HELIICOPTER IN-FLIGHT TRACKING SYSTEM (HITS)  
TEST AND EVALUATION PROJECT IN THE GULF OF MEXICO  
Michael Geyer, US DOT Volpe Center, Cambridge, MA

Abstract

The National Aeronautics and Space Administration (NASA) Ames Research Center (ARC) is sponsoring deployment and testing of the Helicopter In-flight Tracking System (HITS) in a portion of the Gulf of Mexico offshore area. 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 its effectiveness as an aircraft surveillance system. Sensis Corporation is supplying, installing and maintaining the HITS ground system. This project is being performed in coordination with the Federal Aviation Administration (FAA) and local helicopter operators.

HITS is a dual-technology surveillance system. Gulf of Mexico Offshore Sector

The Gulf of Mexico low-altitude offshore airspace (Figure 1) has unique needs. Helicopter operations in support of gas and oil exploration and production account for the majority of traffic. There are between 5,000 and 9,000 flights each day (platform/platform and platform/shore), involving approximately 625 helicopters, 325 onshore heliports, and 2,000 offshore helidecks. Over 35,000 people work offshore at any given time, in what the U.S. Mineral Management Service considers the most important worldwide location for oil exploration.

Additionally, law enforcement agencies, the military, commercial fishing concerns, and recreational aviation operate in the offshore sector — primarily with fixed-wing aircraft. The majority of offshore operations are performed with very limited surveillance.

Aviation weather conditions in the Gulf can be severe. During the spring, summer, and fall, thunderstorms are the most frequent weather hazard. During winter, reduced hours of daylight, low ceilings, strong winds, and icing conditions may restrict operations. Hurricanes impose the most severe weather hazard, and typically necessitate one full evacuation of the offshore platforms each season.

Surveillance coverage in the Gulf offshore airspace is very limited, due to its inaccessibility and the low-altitude (less than 7,000 ft) trajectories flown by most traffic. Low-altitude coverage with systems that employ line-of-sight signal paths, as virtually all installed and planned systems do, requires a relatively large number of sensor sites. For surveillance in the Gulf, most of the sensors would have to be located on offshore platforms. Consequently, provision of coverage by Secondary Surveillance Radar (SSR), as is used over the U.S. mainland, is economically infeasible for low-altitude offshore surveillance. Installation of larger, heavier, and more costly primary (skin track) radar is even less viable.

Figure 1 Gulf of Mexico Offshore Sector [4]
Multilateration and ADS-B technologies are potential solutions, either separately or in combination, to the need for Gulf offshore sector surveillance. Earlier tests and analyses indicate that multilateration capabilities are comparable to those of SSR in many respects. Additionally, dual-technology multilateration/ADS-B ground stations are less costly, smaller, and lighter than SSR installations by substantial amounts.

The FAA has tested multilateration extensively for airport surface applications, and has included multilateration/ADS-B capabilities in the Airport Surface Detection Equipment - X (ASDE-X) system now being deployed. There is, however, limited experience with multilateration for tracking airborne aircraft. The HITS Test and Evaluation (T&E) project is a Government-conducted, structured, extended-duration test of multilateration surveillance of airborne targets.

The FAA Safe Flight 21 (SF-21) program is evaluating ADS-B capabilities for air-to-air operations as well as for terminal and surface air-to-ground operations. SF-21 tests have involved all three ADS-B data links under consideration by the FAA — Mode S extended squitter on 1090 MHz, Universal Asynchronous Transponder (UAT) on approximately 980 MHz (final frequency is not yet assigned), and VHF Data Link Mode 4 (VDL-4). SF-21 operational evaluations have been conducted at Wilmington, OH, and Louisville, KY, and future tests are scheduled at Memphis, TN. Additionally, the FAA has implemented an ADS-B system based on the UAT data link technology in Alaska.

The HITS T&E effort extends the SF-21 air-to-ground testing to the more challenging over-water environment. HITS uses the 1090 MHz radio frequency channel for both multilateration and ADS-B.

