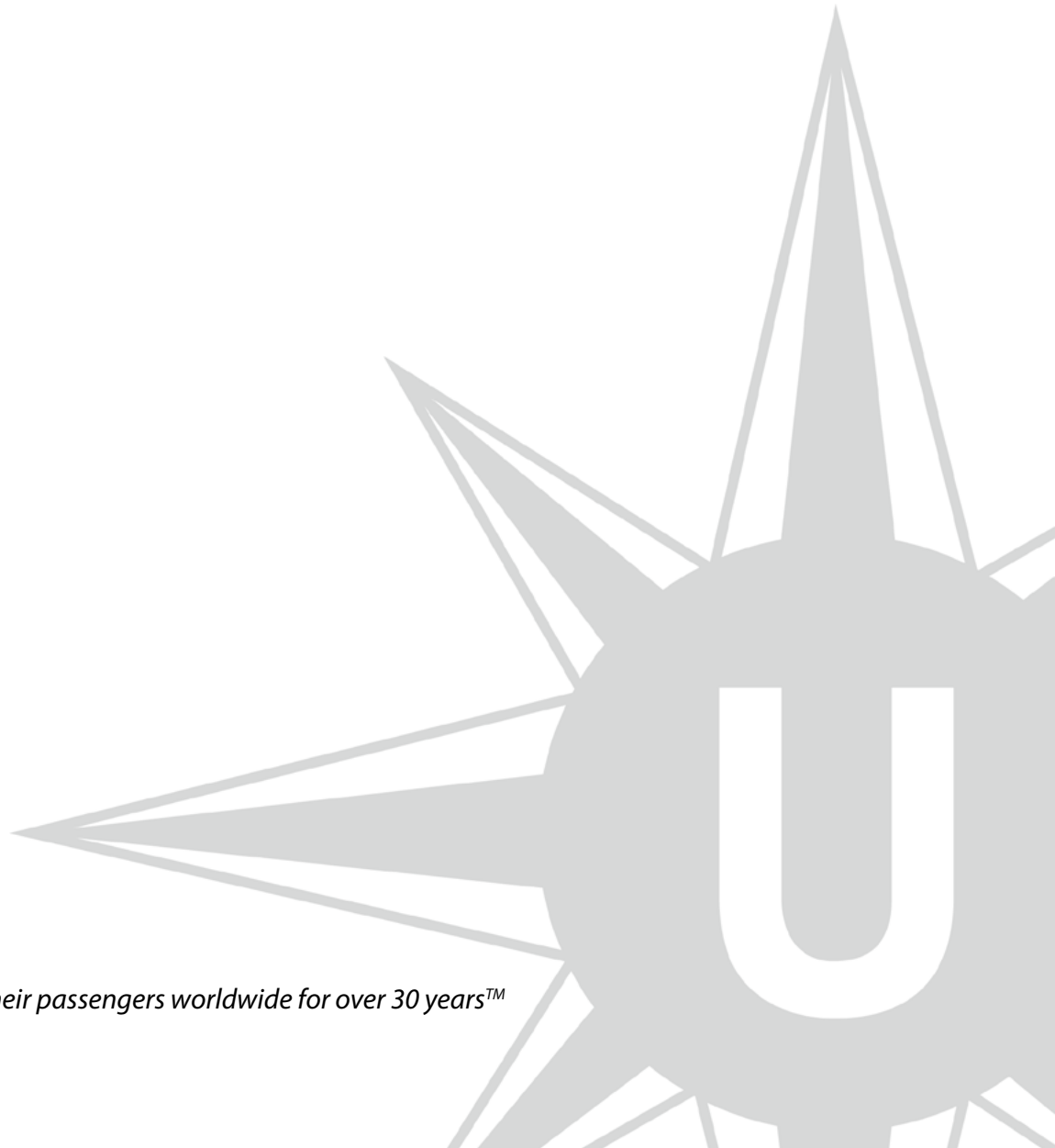
UNIVERSAL® AVIONICS
SYSTEMS CORPORATION

Operating in Satellite-Based Augmentation System (SBAS) Airspace

White Paper

Doc No.: WHTP-2013-17-10
November 2016



Safely guiding pilots and their passengers worldwide for over 30 years™

Executive Summary

The Global Positioning System (GPS) has been used successfully in aviation for many years, but the basic technology does not produce adequate precision and accuracy to allow it to be used as a sole source of navigation. The accuracy and integrity of GPS is greatly enhanced by the use of augmentation information from a variety of sources. The Satellite-Based Augmentation System (SBAS) augments the GPS signal to produce an increased accuracy, integrity, reliability and availability of information for aviation.

