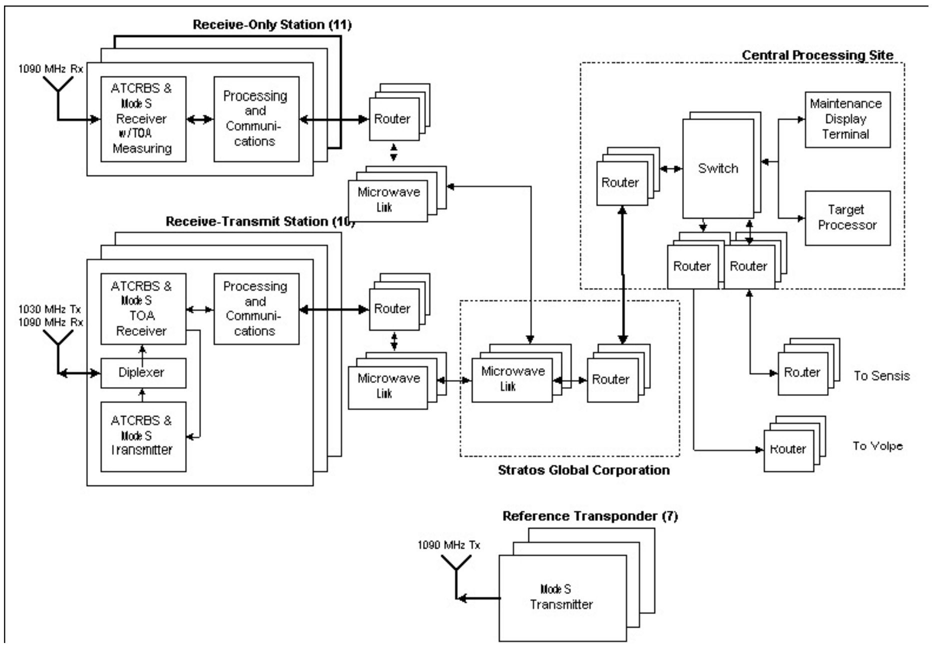

Figure 3 Phase I Ground-Equipment Architecture

Figure 3 shows the RU locations and types. Individual sites, which were placed in the form of a grid of triangles with 20- to 25-NMI sides, were chosen to provide WAM coverage down to 100-ft altitude in the region enclosed by the polygon connecting the perimeter stations. This inner or primary coverage area had a footprint of approximately 7000 NMI2. The strip approximately 20-NMI wide (the nominal spacing between RUs) surrounding inner coverage area was the outer or extended coverage region. WAM coverage in the outer region extended upward from 1000 ft over a footprint of approximately 8750 NMI2.

In terms of coverage footprint and altitude regime, the region under WAM surveillance was approximately 50-percent larger than the terminal area served by an airport surveillance radar. Thus, Phase I provided an initial assessment of the suitability of WAM as a terminal-area SSR replacement. Phase I ADS-B coverage was expected to extend at least 100 NMI from the perimeter of the ground stations, provided aircraft had sufficient altitude to have a line of sight with at least one ground site.

2.3 Phase II Network Architecture

The Helicopter In-Flight Tracking System (HITS) Phase II system was configured to test wide-area multilateration (WAM) surveillance for a small terminal area on the order of 40 NMI in diameter, as opposed to the 120-NMI diameter of a standard terminal area at Intracoastal City, Louisiana (INCY). There is a need for less-capable/lower-cost alternatives to the full-capability terminal area radar surveillance systems now deployed. The FAA maintains air traffic control towers at approximately 400 airports. Of these, approximately half have terminal radars. The cost of a radar installation cannot be justified for the remaining half, based on insufficient traffic levels (particularly air carrier traffic) and/or insufficient frequency of instrument meteorological conditions (IMC). Some of these airports have terrain or other obstacles in/near the primary approach corridor. Additionally, there are non-FAA towered airports with high levels of operations (albeit not air carrier) and relatively high IMC frequencies that could derive safety and capacity benefits from an alternative to conventional radar. High-density helicopter operations bases are examples of these.