The HITS project follows a series of aviation activities in the Gulf. NASA has conducted studies addressing shortcomings in Gulf of Mexico airspace operations [1-3]. The Helicopter Safety Advisory Conference (HSAC), a voluntary organization of offshore exploration and production companies and their fleets, and for-hire fleets, has been addressing helicopter operations and safety in the Gulf since 1978. It is expected that HSAC and its members will participate in the HITS evaluation.

The Gulf of Mexico Working Group (GOMWG) was formed by the Air Transport Association, the FAA Southwest Region, and other entities, in early 1999. The GOMWG's primary focus is Gulf high-altitude airspace capacity limitations that would result from projected growth in traffic between the U.S. and Mexico, Central America, South America, and eventually Cuba. The GOMWG has generated a set of recommendations that focus, in the near term, on providing additional radar and communications capability to reduce coverage gaps in Gulf airspace [4]. The GOMWG recommendations also provide for some partial solutions, in the intermediate to long term, for low-altitude offshore users.

As a result of the GOMWG activity and FAA requirements development work over the past several years, the FAA initiated the Integrated Gulf of Mexico Project (IGOMP) Investment Analysis (IA) in September 2000. The investment analysis will lead to a decision on providing additional aircraft and weather surveillance capabilities, mounted on offshore platforms or buoys, for Gulf airspace. It is not anticipated that either the GOMWG or the IGOMP IA activities will adequately address the low-altitude flight following needs of offshore operations in the next few years.

**Project Activities and Objectives**

The primary activities of the HITS effort are (1) deployment of a dual-technology (multilateration and ADS-B) system that performs aircraft flight tracking; and (2) evaluation of its effectiveness, using SSR as the standard. While HITS will not provide complete coverage of offshore helicopter operating areas in the Gulf, it will cover an area that has sufficient size and traffic levels for an adequate evaluation of HITS capabilities. At the conclusion of the T&E period, the HITS equipment will either be removed or turned over to another organization (e.g., the FAA or offshore operators).

The objectives of the HITS evaluation are to:

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

During testing, HITS will track both (1) instrumented project aircraft flying specified patterns, and (2) target-of-opportunity aircraft, both low-altitude (primarily helicopters) and high-altitude (primarily air carriers). The instrumented project aircraft will carry a differential Global Positioning System (GPS) receiver, which will serve as the reference (“truth”) system. The ADS-B evaluation will necessarily be less extensive than the multilateration evaluation, because targets-of-opportunity will not be equipped with ADS-B transponders.

Controlled/instrumented testing will be performed in less than one month. Target-of-opportunity testing will be conducted over a six-month period, to provide an extended opportunity to observe deleterious events (e.g., target splits) that may occur infrequently. The evaluation criteria employed during this effort are derived from those for the ATCBI-6 SSR exclusively for this project, and are described in a separate paper [5]. Data collected from flight tracking, as well as system/equipment monitoring and calibration information, will be reduced and analyzed in accordance with procedures specifically developed for HITS.

**HITS Surveillance Overview**

Beacon multilateration surveillance, or multilateration for short, is the determination, on the ground, of an aircraft’s horizontal position based on the reception of transmissions from the aircraft transponder at three or more ground sites. The times-of-arrival (TOAs) for the same message are measured at the ground sites and are processed in one location to determine the aircraft position. Within an update interval, only one transponder message need be received to accurately determine an aircraft’s position. That is, multilateration is “monopulse” in the literal sense, although monopulse antennas and receivers are not used.

HITS functions with all civil transponders that transmit on the international standard secondary surveillance frequency of 1090 MHz (Table 1). Supported message formats include: (1) Air Traffic Control Radar Beacon System (ATCRBS) Modes A and C, (2) Mode S short and extended length messages, and (3) emerging ADS-B extended length Mode S message formats. HITS surveillance does not necessitate any changes to currently installed Mode A/C/S transponders.

HITS receivers operate with messages that are (1) elicited by a HITS ground station, (2) elicited by another entity (e.g., SSR or another aircraft’s Traffic alert and Collision Avoidance System [TCAS] unit), or (3) transmitted without being elicited (“squittered”). HITS interrogates ATCRBS-equipped aircraft several times each second, as such transponders do not squitter reliably.

