

# HELICOPTER IN-FLIGHT TRACKING SYSTEM (HITS) FOR THE GULF OF MEXICO

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## Abstract

Helicopters and other low-altitude air traffic over the Gulf of Mexico operate without the benefit of radar surveillance due to the location and range of existing onshore radar installations. The National Aeronautics and Space Administration (NASA) Ames Research Center (ARC) is sponsoring deployment and testing of a prototype Helicopter In-flight Tracking System (HITS) in a portion of the Gulf of Mexico offshore area. Using multilateration principles, HITS determines the location and altitude of all transponder-equipped aircraft without requiring changes to current Mode A, C or S transponders. Best capabilities are provided in the "primary" coverage area, which is bounded by a polygon enclosing the 21 HITS ground sensors. HITS accuracy is highest in this 7,000 nmi<sup>2</sup>-footprint region, and surveillance is provided to aircraft above 100 ft MSL, allowing helicopters to be tracked onto the helideck of most offshore platforms. Transponder-equipped aircraft are also tracked in the "extended" coverage region, an 8,725 nmi<sup>2</sup>-footprint area that forms a border around the primary coverage area. In the extended coverage region, surveillance accuracy is somewhat decreased and minimum coverage altitudes are larger. In addition to multilateration, HITS provides surveillance reports for aircraft equipped for Automatic Dependent Surveillance – Broadcast (ADS-B), a new technology under development by the Federal Aviation Administration (FAA), in both the primary and extended coverage regions. The U.S. Department of Transportation (DOT) Volpe National Transportation Systems Center (Volpe Center) is supporting NASA in managing HITS installation and operation, and in evaluating the system's effectiveness. Sensis Corporation is supplying, installing and maintaining the HITS ground system. Project activities are being coordinated with the FAA and offshore helicopter operators. Flight-testing in the Gulf begins is scheduled for September 2002. This paper

describes the HITS project — specifically, the system equipment (architecture, remote sensors, central processing site, and communications equipment) and system performance (accuracy, coverage, and reliability).

## Introduction

HITS is based on commercially-available equipment which forms the ground segment of a dual-technology multilateration and Automatic Dependent Surveillance – Broadcast aircraft tracking system. Multilateration utilizes signals from Air Traffic Control Radar Beacon System (ATCRBS) (Modes A and C) and Mode S transponders, and requires no changes in current aircraft equipage. Three or more ground stations measure the time-of-arrival (TOA) of the same transponder message. Aircraft horizontal position is determined by joint processing of the TOA measurements at a central location. Only one message need be received in an update interval for accurate position determination. Aircraft identity and barometric altitude are determined by decoding the information in transponder's Mode A and Mode C messages. (The multilateration subsystem can estimate aircraft altitude in very limited locations. This capability can be used to verify altimeter performance, but is not useful for surveillance or flight following.) HITS will also operate with signals from ADS-B Mode S extended squitter transponders now being considered for approval in the National Airspace System (NAS). When ADS-B signals are received, HITS develops a target report by decoding the transponder message, which contains aircraft identity and Global Positioning System (GPS) position. When an ADS-B message is received at three or more HITS ground stations, a multilateration target report is also generated. By virtue of its dual technology capability, HITS facilitates an eventual transition and potential backup to ADS-B surveillance.

Installation and checkout of the HITS was completed in July 2002 and flight-testing is scheduled to occur during the summer 2002 timeframe. During these tests, HITS data may be used on a voluntary basis by helicopter operators for flight following. The test data generated will support a government evaluation of HITS multilateration and ADS-B technologies as future alternatives to Secondary Surveillance Radar (SSR) now used for aircraft separation in the terminal and en route domains.

### **Gulf of Mexico Offshore Low Altitude Airspace**

Helicopter operations in support of gas and oil exploration and production account for the majority of the traffic in the low altitude airspace. On average, there are more than 5,000 daily flights between platforms, or between platform and shore, flown by some 600 helicopters. There are more than 300 onshore heliports and more than 2,000 offshore helidecks. More than 35,000 people work offshore at any given time.

Surveillance coverage in the Gulf of Mexico offshore airspace is currently very limited due to the long distances from the onshore radar sites and the low-altitude flight trajectories followed by most traffic. For full low-altitude coverage, a relatively large number of line-of-sight surveillance sensors are needed, with many located offshore. Consequently, provision of coverage by secondary radar, as is used throughout the NAS, is economically infeasible. Use of larger, more costly primary radar is even less viable.