With the imminent decommissioning of 400 legacy VOR ground-based navigation systems already underway in the United States, regional SBAS programs have grown substantially over the past 8 years. This technology is a critical component of the FAA's Next Generation (NextGen) program and the EUROCONTROL SESAR initiative. This white paper presents the definition and worldwide use of satellite technologies, and its benefits, as well as equipment installation and certification requirements.

What is SBAS?

Satellite-Based Augmentation Systems (SBAS) are an integral part of the worldwide effort to reduce dependency on ground-based infrastructure and leverage the precision and accuracy provided by satellite technologies. This system can provide approaches to runway ends at the same minima (200 ft) as a Category I, ground-based Instrument Landing System (ILS) while improving safety.

An SBAS consists of a network of precisely surveyed ground reference stations widely dispersed to recieve and process satellite signals. The ground reference stations send satellite data to master stations, which then determine the integrity, differential corrections, residual errors and ionospheric information for each monitored satellite and generate Geostationary Earth Orbit (GEO) satellite navigation parameters. This information is sent to a Ground Earth Station (GES) and uplinked along with the GEO navigation message to GEO satellites. The GEO satellites broadcast integrity, correction data and ranging signals to GPS/SBAS receivers worldwide. Together, ground-based reference stations, satellite-based signals and aircraft sensor systems comprise the SBAS architecture for aircraft navigation. Ultimately, the SBAS provided integrity and correction data significantly improves the accuracy and reliability of the GPS position estimates.

Several regional SBAS programs have been implemented to date, each complying with a common global standard. Therefore, all are compatible and interoperable and do not interfere with each other. An operator with an SBAS-capable receiver can benefit from the same level of service and performance no matter the coverage area they are in.

Existing SBAS systems include the Wide Area Augmentation System (WAAS), European Geostationary Navigation Overlay Service (EGNOS), Multi-functional Satellite Augmentation System (MSAS) and GPS-Aided Geo-Augmentation Navigation (GAGAN). Designed in compliance with RTCA DO-229 to meet current standards and emerging technology in satellite-based navigation, Universal Avionics' SBAS-FMSs are compatible with each of the regional SBASs previously mentioned.

WAAS

The Wide Area Augmentation System (WAAS) was the first SBAS approved for aviation use. It was developed by the US Federal Aviation Administration (FAA) to augment the GPS, with the goal of improving its accuracy, integrity and availability. Commissioned in July 2003, WAAS serves North America, with benefits extending into Central America, South America and over the Atlantic and Pacific Oceans.

Photo Courtesy of European GNSS Agency

EGNOS

The European Geostationary Navigation Overlay Service (EGNOS) is an SBAS developed by the European Space Agency, the European Commission and EUROCONTROL. Commissioned for Safety-of-Life Service in March 2011, EGNOS serves Europe and the northern portion of Africa. Since the EGNOS satellites were first approved in 2011, over 880 RNP/RNAV procedures have been published with implementation varying per country, and over 400 LPV type or APV Baro approaches. As of mid-2016, several hundred are in the planning stage to be published.

In addition to LNAV and LNAV/VNAV procedures, European authorities are publishing RNAV procedures referred to as "APV Baro". These are approaches with barometric vertical guidance instead of GPS EGNOS vertical guidance, flown to the LNAV/VNAV Decision Altitude/Height (DA/H).

MSAS

A Japanese SBAS, the Multi-functional Satellite Augmentation System (MSAS), supports differential GPS designed to supplement the GPS system by reporting and improving on the reliability and accuracy of those signals. Commissioned in 2007, MSAS serves Japan and the surrounding area.

GAGAN

The GPS-Aided Geo-Augmentation Navigation (GAGAN) is a planned implementation of a regional SBAS by the Indian government to improve the accuracy of a Global Navigation Satellite System (GNSS) receiver by providing reference signals. Currently under development, GAGAN will serve India and the surrounding area.

Benefits of SBAS

The primary objective in establishing SBAS is to increase safety for aviation. By improving the accuracy, integrity, reliability and availability of GPS, SBAS increases the navigation capability for all classes of aircraft in all phases of flight. It's because of the increased integrity of the GPS navigation position that SBAS capable systems are classed as primary navigation equipment.

Accuracy

As expressed in terms of Navigation System Error (NSE), accuracy is the difference between the real position of the aircraft and the position provided by the airborne equipment. By providing the user with corrections to the satellite orbit and clock errors as well as to the ionospheric residual propagation error, an SBAS assures the compliance with respect to the accuracy requirements.