For helicopters operating in the Gulf of Mexico region, instrument-flight-rules flights over the water are conducted using nonradar procedures. The Lafayette, Louisiana, terminal radar approach control facility (TRACON) controls overland IFR traffic arriving/departing Intracoastal City, Louisiana, above a minimum altitude of 500 ft. Only one helicopter is permitted to approach/depart below 500 ft at one time (one-in/ one-out rule). For example, a helicopter on approach to INCY necessitates that all departing aircraft hold on the ground and all arriving aircraft maintain positions outside the INCY operating area until the helicopter of interest has landed or canceled the IFR operation. The HITS Phase II system provided an opportunity to assess WAM as a terminal surveillance system in a high-density helicopter operations area.

The Phase II configuration involved a reduction in the number of the Phase I RUs and relocation of some equipment. This configuration employed 7 RUs, 3 ROs, 4 RTs and 2 RXs. The ROs used AS-177B omni directional antennas, and the RTs had DME 5100A antennas. The CPS remained at the PHI facility in Lafayette, Louisiana.

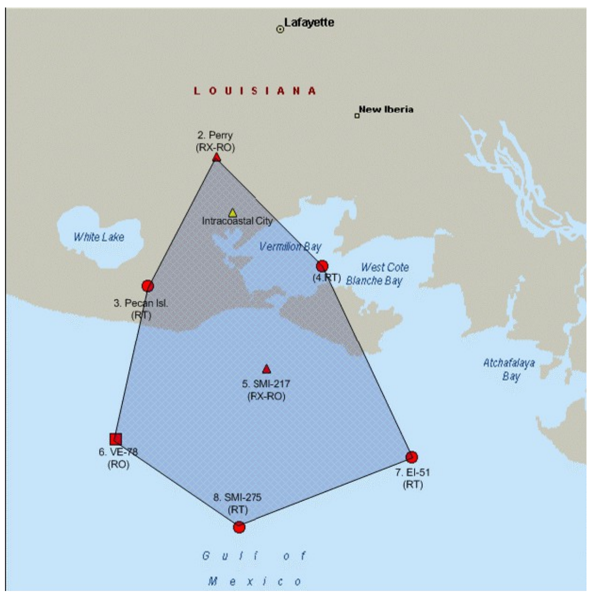

Figure 4 – Phase II Coverage Area

The Phase II sites were selected to provide WAM coverage of the area surrounding Intracoastal City (INCY, Figure 4). The inner coverage area, depicted by the polygon connecting the perimeter ground sites, had a footprint of 1600 NMI2 and corresponded to WAM coverage down to 100 ft of altitude. WAM coverage was designed for the surveillance of helicopter launch and recovery operations at Intracoastal City, and included all the offshore IFR arrival/departure navigation fixes. ADS-B coverage extended approximately 100 NMI from the inner coverage area in all directions an area with a footprint of approximately 20,000 NMI2.

2.4 Phase III Architecture

Most of the two FIRs in Houston's airspace, and a portion of the Miami FIR, lack continuous surveillance coverage, which significantly limiting their capacities. Aircraft traveling in nonradar airspace use time-based, oceanic in-trail separation standards of 10 min (Houston West) and 15 min (Houston East and Miami). In terms of distance, these time separations are approximately equivalent to 50 to 100 NMI (depending upon aircraft speed), figures that are dramatically larger than the 5-NMI separation standard for radar-controlled domestic en route airspace. A consequence of large required separations is that, during busy traffic periods, some aircraft departing from Gulf coast states and bound for Central/South American destinations cannot be assigned to their preferred altitudes (generally above FL300) without incurring 1- to 2-hour ground delays.

Whereas Phases I and II were directed at WAM surveillance of terminal-area-like airspace regions, the first objective of the Phase III configuration was providing ADS-B coverage of en route/oceanic airspace. Specifically, the Phase III system was designed to provide ADS-B surveillance coverage across most of the U.S. flight information regions (FIRs) in the Gulf at 24,000 ft above sea level (ASL) and higher (Figure 5). To accomplish this goal, 8 RUs were sited in and around the Gulf of Mexico—5 on shore and 3 on deep-water platforms 100 to 120 NMI from the U.S. southern coast. The sites selected were located on the backbone of the network installed by Stratos Global Corporation, a commercial telecommunications service provider, to minimize communications installation costs and improve reliability. Accordingly, these sites were not optimally located for multilateration performance. The CPS for Phase III was located in the Dynamic Simulator (DySim) room within the FAA's Houston Air Route Traffic Control Center (ARTCC).

