Satellite-Based Augmentation Systems (SBAS)
Wide Area Augmentation System (WAAS)
European Geostationary Navigation Overlay System (EGNOS)

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Satellite-based augmentation systems (SBAS) are designed to dramatically improve GPS performance. Many nations are making plans for SBAS service that appear under a variety of names. The European and Japanese equivalents, EGNOS and MSAS, are in orbit. Other systems are GAGAN in India and BEIDOU planned for China. In the aggregate, these systems will cover most of the globe with GPS augmentation service.

The Wide Area Augmentation System (WAAS) is the United States’ implementation of SBAS. WAAS covers virtually the entire Western Hemisphere. All of the planned systems cover huge areas of the world. EGNOS is now being planned to include Africa as well as all of Europe. It is important to point out that these satellite signals are designed to a common technical standard. WAAS receivers will work within any SBAS coverage, and in some regions, the satellite signals from various systems will overlap. The international standards, in fact, require receivers to provide up to 19 SBAS satellite locations.

Current GPS Limitations

Since its introduction, IFR-approved GPS has been characterized as a supplemental means of navigation. The following quotes from the Aeronautical Information Manual emphasize the point:

“Properly certified GPS equipment may be used as a supplemental means of IFR navigation for domestic en route, terminal operations, and certain instrument approach procedures (IAPs).”

“Aircraft using GPS navigation equipment under IFR must be equipped with an approved and operational alternate means of navigation appropriate to the flight.”

Simply stated, “supplemental” says that you cannot rely on GPS as the only means to operate while IFR. Even to achieve supplemental authorization, GPS receivers employ internal monitoring to double-check their position using additional satellites. This is known as RAIM or Receiver Autonomous Integrity Monitoring. The recent release of Advisory Circular AC 90-100 has sharply increased awareness of RAIM importance for conventional GPS. Again, quoting from the AIM:

“Without RAIM capability, the pilot has no assurance of the accuracy of the GPS position.”

This situation leads to one significant GPS limitation. The RAIM within the GPS receiver is not always able to perform its function, primarily due to the satellite geometry available at a specific location and time.

There are other GPS limitations that contribute to its current supplemental status. In addition to integrity, accuracy must be enhanced. And while GPS is extremely accurate today for lateral navigation, it is not adequate for vertical navigation. Signal degradation occurs because of changes in the Earth’s ionosphere for example. Dependability is also a concern. In engineering terms, dependability is known as continuity. The variations in satellite geometry over short periods prevent basic GPS navigation from achieving the high safety standards that the FAA and other regulatory agencies around the world demand. For these reasons, augmentation methods have been developed to enable GPS to reach its potential for vertical as well as lateral navigation. SBAS provides this augmentation.
How SBAS Works

All SBAS systems require three primary elements. These are 1) geostationary satellites, 2) reference stations on the ground and 3) the airborne WAAS receiver and antenna.

North American coverage requires approximately 35 ground reference stations, with locations to cover the contiguous 48 states, Hawaii, Alaska and Puerto Rico. This number also includes stations located for service in Canada and Mexico. Discussions are underway to provide stations in South America. All these stations are precisely surveyed so that their exact location is known.

The ground reference stations are linked to form the U.S. WAAS network. Each station in the network transmits its current GPS performance data to master stations where correction information for every satellite is computed as it applies to the location of the various reference stations. The correction data is then transmitted to the WAAS satellites where it is re-broadcast for any receiver within the satellite’s reception. This broadcast is on the same frequency as ordinary GPS signals. The receiver then uses the best corrections available depending on its present position. The broadcast data also contains integrity information about the health of individual satellites. One additional benefit is that the WAAS satellites themselves can be used like any GPS satellite to aid in determining position.

This short summary characterizes very sophisticated technology. Satellite-based augmentation systems are designed to high safety standards commensurate with use in navigation. For example, a design requirement of SBAS is that any GPS anomaly that could cause misleading information must be detected, corrections calculated, up-linked and re-broadcast so that the airborne receiver can have the information within six seconds of the time the condition occurred. Other systems on the airplane must then provide appropriate alerts for the pilot.
One original WAAS design goal was to reduce GPS errors down to seven meters. Measured performance indicates that errors of less than three meters are being observed. Further, conventional GPS provides only lateral navigation. Under certain conditions, GPS lateral navigation could be unavailable to conduct instrument approaches as often as 1 minute out of 20 minutes. With WAAS, vertical navigation is also available, and yet the time that it is not available will be reduced to 1 minute in approximately 20 hours. For lateral navigation only, this time is reduced to 1 minute in 1500 hours.

WAAS provides high integrity and high availability GPS. These characteristics allow GPS to change from supplemental means to primary means of navigation.

SBAS introduction results in a lengthy benefits list for the aviation community. Aircraft operators, the ANSP's, and local airport authorities and operators will all participate in SBAS benefits.

**BENEFITS FOR AIRCRAFT OPERATORS**

GPS/WAAS As Primary Means Of Navigation in U.S. airspace

Quoting once again from the Aeronautical Information Manual (AIM):

"Unlike TSO-C129 avionics, which were certified as a supplement to other means of navigation, WAAS avionics are evaluated without reliance on other navigation systems. As such, installation of WAAS avionics does not require the aircraft to have other equipment appropriate to the route to be flown."

