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FAA Satellite Navigation Product Teams

SatNav News

WAAS is Accepted

by Greg Thompson, GPS TAC/AND-730

Robert Eckel (left), Raytheon Company and Charlie Keegan, Associate Administrator for Research and Acquisitions (ARA-1)

The FAA accepted the Wide Area Augmentation System (WAAS) from prime contractor, Raytheon Company, on Friday, January 24th, eight months ahead of schedule. As members of the WAAS management team looked on, the WAAS contracting officer, Susan Eicher, officially signed the acceptance of the initial phase of WAAS from Raytheon Company. This moment was the culmination of many years of hard work as FAA moved toward the implementation of satellite navigation for instrument use.

The WAAS system is comprised of a network of ground-based stations that continually monitor the Global Positioning System (GPS). This network is able to compute corrections to GPS and broadcast this information over geostationary satellites to users across the country. With GPS, pilots can determine their position anywhere in the world, with very high accuracy. As much of a revolution as GPS already represents, the use of basic GPS does not meet the stringent requirements for the more strenuous phases of flight. For the first time, WAAS will enable the use of GPS for instrument approach across a majority of the national airspace. Upon commissioning, expected later this year, pilots will be able to use WAAS on a majority of the existing lateral navigation/vertical navigation (LNAV/VNAV) approaches. This is significant, giving WAAS an instant capability, with the existence of approximately 700 LNAV/VNAV approaches currently. For more information on available approaches, please see http://gps.faa.gov/CapHill/index.htm.

In this issue:

LAAS Contract Signed

The Federal Aviation Administration (FAA) awarded the Local Area Augmentation System (LAAS) contract to Honeywell International, Inc. of Minneapolis, MN. The first of three contract phases is valued at $16.7 million and provides for the software and hardware design of the Category I LAAS. Phase II and III total an additional $340 million and would cover the development and production of the Category I system. For more information, please see the FAA press release at http://www2.faa.gov/index.cfm/apa/1062?id=1737.

PASS Congratulates WAAS Program Office on Completion of Contractor Acceptance Inspection

WASHINGTON, DC – Michael D. Fanfalone, President of the Professional Airways Systems Specialists (PASS), congratulated the Wide Area Augmentation System (WAAS) program office for recently completing the WAAS contractor acceptance inspection.

"Completion of the contractor acceptance inspection means that WAAS maintenance will now transition from the contractor (Raytheon) to Airway Facilities employees," Fanfalone said. "It is a big step towards commissioning the system."

Fanfalone also expressed the need to resolve training and safety issues still surrounding the system. "The program office has come a long way, but there is still a lot to do before we get to commissioning – especially in regards to training and safety," he said. "We are confident that the program office will continue to work with our WAAS liaison, Claude Hammond, to resolve the remaining issues."

PASS represents more than 7,600 employees of the Airway Facilities division of the Federal Aviation Administration who install, maintain, support and certify air traffic control equipment.

WAAS Completes Hardware FCA/PCA

by Wally Peterson, GPS TAC/AND-730

The completion of the Wide Area Augmentation System (WAAS) Functional Configuration Audit (FCA) and Physical Configuration Audit (PCA) at the end of 2002, constituted a major milestone on the path to WAAS Contractor Acceptance Inspection (CAI) and commissioning. The hardware FCA, completed on October 28, 2002, was conducted at WAAS prime contractor Raytheon's facility in Fullerton, California. After completion of the FCA, the configuration audit team conducted detailed comparisons of the equipment to the formal drawings, as a part of the PCA. WAAS sites in California (Fullerton, Santa Paula, Palmdale, and San Diego) were visited as part of the PCA, conducted from October 29 through November 4. The successful completion of the hardware FCA/PCA was a major step supporting the achievement of CAI in January 2003.

Next Steps to WAAS Commissioning

by Mary Ann Davis, GPS TAC

The Wide Area Augmentation System (WAAS) is on track to be commissioned into the National Airspace System (NAS) later this year. With the successful achievement of the critical WAAS Contractor Acceptance Inspection (CAI) milestone in January, WAAS is now in the final stretch towards commissioning. Although WAAS has been in operation since 1999 and has been adopted by a myriad of users since that time, WAAS will not be authorized for certain aviation operations until commissioned. "Commissioning" is the process the Federal Aviation Administration (FAA) uses to define the point when a new system has been deemed safe and ready for incorporation into the NAS. During the commissioning process, a list of internal checks and balances in the form of an In-Service Review (ISR) must be successfully addressed for the system to receive the green light for commissioning. This commissioning deems the new system reliable for pilots who rely on its use in safety critical situations.