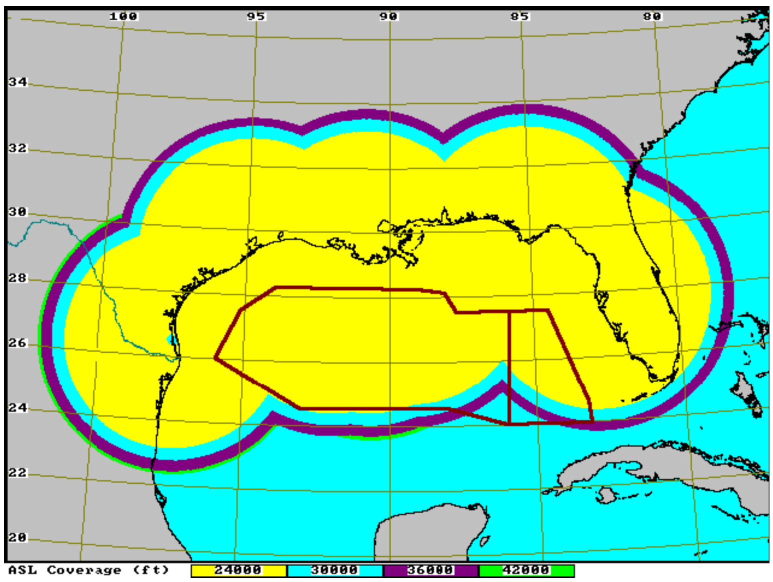

Figure 5 Phase III RU Locations and Predicted ADS-B Surveillance Coverage

Coverage of such a large area (approximately 486,000 NMI2) necessitated several significant equipment/ deployment changes from Phases I/II: (a) wider spacing of RUs (approximately 200 NMI vs. 20–25 NMI for Phases I/II); (b) exclusive use of the higher-gain FAA DME Model 5100A antennas at the RUs (for reception over greater distances); (c) a newly developed high-power interrogator (for transmitting over greater distances); and (d) a GPS receiver within each RU to synchronize the clocks (eliminating the use of reference transponders, which required line-of-site visibility to multiple RUs.

Two high-power interrogators were purchased from DRS Signal Solutions West (formerly Zeta Corporation) and integrated with the Sensis RT equipment. One unit was installed at Morgan City, Louisiana (MCY), to elicit information from ATCRBS and Mode S transponders. The remaining high-power interrogator was retained as a laboratory test specimen and spare. As in earlier phases, each site had an uninterruptible power supply and a router that provided the interface to the communications system linking the RU with the CPS.

Phase III focused on surveillance of aircraft in the Gulf high-altitude Oceanic sectors (Figure 5). The Gulf Oceanic sectors begin approximately 75 NMI south of the U.S. coastline and extend southward to the boundaries with Flight Information Regions (FIRs) managed by Mexico and Cuba, 300–350 NMI from the U.S. coast. Vertically, the high-altitude sectors extend upward from FL180 to FL600. Flight operations in these sectors are entirely under instrument flight rules, controlled by the Houston Air Route Traffic Control Center (ARTCC) and Miami ARTCC.

3 HITS Evaluation Summary

Test results are briefly described for the three deployment phases. Results depend most strongly on the following test conditions:

- Aircraft altitude regime: low (less than 3k ft), mid (approximately 10k ft), and high (greater than 20k ft)
- Analogous airspace type: terminal (ground sensors less than 50 NMI from aircraft), and en route/ oceanic (ground sensors up to 250 NMI from aircraft)
- Measurement/transponder type:
  - WAM with Air Traffic Control Radio Beacon System (ATCRBS) transponder
  - WAM with Mode S short squitter transponder
  - WAM with Mode S extended squitter transponder
  - ADS-B with Mode S extended squitter transponder

Although of developmental value and technical interest, WAM capability with Mode S extended squitter transponder has operational use only as a backup to ADS-B for that equipment combination. Funding did not permit testing all combinations of conditions.