Multilateration and ADS-B technologies have the potential to fill this need, as multilateration surveillance appears to be comparable to SSR, is less costly, and the equipment is smaller and lighter than SSR by substantial amounts. Multilateration has been tested extensively for airport surface applications — e.g., tests in Atlanta (1996) [1] and Federal Aviation Administration tests at Dallas-Fort Worth (1998-1999). The FAA plans to deploy multilateration/ ADS-B systems similar to the HITS equipment as part of the Airport Surface Detection Equipment, Model X (ASDE-X) system now scheduled for installation at 25 medium-to-large airports [2]. There is, however, limited experience

with multilateration for tracking of airborne aircraft in wide area applications. The HITS test and evaluation (T&E) provides an opportunity to validate this technology for airborne targets, and simultaneously to demonstrate its benefits for helicopter operations.

ADS-B capabilities are being evaluated by the FAA Safe Flight 21 (SF-21) program. Operational evaluations have been conducted in the Ohio Valley at Wilmington, Ohio (July 1999), and Louisville, Kentucky (October 2000). Future tests are scheduled at Memphis, Tennessee and Louisville. Additionally, the FAA has implemented an ADS-B system based on the Universal Access Transceiver data link technology in Alaska. The HITS T&E effort extends the SF-21 work in the area of air-to-ground surveillance to the Gulf of Mexico offshore area. The HITS effort will not include air-to-air surveillance or operational benefits evaluations that are part of the SF-21 project.

NASA's current activities in the Gulf follow a series of studies addressing shortcomings in Gulf of Mexico airspace infrastructure. The Helicopter Safety Advisory Conference (HSAC), a voluntary organization of offshore exploration and production companies and their fleets, for-hire fleets, FAA organizations, and many others, have been addressing helicopter operations and safety in the Gulf since 1978. It is anticipated that HSAC and its members will participate in the HITS evaluation, either as industry observers or as cooperative partners in the T&E.

The Gulf of Mexico Working Group (GOMWG), initiated by the FAA Southwest Region, was formed in early 1999 to address Gulf high-altitude airspace capacity limitations that would result from projected growth in air traffic between the U.S. and Mexico, Central and South America, and Cuba. The GOMWG work culminated in a set of recommendations that focus, in the near term, on providing additional radar and communications capability to reduce coverage gaps in Gulf airspace. The GOMWG recommendations primarily address air traffic management and air carrier concerns regarding high-altitude sectors, but provide for some partial solutions, in the intermediate to long term, for low altitude offshore users.

As a result of GOMWG activities and FAA requirements development work over the past several years, the FAA initiated the Integrated Gulf of Mexico Project Investment Analysis in September 2000. The investment analysis concluded with a decision not to proceed, at that time (August 2001, with implementing new surveillance and communications programs for the Gulf

### HITS Configuration and Test Area

The Sensis Corporation has designed and installed the HITS surveillance equipment in the offshore area in the Gulf of Mexico. The U.S. DOT Volpe Center is responsible for the technical evaluation and will contrast HITS performance to that of a traditional secondary surveillance radar. A block diagram of the HITS ground equipment – consisting of 21 Remote Units (RUs) and a Central Processing Site (CPS) – is shown in Figure 1.

The simplest remote site includes the following (see Figure 2):

- An antenna, either Navy AS-177B which has omni-directional azimuthal coverage

(used in shipboard installation), or FAA DME Model 5100A which also has omni-directional azimuthal coverage and is currently deployed at navigation facilities throughout the NAS;

- A 1090 MHz receiver, capable of detecting and decoding messages in the ATCRBS Mode A/C and Mode S short/extended squitter formats and measuring the message TOA;
- An uninterruptible power supply;
- A router, providing the interface to the microwave communications system that links the RU with the CPS.

Ten of the 21 RUs will also have the capability to solicit emissions from ATCRBS and Mode S transponders. In addition to the capabilities itemized above, these RUs — termed receive/transmit (RT) units — also have 1030 MHz interrogators (Modes A/C and S). The remaining 11 RUs are termed receive-only (RO) units.

