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FAA Satellite Navigation Product Teams

SatNav News

LAAS Benefits Analysis

by Kristi Foster, GPS TAC/ATO-W Navigation Services

The FAA has contracted with IBM Business Consulting Services to provide an independent analysis that estimates the benefits attributable to the Local Area Augmentation System (LAAS) beyond those provided by existing and planned navigation services. The benefits analysis will provide information to support FAA executives in decisions regarding LAAS development and deployment, and airlines and other industry participants in decisions to deploy and equip with LAAS. The benefits analysis will establish a baseline for quantifying the overall value that LAAS adds to the National Airspace System, and provide a fact-based account of the potential benefits of LAAS capabilities. The benefits analysis time horizon is 20 years (2009 – 2028).

The LAAS benefits analysis scope includes the potential users of LAAS as major and regional air carriers, cargo operators, corporate operators, and operators of general aviation aircraft (Alaska only). The applications of LAAS are as a precision guidance system and a complement to other systems. LAAS operations include precision approach and landing guidance, precision takeoff and departure guidance, terminal area navigation, and surface navigation. The 120 airports included in the benefits analysis include airports associated with likely LAAS users, low rate initial production (LRIP) sites, FAA Operational Evolution Plan (OEP) airports, current Category (CAT) II/III ILS airports, and qualifier CAT II/IIII airports.

The LAAS benefits analysis team was formed to determine the baseline and assumptions for IBM's benefits assessment. The benefits team consists of key FAA offices and industry participants from MITRE, and IBM. The benefits analysis is not a formal business case, as IBM is only examining the benefits of LAAS. ASD will complete the cost portion. Initially, ASD completed an independent rough-order-of-magnitude, which concluded that the FAA benefits of LAAS do not outweigh the costs associated with the program.

IBM and the FAA collaboratively developed a list of assumptions for IBM to use as a basis for their analysis. In particular, it is important to note that IBM was instructed to perform their analysis for two different scenarios: 1) assuming 0 percent WAAS equipage; and 2) assuming 100 percent WAAS equipage, for all types of operators. These scenarios were chosen to place bounds around the uncertainty associated with future decisions on WAAS

In this issue:

The **SATNAV News** is produced by the Navigation Services (ATO-W) branch of the Federal Aviation Administration (FAA). This newsletter provides information on the Wide Area Augmentation System (WAAS) and the Local Area Augmentation System (LAAS), and initiatives associated with the implementation of satellite navigation into the National Airspace System (NAS).

equipage. Additionally, during the course of the analysis, IBM intends to provide a sensitivity analysis on those assumptions with high uncertainty.

IBM will identify, describe, and quantify the efficiency and safety benefits of LAAS CAT I and CAT II/III straight-in approaches, complex procedures, and the use of LAAS as an enabler of other technologies.

To date, the following milestones have been accomplished for the LAAS benefits analysis:

- ✔ *The establishment of the navigation capabilities baseline was completed in November 2003*
- ✔ *A list of incremental capabilities that LAAS can provide above the current baseline was completed in December 2003*
- ✔ *IBM presented an analysis of preliminary findings of the potential incremental benefits from LAAS in February 2004*

IBM has been working with representatives from industry and several airlines during the development of the navigation baseline, LAAS capabilities, and preliminary findings. IBM is currently consulting with five airlines and five airports that have previously demonstrated support for the LAAS program to validate analysis findings performed to date, and to understand current operations and how LAAS may provide additional benefit to these operations. The objective is to use data gathered during these visits to verify/validate the methodology and mathematical formula IBM is currently using to quantify benefits of LAAS. The airline analysis will encompass airports relative to that particular airline's operations. The expected outcome is to make the airlines and airports aware of the potential LAAS benefits to their specific operation.
IBM will provide an update to the preliminary findings in June 2004. The final LAAS Benefits Analysis Report is expected by October 2004.

This work continues to be an important milestone for the LAAS program and is an essential part for the decision making on how to proceed with the development and implementation of LAAS technology.

