

**THE BENEFITS
OF LPV
APPROACH
OPERATIONS
FOR THE
AIRLINE
OPERATOR.**

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There has been much discussion about the deployment of the Satellite Based Augmentation Systems (SBAS) and the new Instrument Approach Procedures that they enable termed the Localizer Performance with Vertical Guidance (LPV) approaches.

As of the writing of this document, the FAA has published more than 3500 LPV procedures around North America with its system, called WAAS (Wide Area Augmentation System)¹ and the European EGNOS system is online with APV SBAS approaches being published at an increasing rate across Europe².

The value proposition of SBAS for airline operations though is slightly different than that for business jet and general aviation operators. The purpose of this paper is to outline the unique benefits of LPV approach procedures for Airlines as the capability becomes available on airline transport aircraft worldwide. First however a brief overview of terminology and acronyms is provided.



1. For latest information on LPV approaches available in North America, refer to the following link: http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/approaches/index.cfm
2. For latest information on APV/SBAS approach availability in Europe via an interactive LPV Map, refer to this website (requires registration): http://egnos-user-support.essp-sas.eu/new_egnos_ops/

TERMINOLOGY, ACRONYMS AND OVERVIEW

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Most readers will be familiar with the concept of navigation using a Global Navigation Satellite System (GNSS) through their experiences with automobile or personal navigation systems.

The increasingly ubiquitous Google Maps and alternative smartphone apps that can utilize the United States Global Positioning System (GPS) system worldwide have increasingly become part of our daily lives. GPS was the first operational GNSS system to provide global coverage beginning in 1994, and devices that utilize the GPS system have since become irreplaceable.

An alternative to GPS, the Russian GLONASS (Globalnaya Navigazionnaya Sputnikovaya Sistema) is also fully operational today, and provides very similar services to GPS but with a slightly different technology. Commercial devices with GNSS capability for location and navigation such as the iPhone (beginning with the 4S) can utilize both GPS and GLONASS today. Other countries have begun launching systems that will provide global GNSS coverage by 2020 including the Beidou 2 system in China, and Galileo in Europe.

Basic GNSS systems such as GPS, GLONASS and other entrants can be augmented to improve the navigation system's attributes, such as accuracy, reliability, and availability, through the integration of external information into the calculation process. One approach to augmentation is termed Satellite-Based Augmentation System (SBAS), which is the focus of this paper. SBAS is a system that supports wide-area or regional augmentation through the use of additional satellite-broadcast messages. Such systems are commonly composed of multiple ground stations, located at accurately-surveyed points. The ground stations take measurements of one or more of the GNSS satellites, the satellite signals, or other environmental factors which may impact the signal received by the users.

Using these measurements, information messages are created and sent to one or more geo-stationary satellites for broadcast to end-users with SBAS-capable equipment to provide the augmented position data which consists of both a highly accurate lateral position and altitude.

There are two SBAS systems that are fully operational today for aviation users: the WAAS (Wide Area Augmentation System) in North America operated by the FAA since 2003, and the EGNOS (European Geostationary Navigation Overlay Service) operated in Europe by the European Commission that became available for aviation operations in 2011. In addition, Japan and India have their own systems: Japan's Multi-functional Satellite Augmentation System (MSAS) and India's GPS-Aided Geo Augmented Navigation (GAGAN) that have both been operationally approved, but as of the writing of this paper, neither is utilized to provide LPV Instrument Approach Procedures. Additional SBAS systems are proposed, the Russian GLONASS System for Differential Correction and Monitoring (SDCM), as well as the Chinese Satellite Navigation Augmentation System (SNAS).

As of the writing of this paper, the fully operational WAAS and EGNOS systems provide the capability for LPV approach procedures down to Category I. The LPV approach is neither a precision or non-precision approach. Rather it is classified in a third category referred to as Approach with Vertical Guidance (APV) that was created to include instrument approaches based on a navigation system that is not required to meet the precision approach standards of ICAO Annex 10 such as Instrument Landing System (ILS), but provides course and glidepath deviation information. LNAV/VNAV and other approach types are classified alongside LPV in the APV approach category.

The LPV approach was not implemented as an entirely new approach type, but rather as a new sub-type of RNAV (GPS) or RNAV (GNSS) approach. This approach type utilizes SBAS systems such as WAAS and EGNOS (and eventually the other SBAS systems mentioned earlier) to provide lateral and vertical approach guidance during instrument approaches. LPV terminology is not used universally.

In the ICAO parlance (preferred by EUROCONTROL), GNSS approaches utilizing SBAS are referred to as Approach Procedures with Vertical Guidance SBAS or APV SBAS (sometimes in print as APV/SBAS). For the purposes of this paper, LPV and APV SBAS are used interchangeably. When an LPV procedure is approved at an airport, it is added as a line of minima to an RNAV (GPS) or RNAV (GNSS) approach plate. An example RNAV (GPS) approach plate including LPV minima is provided in Figure 1 with the LPV line of minima information highlighted.