In addition to the completion of the ISR checklist complementary activities leading to commissioning and supporting the operational use of WAAS into the NAS are underway. The FAA is working to ensure the availability of procedures used in conjunction with WAAS. At commissioning, procedures will be available for approximately 700 runways. Also, internally, the FAA is working closely with air traffic controller and airway facility representatives, and other FAA personnel that will be closely involved with WAAS once it is commissioned. This coordination is important to prepare for a smooth transition to operational status within the FAA. There is also coordination with avionics manufacturers to help ensure WAAS aviation receivers are available on the market to coincide with commissioning. All these activities are critical for successful commissioning.

WAAS commissioning represents a key milestone for the aviation community, as it will offer a new level of navigation capability within the U.S.

WAAS Operations and Maintenance Training

by Christine Cave, GPS TAC

The first in a series of four WAAS Operations and Maintenance training sessions this year was completed in February and the last ended April 29, according to WAAS Operations and Maintenance team lead Jorge Boubion. He is one of the first operators trained who will run the WAAS after system commissioning.

Boubion said there is one team of seven operators on each coast, with one member in each group selected to serve as a team lead. The operators handle ordinary issues such as trouble-shooting, while the team leads offer their support, Boubion said. Team leads would generally handle administrative issues such as WAAS schedules and are assigned the System Administrator role, he said.

Wallace Finks (left) and Jorge Boubion at O&M console

There were four operator courses for fiscal year 2003 and an additional two courses planned for FY 2004 that are not yet scheduled, Boubion said. All of the Operator and Maintenance academy training for fiscal year 2003 will be completed in April. All Operators and Maintainers were also certified on the WAAS by running through procedures and passing practical certification exams, Boubion said. At the end of each program, operators have reviewed up to 95 percent of the anticipated responsibilities for the position, he said.

FAA Operations Support organization (AOS-240) used the software for their test bed system and used the Oklahoma system to test software, Boubion said. In addition, operators worked on AOS-240 operations testing and evaluation of the system, he said. These activities occupied much of the operators' time after they completed training, Boubion said.

For its WAAS operators, FAA looks for experience in navigational aids, a GPS background and operations background in either a Systems Operations Center (SOC) or an Operations Control Center (OCC). The three OCCs are located in San Diego, Kansas City and Atlanta. They monitor, control and coordinate for facilities under their domain, Boubion said. Each Air Route Traffic Control Center (ARTCC) and large Terminal Radar Approach Control (TRACON) has an SOC. Having that type of experience is a big plus because it means the operators can easily deal with daily FAA operations procedures, he said.

Jeffrey Jones, one of several Operations and Maintenance trainees, said the WAAS would be monitored 24 hours a day, seven days a week. Jones said the normal operations configuration would be formed with a

Controlling Operator on the Pacific side, called the Pacific Operations Control Center (POCC), with system monitoring taking place on the opposite coast. The system would also run vice versa, with one controlling operator at the National Operations Control Center (NOCC), while the POCC acts as monitor.

The WAAS Wide Area Network (WAN) is heavily based on networks comprised of subsystems, communication routers, switches and hubs. The Operations and Maintenance staff uses software called Netview, which is used to manage all of the networks.

Boubion said the operator's console is made up of four screens that show different parts of the network and performance of the system. Raytheon has added a control panel with specialized function buttons. Two screens list information about the network and one screen interprets the information into a visual image. The fourth screen is the message center processor (MCP), used to download data from the satellite providers when they execute satellite maneuvers. The information is then loaded into the WAAS so it knows the satellites' new positions.

Operator Lisa Skidmore said they are trained to monitor the WAAS system on a national basis and will call on maintainers when parts need to be replaced or repaired. Maintainers are identified for all 25 WAAS reference stations (WRS). Operators must take extra care because any actions they take can have a national impact on the WAAS service.

Jones says he's excited to be working with the WAAS program and taking part in the emerging technology of using GPS for satellite-based instead of ground-based landing systems. In Alaska for example, one out of every nine residents is a pilot, nearly six times the ratio in the Continental United States. Alaska stands to be a large user with the soon to be added benefits of WAAS. In the future, Jones says he sees many applications of satellite-based navigation enhancing people's lives. The accomplishments of Freeflight with its direct route flights and Capstone enhancing aviation safety in Alaska are current examples. We want the word to get out to advertise WAAS," said Jones.

Enroute WAAS navigation, starting in July, will provide LNAV/VNAV service. We believe it is possible to provide even better performance. That is a challenge I look forward to participating with," Jones said.