3.1 Wide Area Multilateration

• For terminal surveillance, WAM met most of the performance criteria. Horizontal-position error was consistently in the range 100–200 ft (95 percent), satisfying the standard of 416 ft (95 percent) by a large margin. Resolution of closely spaced targets was superior to that for radar. The major performance concern was the inability to obtain transponder messages from low-altitude aircraft as frequently as required for a SSR, particularly from aircraft equipped with low-end ATCRBS transponders.

• For en route/oceanic surveillance, WAM demonstrated potential for providing aircraft data in nonradar areas with more accuracy than a SSR. As the first and only test period ever devoted to WAM surveillance of en route- or oceanic-like airspace, these results should not be taken as definitive of the capabilities of the technology.

• WAM performance with Mode S transponders was generally better than that for ATCRBS transponders. This occurs for several reasons: (a) Mode S transponders broadcast a DF11 message once each second, from which the aircraft position can be estimated without an interrogation; (b) Mode S transponder messages contain a unique aircraft identifier, facilitating the clustering of detected versions of the same reply received at diverse geographical locations, and (c) Mode S transponders typically have higher performance capabilities than ATCRBS transponders.

3.2 Automatic Dependent Surveillance – Broadcast

• For several extended flights above Flight Level 220, ADS-B satisfied the performance standards defined for this effort. No performance issues were identified that would preclude ADS-B from use as a sensor for mid- or high-altitude aircraft.

• Complete surveillance coverage of the Gulf of Mexico high-altitude airspace is limited by availability of RU locations on offshore platforms and possibly buoys and not by surveillance equipment performance.

• HITS equipment operated with minimal disruption on petroleum platforms in an unfavorable weather environment.

• Communications from offshore platforms to a land-based facility by a commercial telecommunication service provider did not meet FAA availability standards.

• Approval for access to deep-water offshore platforms is generally challenging and difficult at times.

4 Host Computer System Assessment

The Houston Center Air Route Traffic Control Center (Houston Center) currently employs the Host Computer System (HCS) as the en route automation system. The HCS accepts digitized inputs from primary and secondary radar in the Common Digitizer – 2 (CD-2) formats. Two types of messages are transmitted from the radar site to the HCS – beacon report messages and the Real Time Quality Control (RTQC) messages. The beacon report message provides the aircraft's beacon code, barometric altitude, slant range to the radar antenna, and radar azimuth from magnetic north. The RTQC messages include the beacon status message, and the beacon test message. Other messages are included in the RTQC message stream but were not included as part of this evaluation.

The Safe Flight 21 Program Office was directed by the FAA's EnRoute and Oceanic to create "pseudo" radar reports from the HITS surveillance infrastructure in the Gulf of Mexico to interface with the existing automation platform, the HCS, at Houston Center. HITS surveillance data was provided to external users using the Euro Control standard Asterix Category 10 data format. The scope of the HCS evaluation was to convert the Asterix Category 10 data to the CD-2 data format accepted by the HCS. The FAA's Safe Flight 21, the FAA Technical Center, the Volpe Center, and Sensis Corporation defined an evaluation program to accomplish three objectives:

- Verify the conversion of Asterix Cat 10 surveillance messages (pseudo radar reports) to CD-2, including the beacon report and RTQC messages,
- Assess the impact on the HCS with the "pseudo radar reports" from the HITS surveillance system
- Verify that the integration of virtual RADAR sites that represent the ADS-B sensor data and their respective coverage areas, provide for seamless consistent processing and representation of aircraft, tracking and presentation throughout the Air Route Traffic Center's (ARTCC) airspace.

The evaluation of the HCS took place at the IIF facility at the FAA Technical Center at Atlantic City, NJ using both recorded Asterix Cat 10 data supplied from the HITS surveillance system in the Gulf of Mexico as well as injected targets from the FAA Technical Center's target generation equipment. One limitation with current Mode S 1090 extended squitter transponders is the DF 17 message (ADS-B message) currently does not contain a field for the aircraft's beacon code. For this evaluation, the beacon code was inserted, or hard coded, into the created "pseudo radar reports" to allow the message reports to accepted by the HCS. It is expected the Mode S 1090 extended squitter transponder requirements will be updated to include the aircraft's beacon code in the DF 17 message.