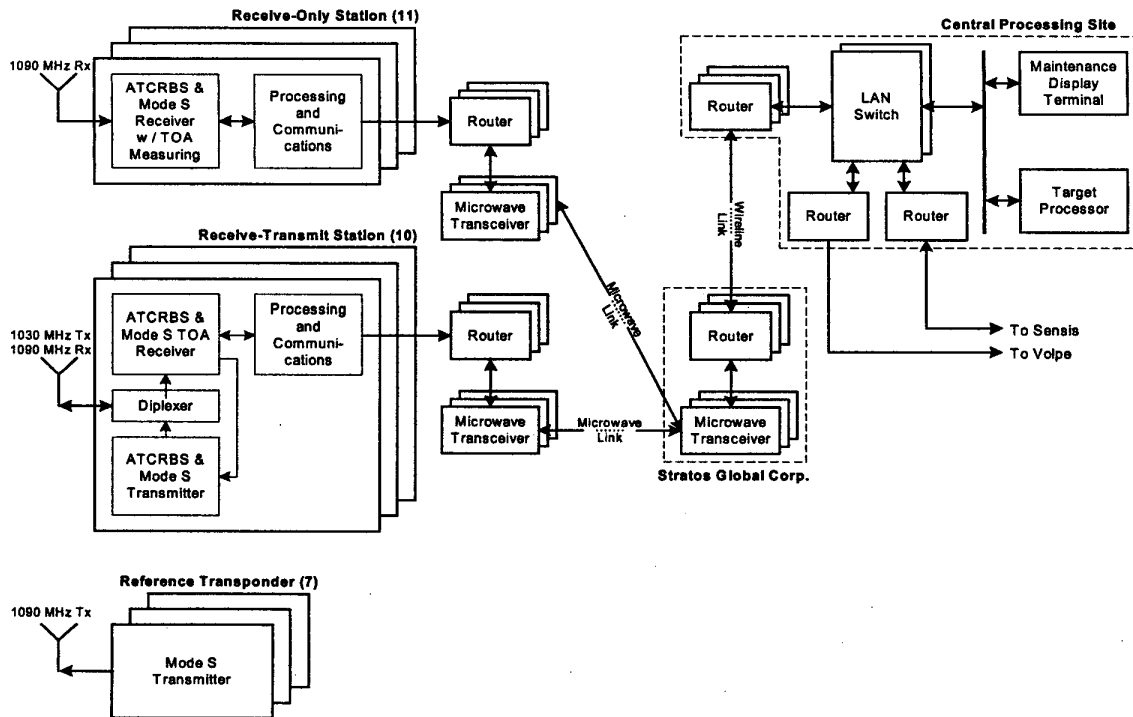
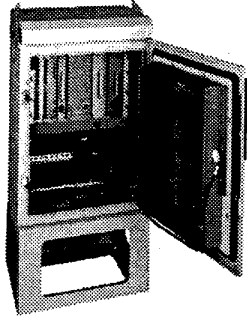
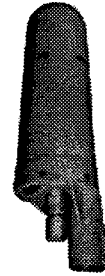


Figure 1: HITS Multilateration/ADS-B Ground Equipment



(a) RU Electronics Cabinet (24"x18"x42")



(b) AS177B Omni Antenna (6.5"x20")

**Figure 2. Remote Unit Equipment**

Reference Transponder (RefTran, RX) units will be installed at seven RO sites. Each RefTran is housed in a separate cabinet, identical to that for the RO. The primary function of the RefTran network is to synchronize the RU clocks, which is necessary to ensure consistency of the TOA measurements used in the multilateration calculations. To provide this capability, the RefTran sites are selected so that (1) each RU is visible to one or more non-collocated RefTran, and (2) each group of RUs that can see a given RefTran has at least one RU that can see another RefTran.

A RefTran contains the equivalent of an aircraft Mode S transponder transmitter. Each RefTran is assigned a unique Mode S code, and broadcasts a message containing that code approximately once per second. RU clock synchronization is accomplished by, in effect, adjusting individual clocks so that the relative message reception times are consistent with the

surveyed distances between the RefTran and its associated RUs.

The network of HITS RU sites is shown in Figure 3, and details concerning each site are given in Table 1. Sites 1, 2, and 3 are collocated with onshore communications facilities; the remainder of the sites are located on offshore resource exploration and production platforms. The RU antennas are between 115 ft and 240 ft above sea level, and the average separation distance is approximately 20 nmi. The north-south distance between sites 1 and 20 is 118 nmi; the east-west distance between sites 12 and 15 is 66 nmi. The five sites surrounding Intracoastal City area are intended to provide terminal radar-like coverage within the irregular pentagon connecting these sites. Intracoastal City is a high-density helicopter operations hub, and the adjacent area is densely populated with oil and gas platforms (both offshore and in the surrounding waterways and lakes).