LPV approaches take advantage of the improvements in the accuracy of the lateral and vertical guidance achieved by SBAS to provide an approach procedure very similar to a Category I ILS. Like an ILS, an LPV has vertical guidance and is flown to a Decision Altitude (DA)/Decision Height (DH) rather than an Minimum Descent Altitude (MDA). The design of an LPV approach incorporates lateral guidance with increasing sensitivity as an aircraft gets closer to the runway threshold. Sensitivities, and therefore corrections to get back to the inbound course are nearly identical to those of the ILS at similar distances. This is intentional to aid pilots in transferring both their ILS cockpit procedure familiarity and flying skills to LPV approaches.

Another thing to note on Figure 1 is that the LPV ceiling and prevailing visibility are by far the lowest amongst the other options (LNAV/VNAV and LNAV) at this particular field, the ceiling minima being nearly 300' lower in fact.

With an actual ceiling as low as 2000 feet at the field, an LPV approach capability would likely result in a landing being accomplished whereas without it, an aircraft might be forced to proceed to its alternate. Note that there is no ILS capability at this field.

Unlike the base GNSS systems they augment, SBAS systems which are reliant on geo-stationary satellites do not provide global coverage. For example, the WAAS system operated by the United States provides SBAS coverage primarily to North America. The value of LPV Approach operations then is limited to operations in the areas of the globe that have SBAS coverage.

LPV approaches are added as a new line of minima to an RNAV GPS or RNAV (GNSS) approach at the airport.

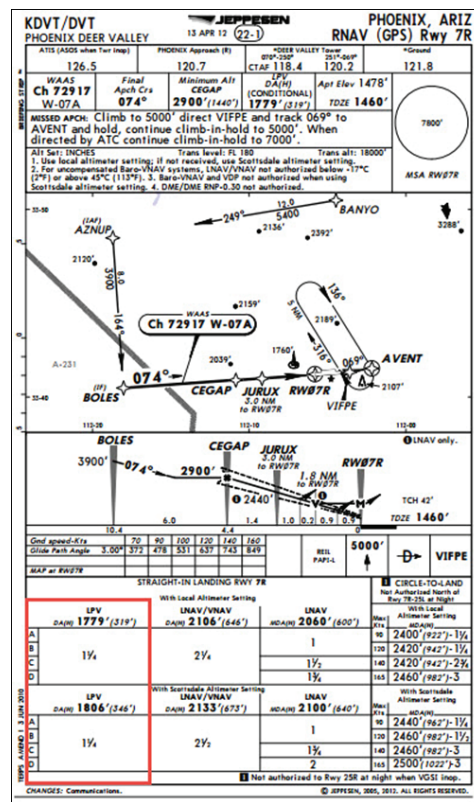


Fig 1: RNAV (GPS) Approach with LPV Line of Minima

Figure 2 shows the current availability of SBAS as a function of location, and as outlined previously that is limited primarily to North America and Europe (the purple and violet shaded regions) at the time of the writing of this paper.

(Note: an SBAS-capable receiver in the MSAS coverage area does provide other advantages such as improved accuracy, integrity, service continuity and availability for lateral navigation but at the current time, there are not LPV/APV SBAS approaches available in the region covered by MSAS due to the systems current inability to provide vertical guidance).

As the new SBAS systems listed previously are brought into operation and the technology deployment expands and is enhanced through dual-frequency operation, there is high potential for the area of highly reliable coverage for LPV operations to increase. Dual-frequency systems will be fully robust against ionospheric gradients that currently limit vertical guidance during severe ionospheric disturbances, and other factors that prevent its full utilization in some areas. Adding the capability to an aircraft provides a valuable feature today that will increase as SBAS systems, technology improvements and geographic coverage expands over time.