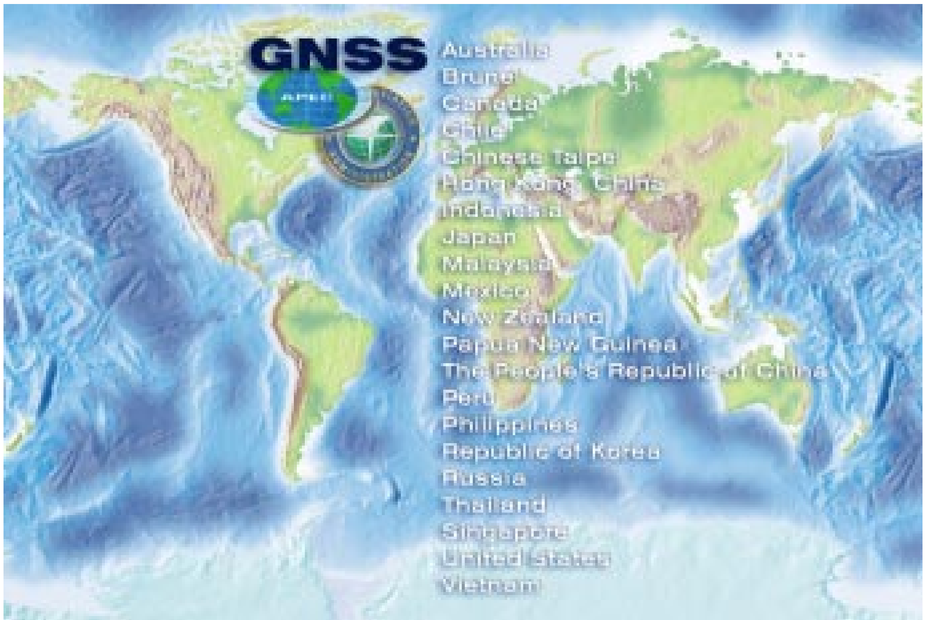
"One of the few problems WAAS is having right now is advertising, letting people know what it is and how it can be used," Boubion said. "It is considered a crawling baby now but in the future it will continue to improve in performance and grow in importance as the number of its users increase," he said. "We've got a team of good people and the system, while not yet complete, is technically challenging," he added.

"Operators will continue certain training procedures only available on the live WAAS system. That training will be completed before this summer's anticipated WAAS commissioning. We expect that by gaining experience on the live system we'll become proficient at fault isolation and other maintenance skills," Boubion said.

GNSS Cooperation in the Asia Pacific Economic Cooperation (APEC)

by Leah Moebius, International Research and Acquisitions Division/ASD-500

The FAA has been cooperating with nations in the Asia-Pacific region to adopt U.S. GPS technologies to achieve a seamless, interoperable air traffic control system that will provide significant safety and efficiency benefits for U.S. air carriers. To facilitate this cooperation, the FAA, through its membership and participation in the Asia Pacific Economic Cooperation (APEC) and the International Civil Aviation Organization (ICAO), is providing technical assistance and support to the region in the development of a common direction and general implementation path for a regional seamless satellite navigation capability.



What is APEC?

APEC was established in 1989 in response to the growing interdependence among Asia-Pacific economies. Begun as an informal dialogue group, APEC has since become the primary regional vehicle for promoting open trade and practical economic cooperation. Its goal is to advance Asia-Pacific economic dynamism and sense of community.

There are 21 nations participating in APEC. They are: Australia; Brunei; Canada; Indonesia; Japan; Republic of Korea; Malaysia; New Zealand; the Philippines; Singapore; Chinese Taipei; Thailand; the United States; the People's Republic of China; Hong Kong, China; Mexico; Papua New Guinea; Peru; Chile; Russia; and Vietnam. For more information on APEC, please see http://www.iot.gov.tw/apec_tptwg/.

Global Navigation Satellite System (GNSS) and APEC

Many of the countries within APEC have already stated their individual (and regional) commitment to implement GPS-based navigation technologies and some of these economies have begun or have already established a test bed. Some economies are beginning to utilize supplemental GNSS, while other economies are preparing for operational capability of their system. The underlying challenge that remains is to bring the individual efforts currently being planned and executed within the region into a single, cohesive effort to provide for a regional satellite navigation capability.

APEC and FAA's Role

FAA's Office of International Research and Acquisition, ASD-500, in concert with the Department of State, Department of Transportation, and the Transportation Security Administration, actively supports and participates in the APEC, and in particular, the Transportation Working Group (TPT-WG). The TPT-WG addresses safety and security across all modes of transportation including environmental considerations and the adoption of new technologies. ASD-500 is a member of APEC's Satellite Navigation and Communications Advisory Committee (SN&C) and is the Chair for its technical experts working group, the GNSS Implementation Team (GIT). The FAA's Wide Area Augmentation System (WAAS) Program Manager (AND-730) participates and is a member of the GIT, as well.

What is GIT?

The GIT's mission is to promote implementation of regional GNSS augmentation systems, to enhance inter-modal transportation, and recommend actions to be considered by the Advisory Committee in the Asia Pacific region. The GIT members include satellite navigation experts from the economies, representatives from ICAO, the International Air Transport Association (IATA), and the International Maritime Organization (IMO).