For Mode S transponders, HITS utilizes the short-length Mode S identity (DF11) squitter, which is emitted once per second, as the principal multilateration signal source. HITS interrogates Mode S equipped aircraft if the number of received squitters is not sufficient. Mode S aircraft are also interrogated approximately once each 12 seconds to determine their altitude.

HITS ground stations simultaneously function as ADS-B sensor sites, facilitating the transition to that surveillance technology. ADS-B operation requires reception of an aircraft emission at only a single ground station. Aircraft position and velocity (as measured by a GPS receiver), tail number, and other information are obtained by decoding Mode S extended squitter messages.

**HITS Equipment**

Figure 2 shows the HITS ground equipment architecture. In simplest terms, the HITS infrastructure consists of (1) multiple Remote Units

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**Table 1 Selected HITS Receive Formats**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Primary Information</th>
<th>Squittered</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATCRBS Transponders</td>
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<td></td>
</tr>
<tr>
<td>Mode A</td>
<td>Beacon Code</td>
<td>No</td>
</tr>
<tr>
<td>Mode C</td>
<td>Barometric Code</td>
<td>No</td>
</tr>
<tr>
<td>Mode S Transponders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DF11</td>
<td>Mode S Identity</td>
<td>Yes</td>
</tr>
<tr>
<td>DF04</td>
<td>Baro Alt &amp; Mode S ID</td>
<td>No</td>
</tr>
<tr>
<td>DF05</td>
<td>ABC &amp; Mode S ID</td>
<td>No</td>
</tr>
<tr>
<td>ADS-B Transponder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DF17</td>
<td>Lat/Lon</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Not all supported formats are shown*
Remote Units

HITS has two types of RUs (Figure 3). Receive-Only (RO) units receive and decode transponder messages on 1090 MHz and apply a TOA stamp. Receive-Transmit (RT) units, in addition to decoding and time stamping received messages, also interrogate aircraft transponders on 1030 MHz.

The HITS design involves a total of 23 RUs, comprising 12 ROs and 11 RTs. Preliminary locations are shown in Figure 4. Nominal separation between adjacent RUs is 25 nautical miles. Each RU includes an antenna with either omni-directional azimuth coverage (for sites in the coverage area interior) or half-omni azimuth coverage (for sites on the periphery). The omni antenna model is approved for shipboard installation on Navy ships. The half-omni antenna model was developed for the ASDE-X program. By mounting the RU antennas 200 ft above the water surface, coverage is provided for aircraft above 100 ft in altitude.

HITS remote equipment includes five Reference Transponder (Refran) units that are colocated with selected RUs. The primary function of the Refran is to synchronize the RU clocks, a process which is necessary to ensure consistency of the TOA measurements used in the multilateration calculations. To enable synchronization of the RU network, the Refran sites must be selected so that...
(1) each RU is visible to one or more non-colocated Reftrans, 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 dual aircraft Mode S transponder transmitters. Each Reftran is assigned a unique Mode S code, and broadcasts a message containing that code on a fixed schedule. RU clock synchronization is accomplished by adjusting individual clocks so that the relative message reception times are consistent with the relative distances between a Reftran and its associated RUs.

Central Processing System

The HITS CPS receives decoded transponder messages and TOA stamps from all RUs over a commercial communications network. These data are passed to one of several Universal Input/Output (I/O) Modules. The Universal I/O Modules serve as interfaces to helicopter fleet operators desiring the HITS tracking data, as well as the interface between the RUs and other elements of the CPS. The Universal I/O Module places the RU data on a 10BaseT local area network for the Target Processor (TP).

The TP has three main functions. It must associate transponder messages from different RUs — i.e., determine which set of received messages are the result of the same aircraft transmission. Message association is straightforward for a Mode S transponder or an ATCRBS transponder in an aircraft operating under Instrument Flight Rules (IFR), because in these cases the message contains a unique aircraft identifier.