FAA LAAS and European GBAS Working Group Meeting

bv Dieter Guenter, GPS TAC/ATO-W Navigation Services

In April, representatives from the Federal Aviation Administration (FAA) Local Area Augmentation System (LAAS) team participated in a Ground Based Augmentation System (GBAS) working group meeting chaired by EUROCONTROL at the Eurocontrol Technical Unit in Bretigny, France. This European GBAS working group was established several years ago as forum for the development of GBAS technology, for the evaluation of GBAS benefits, and for the development of a GBAS implementation strategy for Europe. In 2003, GBAS working group members visited FAA headquarters and the FAA William J. Hughes Technical Center in Atlantic City, New Jersey to exchange information and to discuss approaches for cooperation. Recently, as a result of the FAA decision earlier this year to move LAAS to a research and development program, European service providers were prompted to re-evaluate their GBAS activities. Representatives from the FAA's LAAS team agreed to provide a presentation on current LAAS plans and activities at the April GBAS meeting to support Europe in their re-evaluation of these plans.

Topics discussed included:

- ***a.*** *Current GBAS Category I activities of individual service providers*
- ***b.*** *Presentation and discussion of LAAS Category I technical issues*
- ***c.*** *Comparison of tools and processes*
- ***d.*** *Presentation and discussion of Category II/III architectures/strategies*
- ***e.*** *Presentation and comparison of the EURONCONTROL GBAS business case and FAA LAAS benefit case activities*
- ***f.*** *Discussion of areas of cooperation.*

Overall, it was agreed that the GBAS working group and the FAA LAAS team should continue their close coordination and develop more detailed areas of cooperation. Many of the present service providers have their national GBAS programs aligned with the FAA program schedule and were planning on LAAS being available in 2006. Changes in the FAA program will have an impact on European implementation efforts, so close coordination between the U.S. and Europe is important. National representatives will be assessing the impact of recent FAA program decisions on their national GBAS plans. Also, it was agreed to coordinate more closely on business case and benefits assessment methodologies and to exchange associated information. The next GBAS meeting is planned for the end of the year, possibly in November, and is considered an important meeting as future national and international GBAS plans/options will be discussed.

WAAS Performance Improvements

by Ed Sigler, GPS TAC/ATO-W Navigation Services

The commissioning of the Federal Aviation Administration's Wide Area Augmentation System (WAAS) in July 2003 provides aviation users with safe and reliable satellite-based navigation for en-route and vertically guided landing phases of flight. However, the FAA is not resting on the laurels of achievement. Instead, the FAA is actively designing and developing towards Full Operational Capability (FOC). These performance improvements will be incrementally inserted into the operational WAAS starting in early 2004. Planned performance improvements to the WAAS will cover the breadth of the program and are intended to increase the availability and reliability of the lateral navigation/vertical navigation, lateral precision with vertical guidance, and eventually global navigation satellite system landing system services throughout the national airspace system.

As the WAAS is an operational safety-of-life navigation system, all performance improvements are thoroughly analyzed and tested prior to introduction into the operational system. To further minimize risk, performance improvements are segmented into separate 'builds' that incrementally contribute to the WAAS performance goals. Individual builds provide for manageability and minimize operational system impacts.

The initial performance build, which began earlier this year, will accomplish two goals: the replacement of selected equipment to increase system reliability and to demonstrate the internal FAA processes and procedures for upgrading the WAAS without performance degradation or safety impacts. Additional performance builds will incrementally add enhanced ground processing algorithms that will provide 1) reduced error bounding, 2) increased WAAS service availability, and 3) improved performance in geomagnetic storms. Another performance build will provide increased bandwidth, reliability, and security for the WAAS backbone network. This network connects the WAAS ground receiving, processing, and transmission elements. The addition of WAAS reference stations in Alaska, Canada, and Mexico will work in conjunction with the algorithm and network performance builds to greatly increase the WAAS service area in Alaska and provide for increased WAAS availability in the Northeast and Southwest United States.

Performance builds will also provide for improved human engineering of WAAS consoles for the FAA's WAAS operators and maintainers via improved operator monitoring and control screens, improved fault isolation procedures, and increased reliability of equipment.