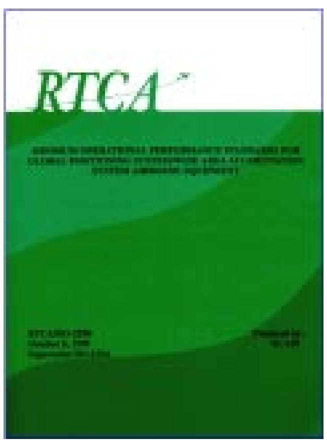
ASD-500's and AND-730's participation in the GIT has helped to establish the GIT's mission, goals, objectives and work program. The GIT experts are working to advance an overall regional approach to GNSS implementation for all modes of transportation, encourage cooperation that will enhance safety and efficiency, and expedite the implementation of GNSS within the economies. Based on this work program, the economies are working toward completing WGS-84 surveys, approving the use of basic GPS in their countries, developing and approving GPS procedures, and have started looking at steps to establish a regional test bed and conduct a regional feasibility study. For more information on GIT, please see http://www2.faa.gov/asd/international/apec.htm

ASD-500 and AND-730 will continue to work with other countries, economies and international organizations for the implementation of a seamless GNSS that transcends national boundaries and improves aviation safety and efficiency worldwide. As more countries begin establishing both Satellite Based Augmentation Systems (SBAS) and Ground Based Augmentation Systems (GBAS), there is a commonly recognized need to establish and maintain adequate cooperation/coordination among SBAS providers so their implementations become a more effective part of a seamless worldwide navigation solution. It is hoped that these cooperative efforts among SBAS providers will lead to improved service outside and in between the nominal service volumes of each SBAS provider.

WAAS Receivers

by Bob Beal, GPS TAC/AND-720

Now that we are getting close to Wide Area Augmentation System (WAAS) commissioning we are beginning to see increased activity from the avionics manufacturers. In December 2002, UPS Aviation Technologies (UPSAT) obtained certification approval under Technical Standard Order (TSO)-C145a for a WAAS Beta sensor; FreeFlight Systems obtained a similar certification in February. UPSAT has developed a full panel mount WAAS Gamma receiver and is obtaining certification approval under TSO-C146a. The company plans to start deliveries in May 2003.



There are three functional classes of WAAS receiver - Class Beta, Gamma, and Delta. Class Beta receivers generate WAAS-based position and integrity information, but do not have their own navigation function. These are certified under TSO-C145a and are typically used in conjunction with a flight management system or to support position dependent, non-navigation functions like Automatic Dependent Surveillance (ADS-B). A Class Gamma receiver is an integrated Beta sensor, navigation function, and database that provides a complete, standalone WAAS navigation capability. This is the typical "panel mount" receiver used by most general aviation aircraft and is certified under TSO-C146a. A Class Delta receiver provides guidance (deviations) only to a precision approach final (similar to Instrument Landing System (ILS)) and consists of a Class Beta sensor and navigation processor. The requisite database is typically resident in a flight management system and accessed by the Class Delta receiver. Because they have a navigation function, Class Delta receivers are also certified under TSO-C146a.

Within each functional class there are four operational classes. Class 1 receivers can be used for oceanic, enroute, departure, terminal, and non-precision approach operations. Class 2 receivers add the ability to fly Lateral Navigation/Vertical Navigation (LNAV/VNAV) approach procedures and Class 3 receivers add the ability to fly precision (LPV/Category I) approach procedures. Class 4 receivers provide navigation to a precision approach final and do not support other navigation functions.

FreeFlight Systems is a relatively new company, but has a long Global Positioning System (GPS) history having acquired Trimble Navigation's business and commuter products division in July 2001. Their TSO-C145a WAAS Beta sensor can simultaneously track 10 GPS satellites and two WAAS geostationary satellites and is being used in the Capstone II program. Capstone II is the FAA's free flight demonstration program being conducted in Alaska. In Capstone II, position information produced by the WAAS receiver is used by a flight management system produced by Chelton. In addition to their TSO-C145a receiver, FreeFlight Systems is developing a TSO-C146a Gamma 3 panel mount receiver and will be offering a TSO-C146a Gamma 2 WAAS upgrade for their existing 2101-series panel mount GPS receivers.

The UPSAT Beta sensor can simultaneously track up to 12 GPS satellites and three WAAS geostationary satellites. Its first application will be UPSAT's AT9000-series ADS-B Link and Display Processing Unit (LDPU). The LPDU is used in transport aircraft and is an integral part of UPSAT's surveillance and display system. With a 5 Hz position output rate and DO-178B level B software, UPSAT's Beta sensor is capable of meeting all Class 1, 2, 3, and 4 certification requirements.

The most exciting news is UPSAT's new Class Gamma receiver. It is the first panel mount WAAS receiver to hit the market

CNX80

and incorporates their WAAS Beta sensor. It will initially be offered as a Class 1 receiver and will soon be certified to support Class 2 LNAV/VNAV and Class 3 LPV approach procedures. The receiver, denoted the CNX80, not only supports WAAS, but also incorporates VHF communications, VHF Omnidirectional Range (VOR), and ILS with a moving map for situational awareness. The CNX80 is a formidable avionics package that should set the standard for the other WAAS receiver manufacturers.