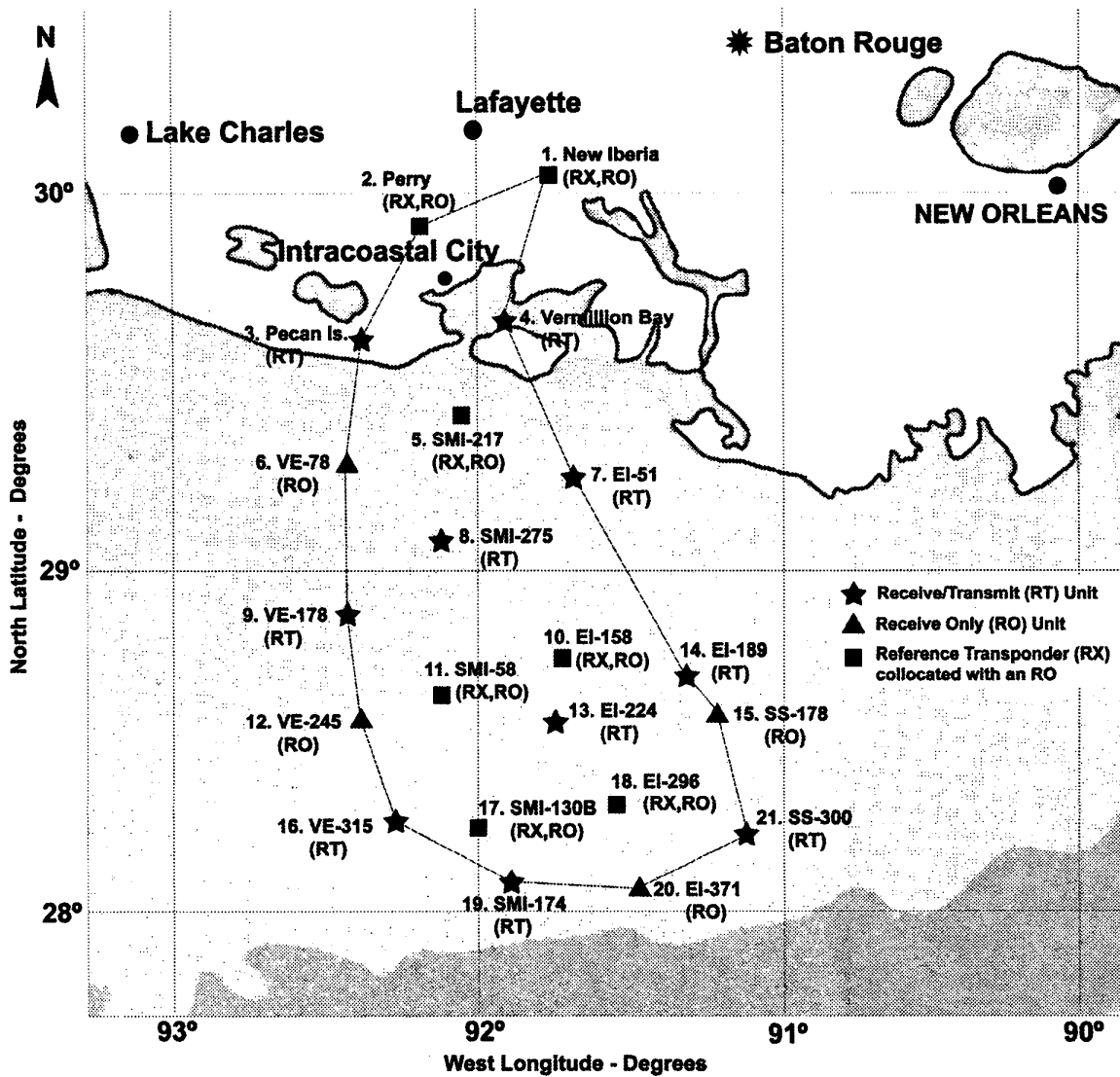


Figure 3: RU Locations and Types

**Table 1: RU Site Information**

<u>No.</u>	<u>Location</u>	<u>North Latitude</u>	<u>West Longitude</u>	<u>Antenna Height (ft MSL)</u>	<u>RU Type</u>
1	New Iberia	30° 02.080'	91° 47.560'	210	RX, RO
2	Perry	29° 55.313'	92° 11.628'	250	RX, RO
3	Pecan Island	29° 37.637'	92° 22.407'	210	RT
4	Vermilion Bay	29° 40.250'	91° 54.850'	150	RT
5	South Marsh Island 217	29° 26.488'	92° 03.664'	212	RX, RO
6	Vermilion 78	29° 16.959'	92° 27.233'	115	RO
7	Eugene Island 51	29° 14.197'	91° 41.037'	230	RT
8	South Marsh Island 275	29° 04.777'	92° 08.095'	145	RT
9	Vermilion 178	28° 52.681'	92° 28.629'	200	RT
10	Eugene Island 158	28° 48.850'	91° 44.332'	170	RX, RO
11	South Marsh Island 58	28° 40.432'	92° 05.729'	230	RX, RO
12	Vermilion 245	28° 34.623'	92° 27.668'	150	RO
13	Eugene Island 224	28° 34.925'	91° 46.059'	148	RT
14	Eugene Island 189	28° 44.884'	91° 22.090'	220	RT
15	Ship Shoal 178	28° 35.937'	91° 12.374'	160	RO
16	Vermilion 315	28° 17.616'	92° 17.611'	125	RT
17	South Marsh Island 130B	28° 17.901'	92° 00.723'	240	RX, RO
18	Eugene Island 296	28° 20.613'	91° 32.294'	150	RX, RO
19	South Marsh Island 174	28° 05.166'	91° 52.522'	160	RT
20	Eugene Island 371	28° 03.861'	91° 29.211'	150	RO
21	Ship Shoal 300	28° 14.530'	91° 07.570'	140	RT