4.1 Host Test Architecture

Safe Flight 21 completed a surveillance siting analysis for both the high and low altitude airspace users in the Gulf of Mexico determining approximately twenty four ground stations would be required to meet the surveillance requirements. However, the HCS interfaces with the PAMRI, an interface peripheral to the HCS that receives and exchanges data with the primary and secondary radars. The PAMRI has twenty four channels available for data input from radar locations and accommodates serial CD-2 data only. The PAMRI at Houston Center receives CD-2 data from twenty long range radar locations and maintains one channel as a backup. Only three channels were available to interface with the proposed HITS surveillance system in the Gulf of Mexico. To fulfill the requirement of the channel availability of the PAMRI, the concept of Virtual Radars was created. For ADS-B surveillance, the Gulf of Mexico airspace was sectored into three Virtual Radars, Figure 6, with each radar site having a maximum range of 256 NMI (based on the limitation of the CD-2 message) and a scan rate revolution of 12 seconds. Each HITS ground station was assigned to one of three Virtual Radar sites. Surveillance output from the HITS ground station would be reformatted into CD-2 and be transmitted by the assigned Virtual Radar based on the targets azimuth and range.

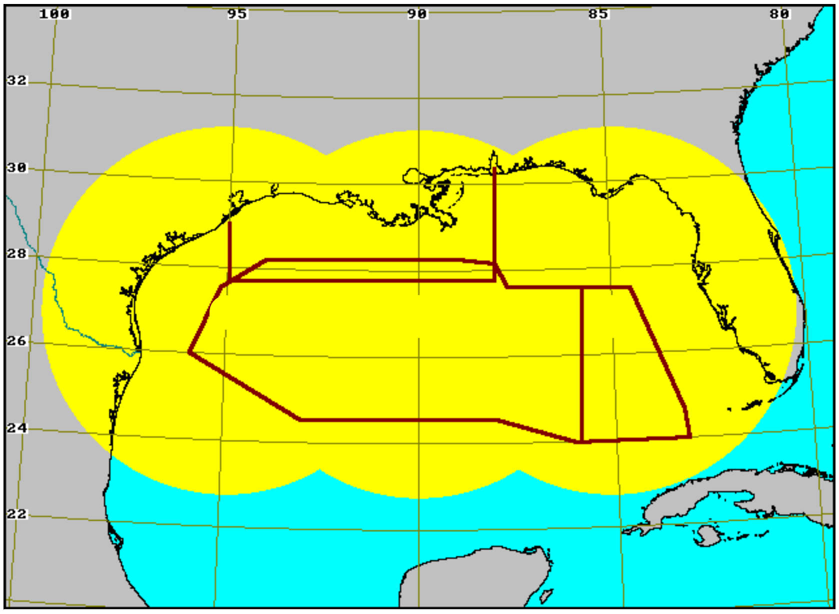

Figure 6 Virtual Radars in Gulf of Mexico

Surveillance data from the HITS surveillance system is output from the Target Processor. The Target Processor receives the ADS-B messages from the surveillance ground stations (Remote Units) and creates composite target reports in the Asterix Cat 10 format. The Target Processor makes available the Asterix Cat 10 messages to external users. Since the Target Processor outputs surveillance data in the Asterix Cat 10 format and HCS receives radar data in the CD-2 format, an additional gateway was necessary to interface between the Target Processor and the Enhanced Communications Gateway (ECG) to provide CD-2 and simulate the Virtual Radars. The ECG accommodates serial radar input and is also capable to accommodate Internet Protocol based radar input as well. The Transfer Communication Protocol based ECG was used in all testing performed at the IIF. The interface and data transfer between the Target Processor and the ECG was conducted in the Host Gateway Computer, as shown in Figure 7.