Although these are the first WAAS receivers certified for aviation use, there are many other WAAS receivers on the market that can be purchased for non-safety applications.

LAAS CAT II/III Status Update

by Navin G. Mathur, GPS TAC/AND-710

The FAA's Local Area Augmentation System (LAAS) program office (AND-710) has actively started addressing Category II/III (CAT II/III) aspects of GPS-based navigation system development. The program office has proposed the development of the LAAS CAT II/III system in two phases. Phase one of the development will consist of the LAAS Ground Facility (LGF) utilizing GPS reception at both L1 and L2 (codeless or semi-codeless), while the airborne will use just the L1 (as they are using in the case of LAAS CAT-I architecture). Phase two will include the use of GPS transmission on the new civil frequency L5 (1176.45 MHz) along with L1 and L2 as used in phase one. Developments relevant to the second phase are highly dependent on the full operational capability schedule for L5 on the new satellites.

For the first phase of the development, some of the efforts initiated by the program office are in the following areas:

a. *RTCA Special Committee 159 (SC-159) Working Group 4 on development and update of Minimum Aviation System Performance Standards (MASPS) for LAAS, Minimum Operational Performance Standards (MOPS) for LAAS CAT II/III Airborne Equipment, and the LAAS CAT II/III Interface Control Document (ICD).*
b. *Internal R&D to define the CAT II/III LAAS Ground Facility (LGF) architecture.*

The aspects of CAT-II/III addressed at the RTCA SC-159 concerns updating the CAT II/III integrity and continuity allocations between air and the ground systems. This task is accomplished as a part of broader update of the LAAS Minimum Aviation System Performance Standards (MASPS, RTCA/DO-245).

The program office Key Technical Advisors (KTA) is pursuing a systematic approach to developing the required architecture for the CAT II/III LGF. The most common denominator for the development of the LAAS ground system architecture is to develop all relevant threats - such as radio frequency interference or satellite signal irregularity - and the associated threat models. Mitigation for each threat will transpire a minimum acceptable architecture for the CAT II/III LGF. Another natural constraint is that the designed system has to be backward compatible to the CAT-I users (such as use of carrier smoothed code based corrections).

The final CAT II/III will have high dependence on the value of Vertical Alert Limit (VAL) that will be selected for CAT II/III. The choice of VAL depends on the philosophy of LAAS being ILS-look-alike v/s LAAS being linear system (in terms of error divergence from the threshold). Presently, the RTCA has specified VAL for CAT II/III at 5.3 meters in the LAAS MASPS, which, some argue, may be too stringent a requirement for CAT II/III. RTCA is presently coordinating a higher value for VAL (close to 10 meters) for CAT II/III LAAS with the international aviation community.

Although the definitions of threats and development of their associated threat models are preliminary, there are a few system components and mitigation strategies that are considered by the program office as an upgrade to the existing LAAS architectures. Some of the components / mitigation strategies under consideration are:

a. *Airborne Pseudolites (APL) for availability and interference robustness.*
b. *Deeply coupled and tightly coupled integration with inertial system for interference robustness and other continuity benefits.*
c. *Position Domain Monitor (PDM) for enhanced ephemeris, ionospheric, and other ground error monitoring.*
d. *Use of Carrier Phase measurement alone below 500 feet of altitude to enhance continuity and availability.*

In anticipation for using any of the above mentioned mitigation strategy, the program office has also initiated the following studies:

a. *APL-Interference-Study to address some concerns of APL interference to the GPS reception.*
b. *L2-Interference-Study to study effect of unintentional interference on codeless L2 reception in an airport environment.*

Further development plans for CAT II/III are pending the Joint Resources Council (JRC) decision in FY 04.

Complex LAAS Procedures

by Bob Beal, GPS TAC/AND-720

In April 2002, the FAA hosted a meeting with the Local Area Augmentation System (LAAS) Satellite Navigation Users' Group. That meeting was the catalyst for a series of follow-on meetings chaired by AND-720 to define the capabilities and the anticipated operational benefits users expect from the LAAS system. Having accomplished these goals, AND-720 is now working with the airports that have been selected to receive the initial LAAS systems to develop procedures that take advantage of LAAS's extremely accurate navigation, integrity, coverage, and flexibility to support complex terminal area operations. These procedures will not be limited to LAAS, but can be flown by any aircraft that can meet the requisite navigation requirements. The Required Navigation Program (RNP) office is developing the generic navigation requirements.

Meetings with the LAAS users in Memphis and Chicago revealed two fundamental capabilities that LAAS should support. The first is complex procedures. The second is precision approach Categories II and III. The LAAS program office is working on plans to develop a Category II and III approach capability. The ability of LAAS to support complex procedures is one of the capabilities identified in the LAAS Operational Concept; however, complex procedures are not part of the initial-LAAS baseline program plan. AND-720 has subsequently developed a plan for implementing complex procedures in parallel with the baseline LAAS development program. LAAS commissioning is not tied to the commissioning of complex procedures, but the complex procedure development process can meet the LAAS commissioning date.