The polygon connecting the peripheral sites in Figure 3 is the footprint of the primary coverage region. Its area is approximately 7,000 nmi<sup>2</sup>. The RU antenna altitudes/separations enable multilateration surveillance above approximately 100 ft in altitude, which includes most platform helipads. Multilateration surveillance is also provided in the extended coverage region (8,725 nmi<sup>2</sup>), constituting the border area approximately 25 nmi beyond the periphery of the RU sites. In the extended coverage region, the minimum surveillance altitude increases to approximately 1,000 feet and the position accuracy degrades moderately. ADS-B coverage extends to a distance of approximately 50 nmi in all directions from the

primary coverage region, resulting a footprint of approximately 20,000 nmi<sup>2</sup>.

Figure 4 simultaneously depicts the HITS multilateration coverage regions and the coverage limits for terminal radars at Lake Charles, Lafayette, Baton Rouge and New Orleans. Coverage contours for several altitudes are shown for the en route radars at Lake Charles and Slidell. The HITS coverage area is transected by domestic and oceanic high-altitude jet routes, a low-altitude Victor airway, and includes portions of Special Use Airspace. Thus, the selected test area will allow for collection of target-of-opportunity data from a variety of aircraft types and operations.

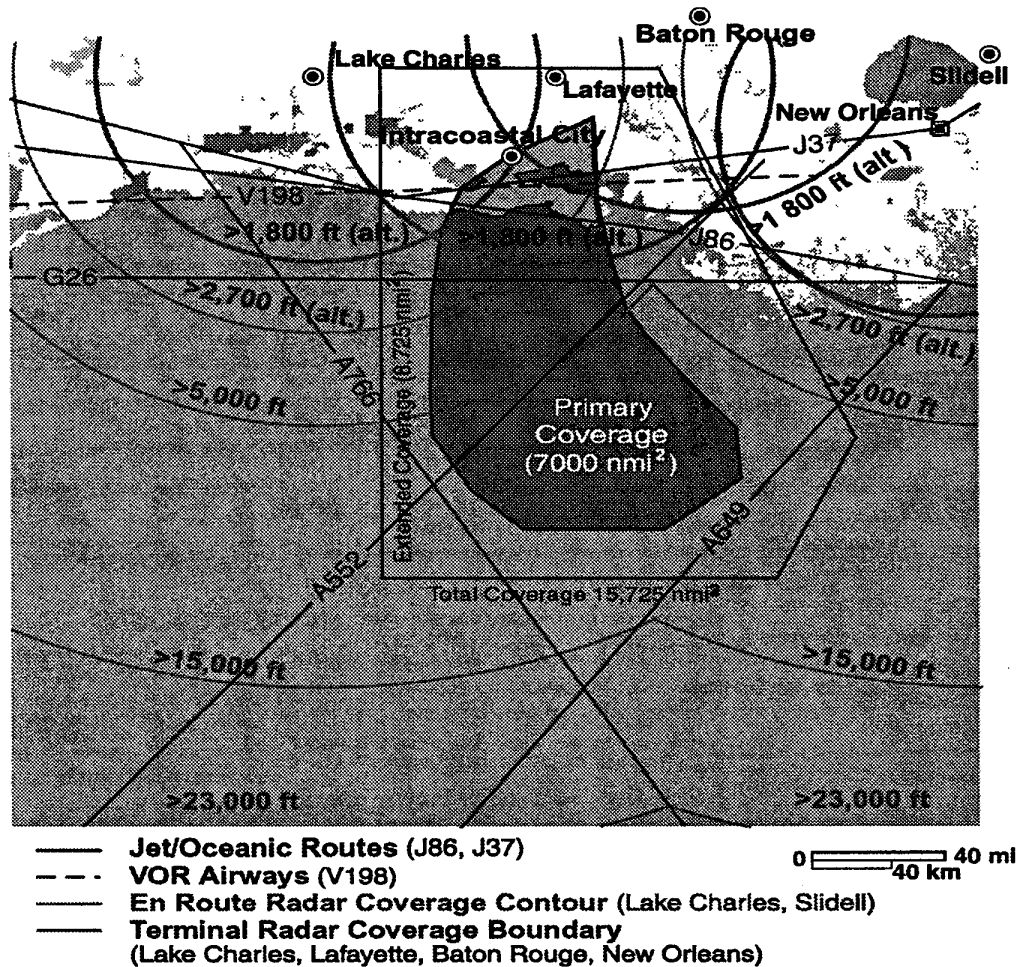


Figure 4: HITS and Secondary Surveillance Radar Coverage

### Central Processing Site

The Central Processing Site, located at the Petroleum Helicopters, Inc. (PHI) facility at Lafayette, LA, includes the Target Processor (TP) computer, displays, and communications equipment. The HITS TP receives decoded aircraft transponder messages and TOA stamps from all 21 RUs over an existing commercial communications network.