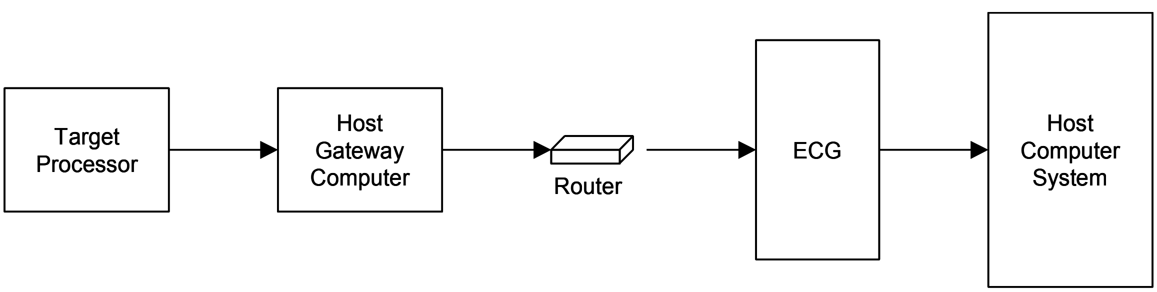

Figure 7 Host Computer System Interface

4.1.1 Host Gateway Computer

The Host Gateway Computer had five primary functions: 1. Target Processor Interface, 2. Interface Initialization, 3. Track File Maintenance, 4. ECG/PAMRI Interface, and 5. CD-2 Message Generation. For this particular evaluation, the Host Gateway Computer also associated the Mode S ID with the Mode 3A Code. Current Minimum Operation Performance Standards (MOPS) DO-260 does not require aircraft to broadcast their beacon code within the ADS-B surveillance message set. For the actual installation of ADS-B in the Gulf of Mexico, it is expected all aircraft equipped with the Mode S extended squitter transponder will be required, as will be stated in MOPS DO-260A, to broadcast the Mode 3A code in the ADS-B message.

The Host Gateway Computer received the Asterix Cat 10 data asynchronously from the HITS Target Processor for all targets equipped with the Mode S extended squitter transponder. Following reception of the Asterix Cat 10 data, the Host Gateway Computer, based on the targets reported position in latitude and longitude, assigns the aircraft to a Virtual Radar. Once assigned to a Virtual Radar, the aircraft's position is converted to a slant range and azimuth position relative to the Virtual Radar antenna location. The Virtual Radar maintains the aircraft's track until 1. slant range is greater than 256 NMI from the Virtual Radar's antenna sight, or 2. the aircraft has entered a region assigned to a different Virtual Radar. Each target (aircraft) is maintained within the Virtual Radar coverage volume based on range and azimuth sector. Each Virtual Radar scans at a rate of one revolution every twelve seconds. The Host Gateway Computer generates the CD-2 message for the HCS based on the targets location in the coverage volume of the Virtual Radar, transmitting a CD-2 message per target once every twelve seconds. Messages sent from the Host Gateway Computer to the HCS are scheduled based on the simulated radar scan rate, including messages for the RTQC functionality and beacon report messages. To accommodate the message transfer from the Host Gateway Computer to the HCS, the Host Gateway Computer establishes an interface with, for this particular evaluation, the Enhanced Communications Gateway (ECG), and the Target Processor.

4.2 Evaluation Criteria and Methodology

The evaluation of the Asterix to CD-2 conversion and the impact on the HCS were conducted at two facilities: the Sensis Corporations, and the IIF Facility at the FAA Technical Center. The initial assessment of the data conversion from Asterix Cat 10 format to CD-2 took place at the Sensis Corp facility. The system configuration of the laboratory, shown in Figure 8, consisted of a Target Processor, Maintenance Display Terminal, Host Gateway Computer, a Mode S target generator, and a Remote Unit. This configuration enabled a preliminary assessment prior to conducting the formal evaluation at the IIF facility.