Some of the benefits of LAAS that were identified by the users when compared to the Instrument Landing System (the system LAAS is designed to replace) include the ability of LAAS to:

- ✔ Support complex terminal area procedures (arrivals, approaches, departures, and missed approaches)
- ✔ Implement multiple, segmented, or variable glide-paths
- ✔ Support extended arrival procedures
- ✔ Reduce air traffic controller workload
- ✔ Support approaches at multiple runway ends using a single LAAS installation
- ✔ Change or create approach procedures without infrastructure changes
- ✔ Support Required Navigation Performance (RNP) operations [linear instead of angular (ILS-like) guidance]
- ✔ Support adjacent airport operations; that is, the ability to use a LAAS system installed at one airport to fly approaches at a nearby airport
- ✔ Expand the use of approaches to closely spaced parallel runways
- ✔ Support aircraft surface movement applications
- ✔ Improve terminal area surveillance through improved navigation accuracies
- ✔ Support runway incursion avoidance systems

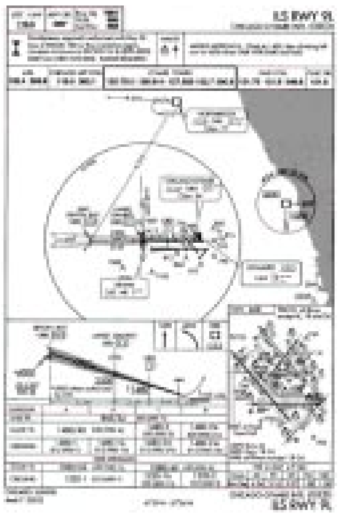


Figure 1

Other LAAS benefits include the ability to achieve consistent, accurate, repeatable performance when compared with the lack of standardization inherent in flight management systems. Furthermore, LAAS does not need an in-aircraft procedure database since LAAS procedures are data-linked to the aircraft by the LAAS ground facility.

AND-720 has initiated the complex procedure development process at the six airports initially scheduled to receive LAAS - Juneau, Phoenix, Chicago, Memphis, Houston, and Seattle. Although the process is just beginning, potential benefits are already emerging. Chicago uses a triple convergent approach procedure to simultaneously feed arriving aircraft to three runway ends (9-Left, 9-Right, and 4-Right) as shown in Figure 1. The arrivals to runway 9-Left require a series of vectors from the air traffic controller. In addition, the aircraft must be able to see the airport and the aircraft on which they are to take interval, which requires visual meteorological conditions (VMC) exceeding the normal VMC conditions of 1000-foot ceiling and three-mile visibility.

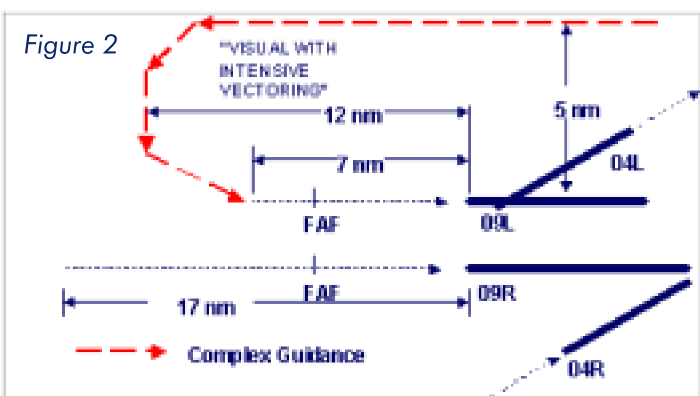


Figure 2

New-guided procedures for Chicago could replace the vectored arrival with a single complex procedure using a descending Radius-to-Fix (RF) leg (i.e., a curved segment). Figure 2 illustrates the existing vectored procedure to runway 9-left and Figure 3 illustrates the replacement RF procedure. The RF procedure can alleviate some of the controller's workload since the controller will be able to issue a single clearance that will