The TP has four main functions. First, it “clusters” transponder messages forwarded from different RUs — i.e., it determines whether a set of received messages is due to decoding the same aircraft transmission. Clustering is straightforward for Mode S transponders or for ATRCBS

transponders in aircraft operating under Instrument Flight Rules, because in these cases the message contains a unique aircraft identifier. Message clustering is more complex for ATRCBS-equipped aircraft operating under Visual Flight Rules in the Gulf of Mexico, as the transportation service providers are provided only one Mode A code for their entire fleet. In this situation — which is the case for most helicopters operating in the Gulf offshore area — trial associations must be established. Only when a sequence of received message groups exhibits a pattern consistent with aircraft flight is a full association declared.

The second major TP function is performing multilateration calculations on a set of associated TOAs to determine the aircraft horizontal position

(latitude/longitude or equivalent). Aircraft altitude is usually determined by decoding transponder messages containing encoded altimeter information. In addition to the measured TOAs, these calculations require the coordinates of the RUs, which are obtained by an accurate positional survey during installation. If three TOAs are available from an aircraft message, then Bancroft's algorithm [3] can be used for the multilateration calculations. If more than three TOAs are available, then a least-squares solution can be implemented and error checking on the TOA measurements is possible. HITS computes multilateration solutions for all transponder message types that the receivers decode, including ADS-B messages.

When an aircraft message is received by four or more RUs, then three-dimensional multilateration solutions (containing aircraft geometric altitude) can be computed. Three-dimensional solutions are not used in this evaluation, and are not considered to be useful for air traffic control purposes, because the accuracy of vertical solutions is quite poor except when an aircraft is nearly above an RU. However, the ability to measure altitude independently of the altimeter could be used for other purposes — e.g., checking barometric altimeter performance as part of a program for implementing Reduced Vertical Separation Minimum procedures.

The third TP function is computation of target tracks, a process that is similar to one performed by air traffic control automation systems. Target tracks is not the subject of this evaluation — i.e., the basic multilateration solution is assessed.

Fourth, the TP monitors the status of all subsystems and schedules transponder interrogations as required.

The output of the TP is interfaced with the Maintenance Display Terminal (MDT) within the CPS via a local area network. The MDT has a graphical user interface for interacting with the RUs and the TP. It monitors the status of the RUs and TP, and can reconfigure the RUs if needed. The MDT also provides the only graphical display of the aircraft being tracked in the current HITS implementation.

A T1 line links the CPS with Sensis Corporation in DeWitt, NY, where a remote MDT

is located. This allows experienced personnel to remotely operate and monitor the HITS ground equipment for most of the six-month test period, enabling quick reaction to unexpected events and eliminating the need for extensive travel.

## **RU – CPS Communications System**

Stratos Global Corporation (SGC), a commercial communications service provider to the offshore petroleum exploration and production industry, provides data communications between the 21 RUs and the CPS site at Lafayette, LA. SGC operates two digital RF microwave systems, Gulfnet and Megastar, in the Gulf area. These systems, operating at 6 GHz, utilize redundant DS-3 rings to communicate with the SGC central communication facility in Lafayette, LA. SGC operates "last mile" radios at 2.3 GHz to establish point-to-point links for sites that are not on the DS-3 network. Data from last mile radios are multiplexed onto the DS-3 trunk, providing connectivity with the main network.

HITS utilizes Time Division Multiplex (TDM) links, operating at 64K bps, to transfer data from the 18 offshore and the 3 land-based sites to the SGC central facility. The TDM links are multiplexed onto the DS-3 rings using Cisco 805 routers. HITS data received at the SGC central communications facility are de-multiplexed from the DS-3 links and forwarded to a multiple channel Cisco 2600 router. Data from all RUs are simultaneously multiplexed onto a T1 line that connects with the HITS CPS at the PHI facility in Lafayette.

## **Data Collection and Analysis System**

During the test period, the DOT Volpe Center Data Collection and Analysis System receives aircraft target data from the CPS via a T1 link — see lower right-hand portion of Figure 5. Target data are in a modified ASTERIX Category 10 format that is similar to the format that would be used in supplying radar data to a Terminal Radar Control or Air Route Traffic Control Center facility. The Data Collection Computer (IBM RS/6000 Model 7248 with AIX Operating System) stores the data for subsequent analysis on IBM-compatible PCs. Data from the instrumented aircraft used for controlled



flight tests will be transferred via portable media. The DC&AS at the Volpe Center will also be fed data for use by the MDT computer (Sun Blade with Solaris operating system). The MDT at the Volpe Center is similar to the unit at the CPS, in that it provides a real-time display of the aircraft being tracked as well as information concerning the status of the RUs and TP. However, the MDT at the Volpe Center does not control or configure the HITS equipment in southern Louisiana and offshore area.