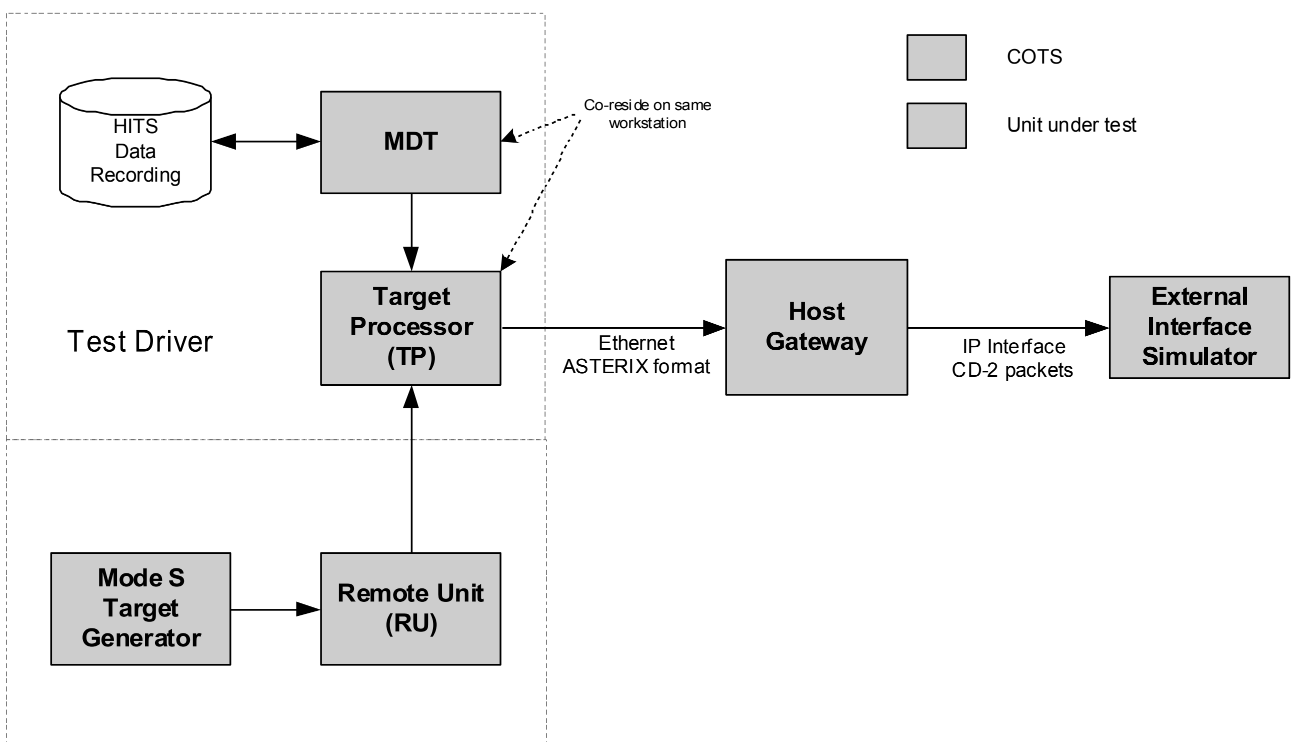

Figure 8 Sensis Corporation Test System Configuration

The evaluation of the HCS took place at the FAA Tech Center's IIF facility in Atlantic City, NJ. At this facility, the FAA Tech Center maintains a HCS to conduct evaluations on system software upgrades or other system enhancements. For this particular evaluation, data from long range radars (CD-2) interfaces with the HCS via the ECG. The ECG, unlike the PAMRI, is not limited by the amount of channels able to receive CD-2 data. However, for this evaluation, it was assumed only 24 channels would be available for a surveillance implementation of ADS-B in the Gulf of Mexico. The equipment used to conduct the HCS evaluation included the Host Computer, the ECG, a LAN switch, the Host Gateway Computer, a Target Processor, Maintenance and Display Terminal (MDT), and an IP based CD-2 radar data stream which utilized the ECG Application Program Interface to output data in the Asterix Cat 33 message set. The Asterix Cat 33 message will be primarily used for airborne traffic. Both recorded data from the ADS-B surveillance system and injected targets were used to conduct the assessment. The original intent of the assessment included a direct connection to the Target Processor at Houston Center, which is part of the Safe Flight 21 surveillance equipment. However, this direct connection was never implemented and never used during the evaluation. Figure 9 shows the equipment configuration at the FAA Tech Center IIF facility.