Finally, significant performance improvements to the WAAS will be realized with the addition of two new geostationary satellites transmitting the WAAS corrections and integrity signal. Users generally can only see one geostationary satellite with our current geostationary satellite constellation. The two new replacement geostationary satellites will significantly increase the availability of the WAAS by providing users with two satellites in view at all times over most of the WAAS service area. The location of these satellites will also result in improved WAAS coverage within Alaska. These satellites and supporting satellite ground equipment are expected to be integrated into the operational WAAS via separate performance builds in 2006.

WAAS Program Rebaselined

by Greg Thompson, GPS TAC/ATO-W Navigation Services

The WAAS Program recently completed a rebaseline effort that culminated in approval of continued WAAS development by the FAA's Joint Resource Council (JRC) on May 3, 2004.

The last approved acquisition program baseline (APB) for WAAS was developed in 1999. Much of the information in the document was out of date and needed to be revised to accurately reflect the current program direction. During FY2005 budgetary formulation, the Office of Management and Budget (OMB) requested that the WAAS program update this baseline.

Every part of the old baseline was reworked. This included the system cost, schedule, performance, and benefits. While developing the cost and schedule data, the decision was made to extend the program baseline out until the year 2028. At first glance, the overall cost seemed to go up. However, when comparing the new baseline to the old baseline for the same time period, the program costs actually went down approximately $500 million.

One of the good news stories of this whole effort was the program benefit portion. An independent analysis of the program benefits determined that WAAS provided a positive cost benefit ratio when considering benefits to aviation only. When considering the recent explosion of WAAS receivers for non-aviation use, the benefits provided grows enormously. Some estimates place the benefits derived from precision agriculture at over a billion dollars!

The new baseline covers development of WAAS to full GNSS Landing System (GLS) capability, providing 200 foot minimums and three-quarter mile visibility through the use of dual GPS frequencies. Implementation of GLS will be concurrent with GPS modernization and is expected to occur in the 2013 timeframe.

International WAAS Closer to Operational Implementation

by Mary Ann Davis, GPS TAC/ATO-W Navigation Services

The FAA is working with Canada and Mexico to extend WAAS service throughout North America. Work on this initiative has been underway for several years, concurrent with WAAS development. Now this extended capability is one more step closer to reality. On May 7th, a bilateral international agreement was signed between the U.S. and Canada outlining cooperative efforts to extend WAAS service into Canada. A similar agreement between the U.S. and Mexico is currently pending and expected to receive final signatures shortly.

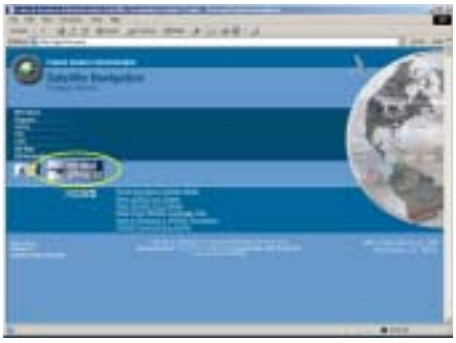
These agreements outline the cooperative activities necessary to successfully extend WAAS service to Canada and Mexico. Under the U.S./Canadian agreement, the FAA will provide four WAAS reference stations (WRS) to NAV CANADA for installation in Winnipeg, Goose Bay, Gander, and Iqaluit or a mutually agreed to alternate site. These stations will then be integrated into the operational WAAS. When this is complete, Canada will gain WAAS operational capability for a significant portion of its territories. Likewise, the U.S. will receive boosted WAAS coverage for the northern portion of the U.S. The pending agreement between the U.S. and Mexico is very similar. The FAA plans to provide five WRSs to Mexico that will then be integrated into the WAAS. These stations are planned for installation in Mexico City, Merida, Puerto Vallarta, La Paz, and Tapachula. When these are integrated into the WAAS, Mexico will gain WAAS capability in its airspace and the U.S. will gain better WAAS coverage at its southern borders. The reference stations for both Canada and Mexico will be integrated into the WAAS in two phases. The first of these phases is expected to be complete in 2006. The bilateral agreements with Canada and Mexico are very significant as they secure the foundation for WAAS service beyond U.S. borders.