## Aircraft Instrumentation

Two aircraft are being instrumented for this project and will be utilized for the controlled flight tests to evaluate the HITS ground equipment multilateration capability — a light helicopter and a light twin-engine fixed-wing. The helicopter is a Bell 206 Long Ranger leased from an offshore helicopter operator. The Long Ranger is equipped with an ATCRBS-type Mode A/C transponder and VHF radio. It also has a GPS receiver, but its antenna will be removed to make room for the HITS instrumentation GPS antenna.

The fixed wing aircraft is a Volpe-operated Piper Aztec. The Aztec is equipped with a Bendix-King model KT 76 Mode A/C transponder and three VHF radios.

The Aztec also has four installed GPS receivers and associated antennas. Plans are to record data from a WAAS-capable Rockwell-Collins model EMAGR, the most accurate of these units, as a backup to the Trimble/Omnistar HITS instrumentation.

In addition to the instrumented light aircraft, to be used to assess HITS multilateration performance, a NASA Boeing 757 research aircraft will be used to evaluate HITS ADS-B performance. The B-757, equipped with Mode S ADS-B avionics, will traverse the HITS coverage area several times at altitudes above FL300 while continuously squittering ADS-B messages, to aid in experimentally determining ADS-B coverage and reception characteristics. The HITS aircraft instrumentation (Figure 6), to be installed on the two project aircraft, will include the following:

- Differential-capable single-frequency GPS aircraft receiver (Trimble model Ag132)

which is interfaced with a demodulator that receives GPS corrections generated by Omnistar Corporation and broadcast in the L-Band by a geostationary satellite.

- Dual band “patch” type antenna to simultaneously receive the GPS signal and Omnistar correction data.
- Laptop computer for data recording, control, and display functions.

The Omnistar real-time differential GPS system has a vendor-stated position accuracy of 1 m. Existing VHF radio assets will be used for voice communications between the aircraft and the HITS Operations Center, and between HITS aircraft operating in close proximity.

A Tel-Instrument Electronics Corp Model T-47S Transponder Interrogator IFF/TACAN/DME/TCAS Test Set will be used to verify the performance of the ATCRBS transponders on both controlled/instrumented flight test aircraft. This test set measures characteristics such as transmit power, receiver sensitivity, and pulse shapes.

## Flight Testing

The objectives of the controlled/instrumented flight tests are to:

- Evaluate HITS multilateration subsystem to determine if it is equivalent in function and performance to secondary surveillance radar — specifically, the Air Traffic Control Beacon Interrogator, Model 6 (ATCBI-6) currently being deployed by the FAA; and
- Evaluate ADS-B function and performance capabilities relative to secondary radar, to the extent possible.

The evaluation criteria include coverage volume, probability of detection, positional accuracy, code performance, and target resolution. These have been derived from requirements for the ATCBI-6 SSR [4] exclusively for this purpose. These criteria are not requirements for the HITS to be a satisfactory flight following system, nor are they contractual requirements for Sensis Corporation. They have been derived to assist the FAA in making certification decisions and developing certification criteria for these two

potential non-radar surveillance alternatives. Detailed evaluation criteria are presented in the Volpe Center HITS Test and Evaluation Plan [5].

During the controlled/instrumented aircraft, both the Piper Aztec and the Bell 206 Long Ranger will fly profiles from approximately 100 feet to 10,000 feet above mean sea level throughout the 7,000 nmi<sup>2</sup> primary coverage area shown in Figure 3. Targets of opportunity will be used throughout the test period from March through October 2002. These will consist of low-altitude petroleum industry helicopters, high-altitude commercial air carriers, and other aircraft operating in the area.

Reports from targets of opportunity can be used to supplement the HITS coverage volume tests by determining when these targets are first and last reported to HITS and how close to continuous the reports are within the coverage region. This information will be valuable, since the targets of opportunity have transponders with different

characteristics than those in the instrumented aircraft.

Another feature of targets of opportunity is that these aircraft fly different trajectories than the instrumented flights in both the horizontal and vertical dimensions. They are also representative of the operational trajectories normally found in the HITS coverage region. Because they involve different transponder and trajectory characteristics, target of opportunity tests may reveal that the operational coverage volume is different than that found using instrumented flights.

The HITS multilateration subsystem is expected to provide two-dimensional position accuracies of  $\pm 30$  ft bias and 25 ft rms jitter when the Horizontal Dilution of Precision of 1.5 or less. HITS recorded position data will be compared to the 1-meter real time differential GPS data recorded on both controlled/instrumented aircraft to verify the expected accuracy.