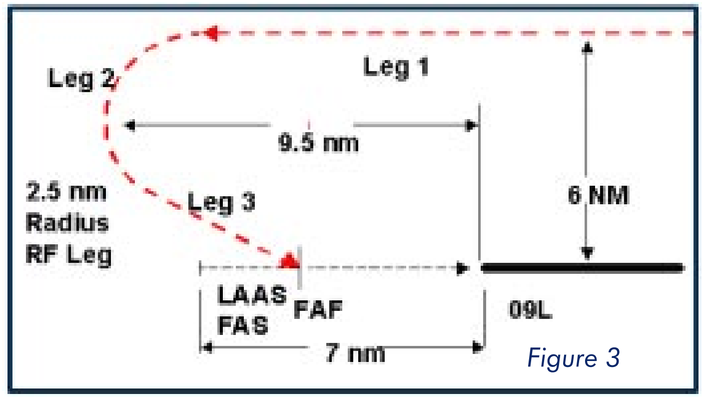


Figure 3

allow the aircraft to execute the entire procedure. The air traffic controller must still verify that the aircraft has the airport and the aircraft on which it is to take interval in sight, but will not have to give vectored guidance. Once the descending RF procedure is in place, other potential improvements will be evaluated including reducing aircraft separation requirements (taking advantage of linear RNP guidance), allowing the procedure to be executed under lower visibility and ceiling conditions, and eventually allowing the procedure to be conducted under Instrument Meteorological Conditions (IMC). The ability of LAAS to use linear and angular navigation to meet very tight RNP requirements anywhere within the LAAS service volume (typically within 20 NM of the airport) enables LAAS to support complex procedures that can not be supported by angular-only systems like ILS. One of the challenges to implementing a procedure like this for Chicago is the missed approach considerations that result when multiple aircraft arrive and depart at the same time. However, if the procedure can be implemented for Chicago, it can be adapted to similar arrival conditions at other airports.

What Are We Doing About GPS Interference?

by Paul Wagoner GPS TAC/AND-720

Yes, it's a weak signal - about the strength of a 25-watt light bulb at 10,000 miles. But let's look at the record. What has been our experience with GPS interference after it was authorized for navigation in 1994? Well, we've had just 12 interference events that resulted in an investigation by FAA Spectrum (they're the folks responsible for protecting the frequencies.) Five of the 12 investigations resulted in finding actual interference from Department of Defense (DoD)-related activities.

Interference Reports
1995-2002

Aviation	48
Non-Aviation	100
TOTAL	*148*
Number Investigated by FAA Spectrum	12

Seven investigations found no evidence of interference. There were 36 other pilot reports but nearly all of those were explained by improper use of the GPS equipment, multi-path, aircraft body shielding, along with some reports that simply could not be duplicated. It should also be noted that receiver manufacturers had some problems with their early production receivers.

So what's the magnitude of the problem? The formal GPS risk and threat assessments conducted by reputable organizations indicate that unintentional interference can be readily dealt with. However, the potential for intentional interference from hackers, crackers or terrorists will be directly measured against our dependence on GPS. For GPS to be a target there needs to be a payoff for the perpetrator. As long as we have fail-safe backup methods to minimize the impact, the intentional jammer will not likely target us. If the U.S. develops a rapid reacting interference locating capability and a responsive multi-government law enforcement team, the need for backup will be significantly lessened. In addition, with improved air traffic control procedures and increased aircraft equipped with low-cost inertial measurement units, the impact of interference will be reduced even more.

FAA Interference Locating Systems

SYSTEM	NOW	WAAS IOC	LAAS IOC
RFI Vans	10	10	10
Portables	15	29	29
Handhelds	150	250	250
Flight Inspection Aircraft	13	15	30

FAA and the Department of Transportation (DOT) have been working the backup issue for years and are considering the report from a Task Force that was formed in December 2001 to determine the systems/methods that will drive future navigation budgets. The Secretary of Transportation will address the Task Force recommendations in the very near future and his decision will be reflected in the next edition of the Federal Radio navigation plan (FRP).

Let's look at the ongoing efforts by the FAA for meeting these issues head-on. The FAA has unilaterally developed a suite of interference locating systems that are spread throughout the National Airspace System (NAS). Not quite all of the required systems have been fielded. But the funding provided in FY03 will put into place in each of the nine FAA Regions the following systems: One Radio Frequency Interference (RFI) Van, Two Portable Locating Systems, and 16 handheld computers. There are also spares at the FAA Technical Center and at the National Operations Control Center (NOCC).

In addition, there are 13 Flight Inspection aircraft, which operate from airports in Anchorage, AK, Sacramento, CA, Oklahoma City, OK, Battle Creek, MI, and Fulton County, GA, which have been equipped with locating systems and can react quickly to interference reports. All 30 Flight Inspection aircraft will be upgraded with locating capability over the next few years. Our goal was to have 15 aircraft available when the Wide Area Augmentation System (WAAS) is commissioned. We have the equipment and the trained personnel available to track down a jammer.

Flight Inspection Aircraft Interference Locating System

What about mitigation, e.g., the jammer operator who refuses to terminate an unlawful emission? The FAA Spectrum office is meeting monthly with the Federal Communications Commission (FCC), the Federal Bureau of Investigation (FBI) and in the near future, the Homeland Security Department to promulgate a memorandum of agreement that establishes the support to be provided by each agency when a suspected hostile jammer is identified.

Portable Interference Location System

FAA has also funded a two-part evaluation of the effects of GPS interference in the enroute and the terminal environment. The enroute evaluation was conducted in November 2002 by controllers from the Jacksonville ARTCC who went to the FAA Technical Center and performed the simulation. The results of this phase, due to be published in mid 2003, along with the terminal evaluation to be conducted in the fall of 2003 will be used to formulate the future navigation aid architecture.