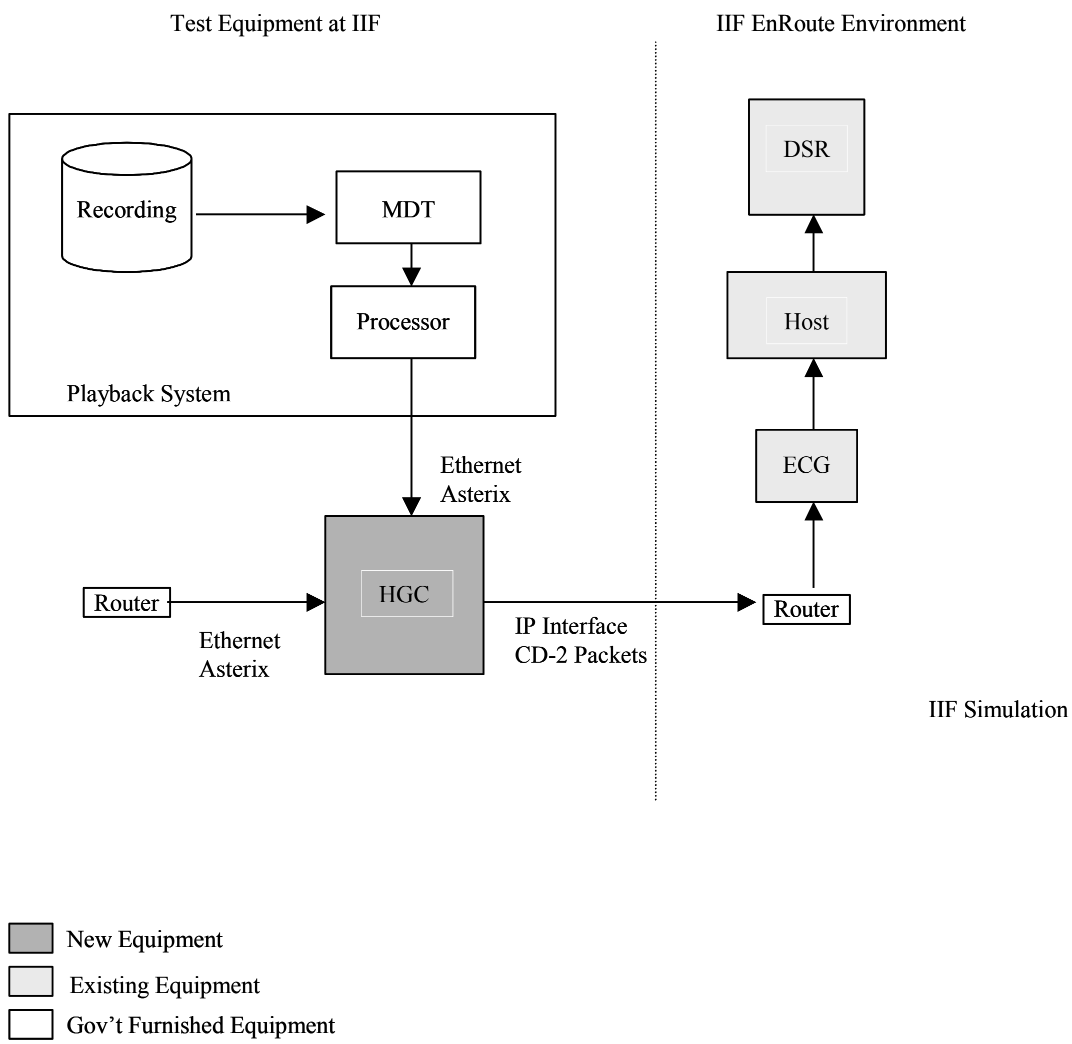

Figure 9 FAA Tech Center IIF Facility Test System Configuration

4.3 Conclusions

The proof of concept activity conducted to assess the impact on the HCS with the interface of non radar systems (ADS-B, multilateration) yielded the following conclusion to the question posed at the commencement of the evaluation: Does the HCS require a new software build or parameter modifications to integrate the Asterix Cat 10 data? The proof of concept demonstrated reports from the Host Gateway Computer can simulate radar scans and convert latitude and longitude position reports contained within the Asterix Cat 10 and the Asterix Cat 33 message set (regardless of sensor) to slant range and azimuth reports and distribute the reports based on the virtual scan of the radar to the HCS. The result is that not only was Asterix Cat 10 Asterix demonstrated to be interoperable with the HCS but also category 33 Asterix.

The CD-2 messages generated by the Host Gateway Computer also satisfied the RTQC functionality of the HCS. However, for this proof of concept, the RTQC messages (beacon search and beacon status) were hard coded from the Host Gateway Computer and transmitted at the appropriate scan interval. Prior to any integration with non radar systems to the HCS, the RTQC functionality will need to be further examined to ensure information indicating the health status and the integrity of the sensor is transmitted to the HCS. For sensor systems using only ADS-B ground stations, the RTQC functionality can be easily satisfied provided the ECG provides the interface with the HCS. The ECG enables input from sensors beyond the current capacity of 24 with the PAMRI.