GPS/WAAS Procedures Data Available on the Web

by Mary Ann Davis, GPS TAC/ATO-W Navigation Services

Did you know that there are over 2500 RNAV approach procedures that can be used with WAAS? Eleven of these approaches are the new LPV approaches which can support minimums as low as 250 feet and 3/4 mile (without approach lights) and more are being added with each procedure publication cycle! Also, did you know that there over 1400 GPS stand-alone procedures that can be flown using WAAS? Where can you find more information on these approach procedures? You can find this information on the new GPS/WAAS Approaches page on the gps.faa.gov website.

This new page contains a listing of all currently available Lateral Navigation (LNAV) approaches, Lateral Navigation/Vertical Navigation (LNAV/VNAV) approaches, LPV (formerly Precision Lateral with Vertical) approaches, and GPS stand-alone. The information for these approaches is contained in



spreadsheets that can be easily sorted by state, airport, approach type, and Part 139 vs. Non-Part 139. This information is updated on the website approximately every 56 days in conjunction with the procedure publication cycle. Other information contained in this page includes future procedure publication dates and a link to the FAA's instrument flight procedures quarterly production schedule. You can find the GPS/WAAS Approaches page by visiting the gps.faa.gov website. A button for the GPS/WAAS Approaches page is available from the front page.

We hope you find this information helpful. Although this information on the website is updated on a regular basis, there may be official changes that are put into effect for these approaches prior to the information being updated on the website. As a result, we ask that you please refer to the latest approach plates and official flight publication material, and not this website, when making your flight plans.

WAAS BETA MMR Contract Signed with Rockwell

Compiled from information received from manufacturer

The FAA Aviation Systems Standards (AVN) organization and Rockwell-Collins have entered into a contract for the WAAS Beta version Multi-Mode Receiver (MMR) that allows for WAAS instrument procedure flight inspection as early as January 2005.

The MMR, a GNLU-930, will be fully certified (black label) and compliant with the WAAS MOPS, RTCA-229C. This Beta version consists of a GPS/WAAS sensor that provides position and integrity data to an integrated navigation system such as an FMS. The MMR uses Fault Detection and Exclusion (FDE) to provide integrity in the absence of the WAAS signal.

Rockwell is on track to deliver the first MMR to AVN by November for modification into the Lear 60 fleet. According to AVN, flight inspection of WAAS procedures (to include LPV approaches) could start by the beginning of next year.

AVN's contract with Rockwell could be supplemented for developing the MMR's Delta version that provides an "ILS look-alike" feature.

Formation of the IPCT

by Steve Albers, GPS TAC/ATO-W Navigation Services

The group formerly known as the Satellite Procedures Implementation Team (SPIT) met April 14-15, 2004 in Arlington, VA. The purpose of the meeting was to discuss reactivating the group and to decide on the focus for future work. It was decided that the new team name would be the Instrument Procedures Coordinating Team (IPCT).

The IPCT is intended to be a "problem identifying" group and not a "problem solving" group whose focus will be on the technical aspects of procedure production and implementation. The acting chairperson of the group is Harry Hodges of AFS-420.

The IPCT is currently drafting a charter and determining its core membership. A final decision on what organization will sponsor the group has yet to be made, but the charter will be approved by the FAA ATO organization. Unless technical issues arise requiring more frequent meetings, the IPCT plans to meet quarterly, with the next meeting planned for July 14-15, 2004 in Arlington, VA. Topics to be discussed include a 34:1 survey issues status report from AFS-420, review of a strawman issue paper on procedure database coding, WAAS receiver issues, and a briefing on the LAAS Equipage and Avionics Pathfinder (LEAP) activities.