Association is more complex for aircraft with ATCRBS transponders operating under Visual Flight Rules (VFR), as many aircraft are assigned the same Mode A code. 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 TP function is performing multilateration calculations on a set of associated TOAs, to determine the aircraft horizontal position. (Aircraft altitude is determined by decoding transponder

Figure 4 HITS RU Locations South of Intracoastal City, LA (PRELIMINARY)
messages.) In addition to the measured TOAs, the multilateration calculations require the coordinates of the associated RUs; these are obtained by a GPS survey during HITS installation.

If three TOAs are available from an aircraft message, then an exact solution of the governing hyperbolic equations is available [6]. 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.

The third TP function is associating ADS-B messages from multiple RUs. After the association process is completed, only one ADS-B target report is generated.

Test Data Analysis System

Figure 5 shows the connectivity among the Sensis CPS, the Volpe Center Data Collection System (DCS) at INCY, and the Volpe Center Data Reduction and Analysis (DR&A) facility in Cambridge, MA. The DCS captures, in real time, target reports outputted by the CPS in All-purpose Structured EUROCONTROL Radar Information Exchange (ASTERIX) Type 10 format. The DCS will also collect information on the status of individual RUs, in the vendor’s format. These data will be sent to the Volpe Center via a T1 line, where they will be analyzed on a daily basis.

Data collected from the instrumented/controlled test flights and targets of opportunity, as well as system/equipment monitoring and calibration information, will be processed in accordance with the HITS DR&A Plan. For each of the defined evaluation criteria, the DR&A Plan provides: detailed descriptions of the data sources; test data processing procedures for multilateration and ADS-B target reports; and information on interpreting the results in determining the extent to which the HITS evaluation criteria have been satisfied.

Flight Test Activities

A minimum of two instrumented aircraft will be employed for the controlled and instrumented flight tests — the light fixed-wing Volpe Center aircraft (Piper Aztec) and a local (INCY) rotorcraft. Additionally, NASA Langley Research Center (Boeing 757) and FAA Technical Center (Boeing 727 or Convair 580) aircraft may participate in HITS testing.

Figure 6 illustrates the HITS airborne instrumentation suite, which includes:

- GPS receiver with integral differential correction capability, with an ARINC 429 bus interface for connection to a Mode S transponder;
- ADS-B Mode-S extended squitter transponder;
- Computer for data recording, control, and display functions; and
- VHF radio for voice communications between the aircraft and the HITS Operations Center, and between HITS aircraft operating in close proximity.

The controlled/instrumentation tests are in some ways analogous to flight checking a radar installation. The instrumentation provides a position reference during the controlled flight tests, enabling parameters such as accuracy and resolution to be evaluated. Some other parameters — e.g., update rate and coverage — will be evaluated using both controlled testing and targets of opportunity.

The target-of-opportunity tests are analogous to operating a radar “off-line” (i.e., without using the data to control aircraft) over an extended period of time, and observing its behavior. In addition to
providing data for evaluation of parameters such as update rate and coverage, the target-of-opportunity tests will be used to determine the nature, severity, and frequency of deleterious behavior by the HITS. By analogy with SSR, deleterious effects may include multipath-prone regions and target splits. The possibility exists that multilateration will exhibit deleterious effects not present in radar.

HITS will not provide a position reference for target-of-opportunity tests. In some cases, apparent deleterious behavior may be investigated by consulting the aircraft flight logs. In the case of high-altitude IFR traffic, FAA radar data will be consulted. Radar data may be obtained directly from the site involved or, at a lower update rate, from the Enhanced Traffic Management System (ETMS) at the Volpe Center. (The ETMS is the source of data used by the FAA Flow Control system.)

**Project Schedule**

HITS project duration is 14 months, from May 2001 to June 2002. The system will be designed and installed during May-September 2001. Acceptance testing will be conducted during October and November. Formal testing will be conducted December 2000 through May 2002. During June 2002, the equipment will either be removed or turned over to another organization for its operation.

**Summary**

The Gulf of Mexico low-altitude offshore sector has thousands of flights per day but little surveillance coverage. Under NASA ARC sponsorship, the HITS dual-technology (multilateration and ADS-B) system will be procured from and installed by Sensis Corporation. The Volpe Center will conduct structured tests, comparing HITS performance to the ATCBI-6 secondary surveillance radar requirements. Results will be available during the summer of 2002.
References