This statement authorizes GPS/WAAS to be used as a primary means of navigation for en route, terminal area and non-precision approaches, and for near-Category I approaches to selected airports throughout the nation. It means that a WAAS-equipped airplane does not require DME, VOR or ADF as long as the destination and alternate airports have RNAV (GPS) approaches available. Those operators that still need conventional sensors may find that a single installation rather than dual is sufficient. Even those operators with existing dual equipage may be able to change the airplane’s Minimum Equipment List and thereby improve dispatch reliability. These benefits apply to all classes of operations, whether Part 91, Part 91K, Part 121 or Part 135. Certain classes of operator may also benefit from the fact that crew training for approaches based on DME, VOR or ADF may no longer be required for their operations approvals.

Today, a required alternate airport must have a non-GPS approach available. With WAAS primary means authorization, an alternate airport need not have any procedure available other than an RNAV (GPS) approach. From a practical standpoint, this means that a much wider choice of authorized alternates may be available. It is also likely that a GPS-only airport may have lower minimums than some other choices. This is particularly true when LPV approaches become more widely available. WAAS alternate airport authorization appears in the AIM:

"The FAA has begun removing the NA (Alternate Minimums Not Authorized) symbol from select RNAV (GPS) and GPS approach procedures so they may be used by approach approved WAAS receivers at alternate airports."

Further primary means benefits are related to operations outside of radar coverage. With WAAS, direct routes are authorized outside of radar coverage. Also, the recent AC 90-100A requirement to perform a preflight RAIM check does not apply for WAAS receivers as long as NOTAMS indicate that WAAS is available.
**LPV Approaches**

Localizer Performance with Vertical guidance (LPV) is a new type of approach procedure being introduced to take advantage of WAAS precision. LPV provides lateral and vertical guidance that is very similar to that used for present Category I ILS approaches.

Temperature restriction is not applicable to LPV and vertical guidance that is very similar to that used for present Category I ILS approaches. Many of the LPV procedures already published have decision altitudes as low as 200 feet height above touchdown with visibility minimums as low as 1/2 mile.

Although LPV minimums appear on RNAV charts, the operation is actually nearly identical to ILS. LPV lateral and vertical deviations are angular. That is, the deviation scale sensitivity increases as the airplane gets nearer to the runway end. The sensitivity is the same as ILS, and all airplanes with Rockwell Collins VNAV will have corresponding flight director and autopilot commands. It must be emphasized that vertical guidance for LPV is not the baro-VNAV that is used to fly the LNAV/VNAV minimums. LPV uses vertical guidance computed from the satellites. Satellite-derived vertical guidance is not affected by cold temperature, so the temperature limitation that commonly appears on RNAV charts is not applicable to LPV approaches. The path is also not affected by altimeter setting, although remote altimeter settings can have an effect on the minimums, as indicated in chart notes.

LPV will provide the lowest RNAV approach minimums. However, on the rare occasions when conditions prevent LPV, the LNAV or LNAV/VNAV minimums can be used. The installed avionics will annunciate the level of service currently available so that the pilot knows which minimums are currently authorized.

There are currently over 2000 LPV approaches published in the U.S. The FAA has plans to add hundreds per year, with the number potentially reaching 4,000 runway ends, each with full vertical guidance. Many of these are on runways with an existing ILS. In this case, LPV provides backup to ILS in the event that either the localizer or glideslope is out of service. An example is one from Jabara airport in Wichita, referenced on the next page. The runway has an ILS, but baro-VNAV is not authorized. LPV will reduce existing 500 foot RNAV minimums to 300.
Benefits in the Airspace – continued

BENEFITS FOR THE AIRSPACE INFRASTRUCTURE

The maintenance and future development costs of the Airspace System will be positively impacted by introduction of SBAS. Since less equipment is required on board aircraft, it follows that airspace service providers will require fewer ground-based navigation facilities. This trend began recently with the FAA announcement to decommission a number of ADF approach procedures. As a large percentage of the fleet becomes WAAS equipped, VORs and Category I ILS systems can be decommissioned.

Installation and maintenance costs for LPV procedures are significantly less than for ILS procedures. The initial cost of installing an ILS exceeds $1M per runway, whereas an LPV has no hardware installation requirements at the airport. Moreover, the cost of inspecting and commissioning an LPV procedure is approximately 90 percent less than that for an ILS. The cost savings in flight inspection is significant because each procedure must be inspected every 18 months. Providing precision approach capability at a low cost can contribute to economic development for smaller airports, and provide the means to off-load air traffic at the busier airports in a region.

Finally, the safety benefit of WAAS/LPV must be mentioned. Unstabilized descent is the greatest cause of approach accidents. LPV will make constant descent approaches available at virtually all runway ends while providing lower minimums than baro-VNAV. This is expected to result in fewer missed approaches, fewer circling approaches and reduction in CFIT accidents.

Rockwell Collins Product Plans

Rockwell Collins SBAS-enabled GPS-4000S receiver is certified and available today, and a service bulletin is available to convert a GPS-4000A to a GPS-4000S. For the replacement of a GPS-4000 or GPS-4000A with GPS-4000S, Approved Model List (AML) STC’s are available.

Rockwell Collins has completed our initial Flight Management System TSO, enabling certification for LPV approach operations as well. Capability, availability and timing of the LPV function will vary depending on the specific aircraft model.
Building trust every day.

Rockwell Collins delivers smart communication and aviation electronics solutions to customers worldwide. Backed by a global network of service and support, we stand committed to putting technology and practical innovation to work for you whenever and wherever you need us. In this way, working together, we build trust. Every day.

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