Survey Pilot Program - the Teenage Years

by Tim Roe, GPS TAC/ATO-W Navigation Services

The Survey Pilot Program is maturing from infancy into its teenage years. As with any teen this is a turbulent age of further discovery and yearning to be grown–up, knowing too much but not really knowing enough. The program has evolved from infancy with the completion of the third pilot survey at Stafford Regional Airport. This survey tested the validity of the new Area Navigation Approach Precision Conventional (ANA-PC) Landing surface. The selected contractor also provided the team with valuable insight for FAA Specification 405 and the associated manuals being developed by National Geodetic Survey (NGS) to support the program. A key factor identified by the contractor is the need to clearly identify the aeronautical nuances within the guidance. Items such as defining the airport elevation and how is it determined, or inquiring why the localizer for Runway 17 is located at the end of the runway marked Runway 35, may seem like basic questions to those who work in the aviation world on a daily basis. However, for the typical land survey professional these questions could lead to some confusion. So the team is busily "beefing up" the survey web site with new and updated information to fulfill this previously unidentified need.

NGS awarded the contract for a data logger to Abacus Software of Silver Spring, Maryland and they are hard at work developing this key piece of software for the new survey process. We expect delivery of the system next year and it will be the final puzzle piece to be put into place. The data logger will serve as the key communication source between the field crew, NGS, and the Airports Geographic Information System (GIS).

The team recently briefed the Pilot Survey Program at the American Association of Airport Executives (AAAE) GIS Subcommittee meeting yielding an excellent response from the conference attendees. We expect to participate in more user conferences, such as AOPA's Fly-in and the AAAE Conference in June, as we continue to get the word out about the Pilot Survey Program. The next three milestones for the program are completing the Advisory Circulars, completing/updating and validating the web site, and ensuring the appropriate guidance for use of Airport Improvement Program is in place.

The team is working diligently to integrate the Airports GIS Data Standard and the Survey Pilot Program requirements, to ensure that the data collected by the third party surveyors is the data needed to further the efforts of the Survey Pilot Program, as well as to support the goals of other FAA lines of business.

Solar Flares Hit Earth – WAAS Bends But Does Not Break

By Tom Dehel, FAA/ATO-P (formerly ACB-430)

At times the Sun launches an attack on the Earth's magnetic field and the earth's ionosphere. The Wide Area Augmentation System (WAAS), a space based navigation system, must survive all these blows, and continue to deliver critical navigation services to aviation and other users.

There have been stories in the news about satellites that have become disabled due to the radiation and material blasted out by the Sun during these rare but severe solar events. However, the WAAS geosynchronous satellites which beam the WAAS correction messages to Earth, and the Global Positioning System (GPS) satellites which provide the raw ranging signals to users have proved very resistant to this form of solar attack. In fact, the communications signals themselves are also only rarely disrupted. In order to understand the relationship between the Sun and WAAS, one needs to understand a very tenuous layer of the Earth's upper atmosphere near the edge of space – the ionosphere.

The ionosphere may be thought of as the battleground between WAAS and the Sun. WAAS en route navigation and non-precision approach services are not affected by disruptions in the ionosphere. These services continued to operate normally despite recent solar storms. However, an important service of WAAS - the provision of vertical guidance to allow Lateral Navigation/Vertical Navigation (LNAV/VNAV) approaches and LPV approaches - can be affected. The reason these services are affected by the ionosphere is not obvious to someone who has not had the opportunity to study WAAS, but the simple explanation goes something like this.

GPS and WAAS fundamentally work by measuring the time it takes a radio wave to leave a satellite and arrive at the receiver. By using the speed of light, one can turn this time delay into a distance. If you know where several satellites are, and you know your distance to those satellites, you can do the math to compute where you are. BUT, the radio signal is not always traveling thru the vacuum of space. In our case, it enters the ionosphere, a rarified but electrically charged medium that can slow the radio signal. This results in the user receiver determining an incorrect range to the satellites, and, as a result, the math will give an incorrect position. This error is small (on the order of tens of meters).