Integrity

System integrity refers to the ability to provide timely warnings to users when the system is producing hazardously misleading information and should not be used as a sole means of navigation. This ability to self-detect system position errors allows the flight crew to be notified in a timely fashion of the error, much like a flag on a VHF navigation radio.

Reliability

The SBAS specification refers to reliability as "Continuity of Function" for the system and is defined as the probability that accuracy and integrity requirements will be supported by the system through- out the flight operation.

Availability

Availability is the probability that the navigation and fault detection functions are operational and meet accuracy, integrity and continuity of function requirements.

Who Benefits from SBAS and How?

Approach procedures utilizing SBAS technology offer several benefits over traditional GPS procedures for operators and National Airspace Systems (NAS) alike.

Operational Benefits

- Augmented signal is accurate enough to be considered primary navigation vs. supplemental
- Offers the ability to MEL other primary navigation equipment and provide dispatch relief
- Eliminates RAIM prediction requirement, reducing pilot workload
- Enables more "Direct-To" operations for potential fuel savings
- File SBAS approach as IFR Alternate saving productivity and fuel, and greater opportunity for landing at airports closer to destination
- Eliminates procedural requirements for minimum temperature restrictions
- Smooth glide path eliminates intermediate step-down procedures on approach, eliminating potential CFIT accidents
- No special training or navigation database requirements
- Allows approaches at smaller municipal airports at night when no local altimeter setting is available
- Eliminates cold temperature compensation
- TSO-C146c SBAS-FMS provides the operator with basic RNP capabilities when properly installed under AC 20-138()

Airport Benefits

- Offers a cost-efficient opportunity for airports to gain ILS-like approach capability without installing ground-based navaids
- No consideration needs to be given to the placement of navigation facility, maintenance of clear zones around the facility or access for maintenance

Airspace System Benefits

- Supports vertically-guided instrument approaches to all qualifying runways
- Vertically-guided approaches reduce pilot workload and provide safety benefits over non-precision approaches
- Satellite-based navigation is a core element of the FAA's NextGen NAS and several other airspace agencies worldwide and supports ADS-B Out systems
- SBAS signal uses standard ICAO parameters for compatibility with future SBASs
- Potential preferred air traffic handling due to improved aircraft capability

SBAS Installation Requirements

What Does an SBAS Upgrade Entail?

"Upgrading" to SBAS involves replacing an existing FMS with a new SBAS-capable FMS. As an in-line replacement, the Universal Avionics SBAS-FMS constitutes minor changes to wiring, antenna, keying and configuration when certified for LPV capabilities. Still, most of the existing wiring may be used. Non-LPV SBAS-FMS installations have fewer changes.

Aircraft certification may also be affected – SBAS-FMS has been approved under TSO-C115b and TSO-C146c (previous FMSs have been approved under TSO-C115b and TSO-C129a). Universal Avionics Service Letter No. 2815, "Installation Considerations for Universal's WAAS FMS" details the specific differences and requirements necessary to replace an existing FMS with an SBAS-FMS. It also describes compatibility with other Universal Avionics products, and power and weight specifications.

SBAS-FMS Certification Guidance

When seeking installation approval of the SBAS-FMS, note that Universal Avionics has obtained 14 CFR Part 23 Approved Model List (AML)-STC number SA02071LA and 14 CFR Part 25 AML-STC ST02070LA. An AML-STC is a multi-model approval method that allows a set of compliance data to be designated as "baseline data" that is applicable to various aircraft models.

The SBAS-FMS installation complies with AC 20-138C for navigation using GPS and SBAS (within coverage of an SBAS complying with ICAO Annex 10) for enroute, terminal area, non-precision approach operations (including "GPS", "or GPS", and "RNAV" approaches), and approach procedures with vertical guidance (including "LNAV/VNAV" and "LPV").

In addition, an SBAS-FMS is capable of meeting the accuracy specifications of the following operational approvals:

- Oceanic Remote (reference Universal Avionics Service Letter No. 2738)
- US RNAV (reference Universal Avionics Service Letter No. 2804)
- Basic-RNAV (B-RNAV) (reference Universal Avionics Service Letter No. 2753)
- Precision-RNAV (P-RNAV) (reference Universal Avionics Service Letter No. 2792)
- RNP – complies with equipage and accuracy requirements of FAA Order 8900.1 (formally 8400.10 Volume 4, Chapter 1, Section 2, paragraph 52,D,(4)), RNP-2, RNP-1 and RNP-0.3 when in enroute, terminal, or non-precision approach modes respectively and the installed equipment provides annunciation to the pilot of the mode that is in use. Refer to Universal Avionics RNP/RNAV White Paper Doc No. WHTP-2013-16-10 for more information.
- VNAV – complies with the requirements for VFR/IFR enroute, terminal area and approach barometric VNAV operations in accordance with the criteria of AC 20-129 and AC 90-97, §7.a(1), for use of DA in lieu of MDA in accordance with 14 CFR §91.175 and 91.205.