The Satellite Operational Implementation Team (SOIT) Interference Working Group (IWG) has been active in identifying the requirements for interference detecting, reporting, locating and mitigating. The SOIT was inactivated in March 2003 but the Interference Working Group will continue to function under the GPS Operational Implementation Working Group (GOIWG). They have facilitated the update of FAA directives, training, and procedures and have been the catalyst behind the development of Mission Need Statement # 338 for spectrum protection that was approved by the FAA Joint Resources Council in June 2002.

So, are we satisfied?

No, not until there is a rapid reaction team that can respond to an interference event, 24/7, and process it step-by-step through the investigative and, if necessary, the law enforcement process. The cooperation and support of the FCC and the FBI may be necessary in case of a non-cooperative interferer. GPS interference protection will continue to be a high priority within the Agency so that pilots can depend on GPS navigation for enroute, approach and terminal operations.

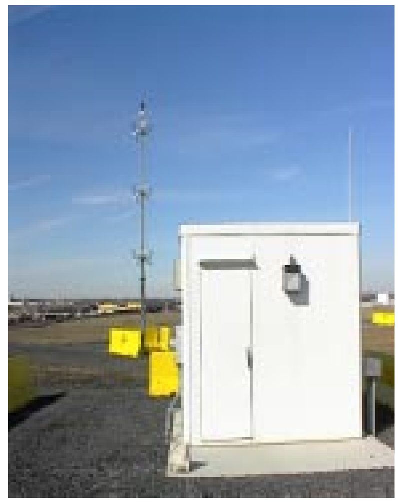
LAAS Siting

by Gregory Clark, GPS TAC/AND-710

Reference Receiver Antenna

Unlike other NAVAIDS currently installed at airports, the LAAS system will have reduced siting constraints when compared to existing terrestrial navigation aids, such as the Instrument Landing System (ILS), the VHF Omnidirectional Range (VOR), and others that have restrictive siting requirements. LAAS is a distributed, modular system made up of the VHF Data Broadcast (VDB) antenna, a Reference Receiver Antenna group (RRA) and a LAAS Ground Facility (LGF) shelter, which houses the processing and transmitting equipment. LAAS equipment has the potential to be sited based on an airport's existing topography without alterations to existing surroundings or the acquisition of additional real estate. Due to the modularity of the system, there is potential to add components to mitigate site-specific issues that would impact system level performance.

Although LAAS has reduced siting constraints, siting criteria would have to be established to determine object clear zones (both transient and stationary) for the RRA and the VDB antenna. Separation requirements must be established to determine minimum distances between RRA to prevent correlated errors. Phase center heights of the antennas would also have to be established for the best coverage for the VDB antenna. The RRA environment would also have to be evaluated for interference to minimize pseudorange measurement errors and minimize ó $_{pr-gnd}$ (the standard deviation of a normal distribution associated with the signal in space contribution of the pseudorange error due to the conditions on the ground).



VDB antenna and housing

The LAAS Program Office has been instrumental in developing criteria for siting that will be in place once the system is ready for implementation. One of the key elements in developing siting criteria for the LAAS has been the formation of the LAAS Siting Working Group (SWG). The group was formed in April 2000, and is made up of a diverse group of engineers with backgrounds in siting, installation, system engineering, spectrum management, and university support. The SWG has been chaired by the FAA Technical Center, which played a key role in developing the LAAS Siting Criteria Document. The Siting Criteria Document was developed to provide guidance to a siting engineer selecting an LGF site at a given airport. The document looks at only siting of the LGF; i.e., other documentation will be developed to provide guidance for system installation.

The LAAS Ground Facility is flexible with regard to siting and installation. However, siting would be a key component to achieving system level performance. Poor siting could impact the LGF's ability to receive satellite-ranging signals. The LGF ranging signals are used to compute pseudorange measurement with acceptable error, to perform integrity functions, and to broadcast corrections.

The site survey team is required to look at the initial siting of the LGF through a map/paper study to determine potential locations. From this point, the group must determine what is feasible by performing a preliminary site inspection and analysis. Finally, a detailed site survey would be performed based on preliminary site inspection and analysis to include (not limited to) a horizon profile, GPS data collection, VDB data collection, and interference data collection. Data received from the site survey would be used for the final site selection process.

The site survey team is required to provide potential candidate sites (including collected survey data) in order to install the LGF equipment. The FAA plans to use tools, which include math models developed by Ohio University, to determine the best installation location. The tools would be used to evaluate the prospective VDB and RRA sites. Tools that are being developed include multipath, propagation and availability models.

The SWG has developed a draft Siting Criteria document, which the PO will provide to the LAAS development contractor as GFI. The development contractor will use the supplied draft Siting Criteria to aid in the development of Contractor's Siting Plan. The FAA plans to develop a LAAS Siting Handbook and the siting handbook will culminate into a final FAA LAAS Siting Order.

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