The ionosphere exists every day – atmospheric gases hundreds of kilometers up in the atmosphere are split into ions and electrons by radiation from the Sun. This is usually a very smooth process. The "extra" delay created is about the same, or rises or declines very smoothly, over distances of thousands of kilometers. Currently, this error can be reduced and proved safe for vertically-guided approaches as long as the ionosphere is in its typical very smooth shape. WAAS, using specialized receivers at its two dozen reference stations, measures this delay, and produces an imaginary grid of the ionospheric delay. This data is sent to users as part of the WAAS message. A civil aircraft receiver, unable to measure the ionospheric delay itself, simply interpolates the WAAS grid of data to identify and remove that "extra" delay which would have resulted in some position error – and thanks to WAAS that error is gone.

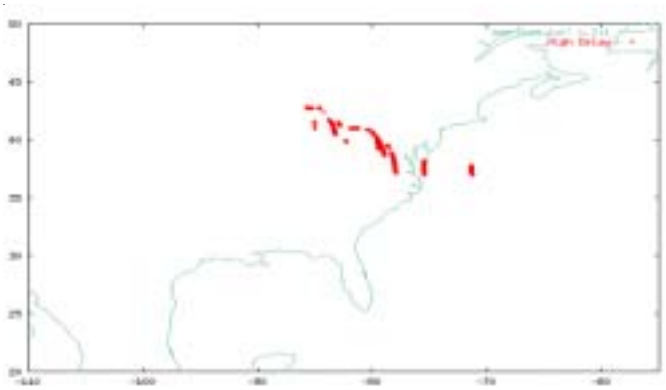
However, there is risk to this WAAS ionosphere correction method if the ionosphere is not "smooth" between the imaginary grid points provided by WAAS. In this case, the interpolation may not be correct. Under the safety constraints of WAAS, the ionosphere interpolation technique may not be used if the ionosphere is not proved "smooth"; therefore, any significant disruptions in the ionosphere above the "normally smooth" condition is treated as a situation where the safety of WAAS for vertical guidance cannot be guaranteed. During these conditions, LNAV/VNAV and LPV approaches are automatically disabled.

To better understand the effects of solar storms on the ionosphere and on WAAS, let's look at the storms of 2003 which took place on October 29, October 30, and November 20. On these days, an especially energetic group of sunspots (a magnetic disturbance point on the surface of the Sun), produced very severe X-ray flares, and blasted out billions of tons of charged material – called a Coronal Mass Ejection. This material has its own magnetic fields and orientation, and can either be deflected by the Earth's magnetic field, or penetrate and disrupt. On these days, the disruptions were very severe – classified as the maximum value of 9 on the geomagnetic Kp scale. They produced several severe "features" and gradients in the ionosphere – good for the advancement of ionospheric studies but bad for aviation users. On these days, the vertical guidance capability of WAAS, used in LNAV/VNAV and LPV approaches, was automatically disabled over most of the country for roughly 6-12 hours each day. This capability was not disabled because WAAS was not continuing to operate and generating the grid of ionosphere corrections, nor was there any data proving the corrections were unsafe. This capability was disabled because the basis of the proof of safety – that the ionosphere be very smooth – was not being met. However, WAAS en route and non-precision approach services were completely unaffected – so, WAAS did bend, but it

did not break. Methods are still being studied to mitigate the effects of these rare events in WAAS, but, in any case, WAAS continues to meet all current requirements of accuracy, availability and integrity.

The figure below shows the location of a "Storm Enhanced Density" feature that developed over the Eastern United States on the afternoon of November 20th. This feature was extremely un-smooth – basically a narrow structure of ionospheric material extending into space. The plot shows the location of the highest density of ionospheric material – provided by measurements made by WAAS and National Satellite Test Bed (NSTB) reference stations as GPS satellites orbited over it.

Storm Enhanced Density (SED) Ionospheric Feature over Eastern US, Nov. 20, 2003



Over the next decade, as aviation gradually transitions to an increased use of WAAS for vertical approaches for more users, there is also a plan to upgrade the GPS satellites to a second civil frequency – L5. This will allow the aircraft receiver to measure the ionospheric delay directly – allowing vertically-guided approaches during even the most severe ionospheric conditions. At that time, the threat of these solar storms will become a distant memory.

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