SBAS-FMS Field Approval Process

STC installations are not required for all SBAS-FMS installations. Universal has worked extensively with FAA over the years to aid customers in obtaining field approvals for their SBAS-FMS systems when meeting certain criteria.

Universal has developed an aid to this process, which is contained in FAA Order 8300.16. The Universal document to assist with this process, which will guide dealers and customers through the FAA Order, is Universal RPRT-2016-1002 Revision 00 or later, entitled "Field Approval Process for the Installation or Upgrade of Universal Avionics SBAS-FMS with LPV Approach Capability." This can be obtained from UniNet, www.uasc.com/UniNet, or your sales representative.

Customers interested in gaining SBAS or LPV capabilities should contact their Universal Avionics Authorized Dealer to determine the applicable certification path for their aircraft. Universal Avionics' Support team is also available to answer questions regarding the Field Approval process at (800) 595-5906 or (520) 573-7627.

LP/LPV Monitor

Universal Avionics' LP/LPV Monitor is required in single SBAS-FMS integrations when seeking compliance approval for LPV approach capability. It provides the cross-side monitoring function required for LPV approach approval.

A configuration module is not required as an external strap configures the LP/LPV Monitor to default settings required for SBAS cross-side monitoring. The LP/LPV Monitor "listens" to the FMS on the cross-side bus and automatically configures itself accordingly. The external strap for the LP/LPV Monitor defines the unit as such and automatically configures for that function based on the FMS configuration. A Control Display Unit (CDU) is also not required since the LP/LPV Monitor is a stand-alone Line Replaceable Unit (LRU).

Levels of Service (LOS) annunciators are necessary when installing the LP/LPV Monitor. The LPV, Lateral Navigation (LNAV)/ Vertical Navigation (VNAV) and LNAV-only approach LOS must be annunciated from the FMS. No duplicate set is required for the LP/LPV Monitor.

Frequently Asked Questions

The following are answers to some commonly asked questions regarding SBAS.

What is an LPV approach?

What is commonly referred to as an "LPV approach" or perhaps a "WAAS approach" is actually an Area Navigation (RNAV) (GPS) approach procedure. LPV approaches are the highest precision GPS aviation IAP currently available without specialized aircrew training requirements, such as Required Navigation Performance (RNP).

How do I tell an LPV approach procedure from a GPS approach procedure?

Area Navigation (RNAV) (GPS) approach procedures utilizing SBAS signal data contain an SBAS Channel ID on the approach chart (upper right corner). When a given procedure contains an SBAS Channel ID, it means that a Final Approach Segment Data Block (FAS DB) is included as part of the approach record. On these plates, multiple approach descent minimums may be published referred to as LPV, LNAV/VNAV and LNAV LOS.

Note that not all approaches provide all three LOS; some are LPV only, some LPV and LNAV/VNAV only and some LPV and LNAV only. These LOS require the FMS to provide annunciations to the flight crew to tell them what integrity level the FMS is providing and subsequently what minimums the aircraft is authorized to descent to before runway visual contact is made.

When flying an RNAV (GPS) approach procedure, how do I know if I'm using SBAS?

The SBAS-FMS uses SBAS lateral navigation for all flight phases when within the SBAS coverage area. In the approach environment, the FMS can use either SBAS or barometric altitude reference information to provide vertical guidance.

If an LPV or LNAV/VNAV LOS is annunciated, the FMS is using SBAS GPS data to provide vertical guidance. This applies to LPV approach procedures as well as many other RNAV approaches. In this scenario, changes to the barometric setting will not affect FMS vertical path or steering.

If the LNAV only or no LOS annunciation is provided, the SBAS-FMS vertical guidance (if provided) is referenced from barometric altitude (not LPV). This is true for any approach type (LPV approach or not). Subsequently, any temperature restrictions on the approach chart will apply and changes to the baro setting will change the FMS vertical path and steering.

Differing levels of integrity are required for the each of the LOS as defined by the procedure's FAS DB. When guidance is being provided for LPV LOS, the approach integrity is monitored by the off-side FMS or LPV Monitor to ensure the integrity meets requirements. This is why dual Universal Avionics FMS (or single SBAS-FMS with LP/LPV Monitor) are required for LPV operations.