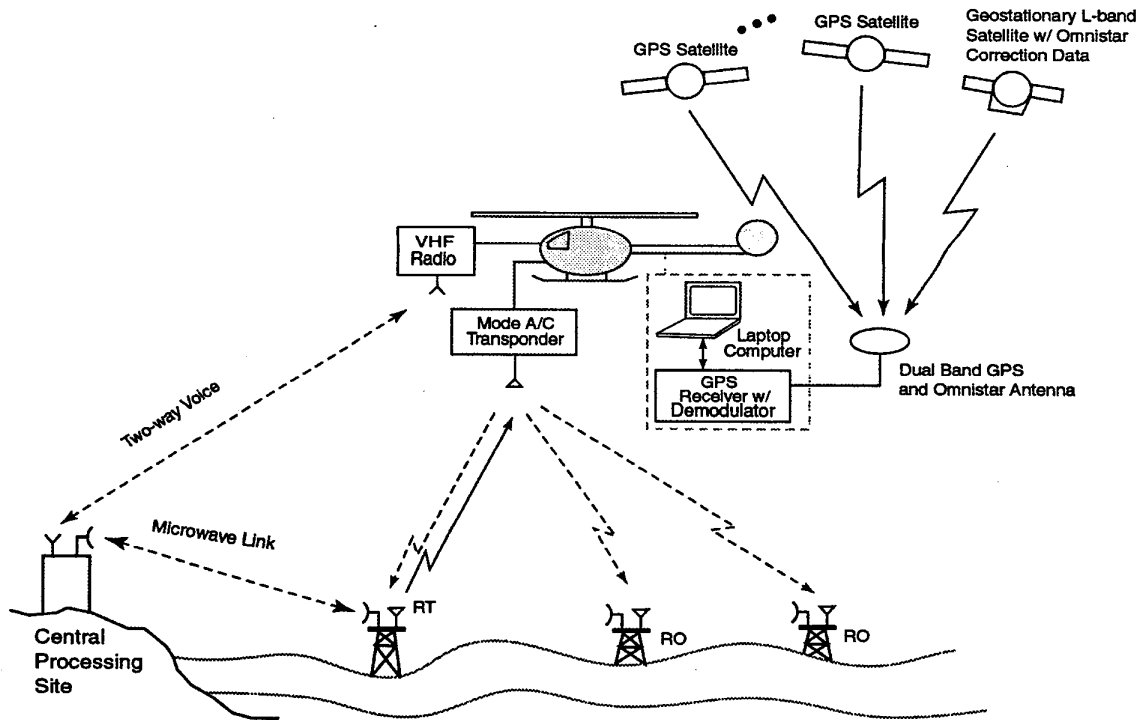


Figure 6: Aircraft Instrumentation Architecture (NOTIONAL)

In order to evaluate the HITS target resolution performance, for which the goal is the 98 percent

resolution of two ATCRBS transponder equipped targets separated by less than 1.7 nmi in slant range,

two instrumented aircraft must be flown in a multiple crossing pattern configuration. The first aircraft will fly on a constant heading at a fixed altitude of 5,000 ft, while the second aircraft will fly a series of "S" turns at a fixed altitude differing from the straight-flying aircraft by approximately 1,000 ft. The ground track of the aircraft will intersect three times as the aircraft traverse 100 nmi of HITS coverage area.

Information concerning the capability of HITS to resolve closely spaced targets can also be obtained from targets of opportunity by using optimal estimates of the target trajectories. The approach consists of determining the relative position of the targets using the optimal trajectories and identifying when these targets approach or are within 1.7 nmi separation. The target reports associated with these trajectories can then be examined in these regions to determine if they exist (i.e., have been resolved) during the times of close proximity.

Statistics for code performance parameters such as code reliability and code validity will be determined by analyzing all of the HITS collected data, from both controlled/instrumented flight test aircraft and targets of opportunity.

### **Concluding Remarks**

Sensis Corporation has installed, and is operating a Helicopter In-flight Tracking System in the coastal area and offshore waters south of Intracoastal City, LA. HITS uses multilateration techniques to track aircraft with operational Mode 3/A, C, or S transponders. The deployed HITS sensor can also determine aircraft position by decoding Mode S extended squitters from ADS-B transponders. The ability of HITS to track aircraft at an altitude of 100 ft above water level in the design HITS coverage area will be verified by the DOT Volpe National Transportation Systems Center. Two flight test aircraft, a helicopter and an airplane, will be used by Volpe Center to generate highly accurate aircraft position data that will be compared, post flight, with aircraft position data obtained from the HITS. The performance of the HITS will be compared to that of a currently-fielded, FAA secondary surveillance radar, using a set of performance criteria developed specifically for comparative purposes. The HITS installation

and the evaluation of its performance are funded by the NASA Advanced Air Transportation Technologies Project Office.

### **Acknowledgement**

The HITS installation and evaluation of its performance are funded by the NASA Advanced Air Transportation Technologies Project Office located at Ames Research Center.

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