Summary

Universal Avionics' SBAS-FMS is a critical component to meet upcoming global mandates. Its accuracy is already required for current and planned mandates including ADS-B, FANS and the Link 2000+ (now ATN B1) Programme in Europe.

This technical white paper is released as a guide to some of the necessary information for operators to consider in order to ensure continuous aircraft operations without limits to airspace or airports, as well as an overview for gaining operational approvals. Please contact Universal Avionics Support for additional information for your specific installation or concern.

Reference List

- Universal Avionics Service Letter No. 2804, UASC FMS Compliance with FAA Advisory Circular 90-100A
- Universal Avionics Service Letter No. 2815, Installation Considerations for Universal's WAAS FMS
- Universal Avionics Service Letter No. 2738, Notice of Approval for Remote/Oceanic Operations in Accordance with FAA Notice 8110.60.
- Universal Avionics Service Letter No. 2753, Basic RNAV (BRNAV)/RNP-5 Operation in European Airspace
- Universal Avionics Service Letter No. 2792, JAA PRNAV UASC Compliance Evaluation Summary
- AC 20-138C, Airworthiness Approval of Positioning and Navigation Systems
- AC 20-129, Airworthiness Approval of Vertical Navigation (VNAV) Systems for use in the U.S. National Airspace System (NAS) and Alaska
- AC 90-97, Use of Barometric Vertical Navigation (VNAV) for Instrument Approach Operations Using Decision Altitude
- TSO-C115b, Airborne Area Navigation Equipment Using Multi-Sensor Inputs
- TSO-C146c, Stand-Alone Airborne Navigation Equipment Using The Global Positioning System Augmented By The Satellite Based Augmentation System
- FAA Order 8900.1 Flight Standards Information Management System

Acronyms

- ADS-B - Automatic Dependent Surveillance-Broadcast
- AML - Approved Model List
- APV - Approach Procedures with Vertical guidance
- B-RNAV - Basic-Area Navigation
- CDU - Control Display Unit
- CFIT - Controlled Flight Into Terrain
- DA/H - Decision Altitude/Height
- EAFAP - Engineering Assisted Field Approval Process
- EGNOS - European Geostationary Navigation Overlay Service
- FAA - Federal Aviation Administration
- FANS - Future Air Navigation System
- FAS DB - Final Approach Segment Data Block
- FGS - Flight Guidance System
- FMS - Flight Management System
- GAGAN - GPS-Aided Geo-Augmentation Navigation
- GEO - Geostationary Earth Orbit
- GNSS - Global Navigation Satellite System
- GPS - Global Positioning System
- ICAO - International Civil Aviation Organization
- ILS - Instrument Landing System
- IFR - Instrument Flight Rule
- LOS - Level of Service
- LNAV - Lateral Navigation
- LPV - Localizer Performance with Vertical guidance
- MEL - Minimum Equipment List
- MSAS - Multi-functional Satellite Augmentation System
- NAS - National Airspace System
- NextGen - Next Generation program (FAA)
- NSE - Navigation System Error
- P-RNAV - Precision-Area Navigation
- RAIM - Receiver Autonomous Integrity Monitoring
- RNAV - Area Navigation
- RNP - Required Navigation Performance
- SBAS - Satellite-Based Augmentation System
- SESAR - Single European Sky ATM Research
- STC - Supplemental Type Certificate
- TC - Type Certificate
- VNAV - Vertical Navigation
- WAAS - Wide Area Augmentation System

About Universal Avionics

Universal Avionics manufactures and markets an extensive line of advanced avionics equipment. Product lines include the UNS-1 SBAS-enabled (WAAS) Flight Management Systems; the EFI-890R/890H Flat Panel Display; a line of Integrated Cockpit Displays; Vision-1® Synthetic Vision System; Terrain Awareness and Warning System; UniLink® Communications Management Unit; Radio Control Units; Cockpit Voice and Flight Data Recorders; Attitude Heading Reference System (AHRS); and the Application Server Unit which integrates charts, electronic documents and checklists with displays systems. For more information about Universal Avionics, visit www.uasc.com.

UNIVERSAL® AVIONICS SYSTEMS CORPORATION

Corporate Offices
3260 E. Universal Way
Tucson, Arizona 85756 USA
(520) 295-2300
(800) 321-5253
Fax: (520) 295-2395

Midwest Operations
Wichita, Kansas USA
(316) 524-9500
(800) 255-0282
Fax: (316) 524-9700

European Office
Basel, Switzerland
+41-61-383-7683

Asia Pacific Office
Singapore
+65 6701 8231
Fax: +65 6701 8001

Internet
uasc.com
E-mail: info@uasc.com