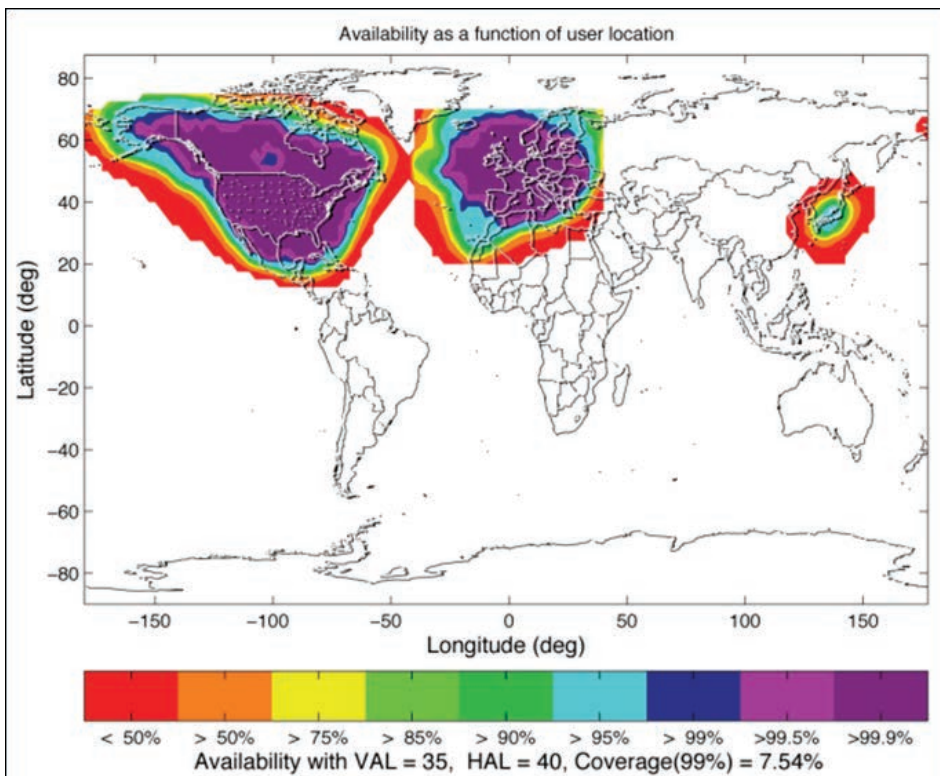


Fig. 2. Current Worldwide SBAS Availability

WHAT IS THE VALUE OF LPV TO AIRLINES TODAY?

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With the appropriate level of understanding established, the discussion can be turned to why LPV is valuable to the airlines operating in these regions, and how they could make the business case for equipping their aircraft and training their crews for LPV approach operations.

In airline transport aircraft, support for LPV operations consists of adding the SBAS capability to the GNSSU/MMR either through either a new LRU, or a software upgrade to the GNSSU/MMR. In most cases, adding SBAS capability also requires a change to TSO-146 compliant GPS antenna along with the GNSSU/MMR upgrade. In addition, the FMS must be upgraded to allow selection of the LPV procedure minima from the navigation database.

Display systems are also updated to support LPV-specific annunciations, but as outlined later most implementations attempt to maintain close commonality for the lateral and vertical guidance supplied to the crew during approach with that of ILS to promote standardization of cockpit procedures and facilitate pilot training. As an aside, the first airline transport aircraft to offer LPV approach capability (note that Airbus accepted neither the US or ICAO terminology, referring to their implementation as “Satellite Landing System”) in forward fit was the Airbus A350 which certified in late 2014. All other in-service airline transport aircraft have to have the capability added via retrofit.

As outlined at the outset, the value proposition to the airline for LPV is slightly different from other operator segments. The primary difference is the nature of the operations that are typical for most airline operators. Scheduled airline operations and their route maps are well established in terms of the routes and city pairs served, with little variability.

Airline operators tend to utilize the larger airports that already have facilities such as ILS approach and required lighting on the primary runway ends. This is not always the case for a number of regional and low-cost operators which operate at alternative airports that are in some cases not as well equipped as those served by the major carriers.

Given that business jets and general aviation aircraft can operate at a much larger range of airports with a much greater variation in capabilities, there is a different value proposition to adding the capability to those aircraft, but the underpinnings from an operational aspect are essentially the same.

Simply put, LPV capability provides the airline operator a stable and near-precision instrument approach option with the lowest minima relative to non-precision instrument approach options when ILS is either not installed or unavailable at airports or runway ends that the operator conducts frequent operations.

Simply put, LPV capability provides the airline operator a stable and near-precision instrument approach option with the lowest minima relative to non-precision instrument approach options when ILS is either not installed or unavailable at airports or runway ends that the operator conducts frequent operations.

Understanding however that the investment in the implementation, operation and maintenance of GNSS and SBAS, individual States such as in the US and the European countries of EUROCONTROL are promoting the advantages of GNSS, SBAS and LPV as part of their overall modernization initiatives such as NextGen in the US, and SESAR in Europe.

In addition to aggressively developing LPV approach procedures throughout North America with 3556 LPVs available as of 7/2015, it should be noted that 1326 of the published LPVs are at airports that conduct scheduled commercial operations with aircraft with greater than 30 passengers (e.g., Part 139 Airports) and have an ILS approach capability as well as LPV.

These airports are amongst those most likely to be supporting airline operations and where LPV has been added to provide additional instrument approach options to all airport users.

The FAA is actively promoting the value of the WAAS system for the improvement of airport and flight operations of all types. The FAA outlines the following advantages of WAAS-enabled LPV approaches as follows:

- LPV procedures have no requirement for ground-based transmitters at the airport, they don't require on-airport facilities to be operational to remain available to LPV equipped aircraft.
- No consideration needs to be given to the placement of navigation facility, maintenance of clear zones around the facility, or access to the facility for maintenance of WAAS-enabled LPV approaches.
- LPV approaches eliminate the need for critical area limitations associated with an ILS. While ILS is in operation aircraft cannot be operated in the ILS critical areas which can affect the normal flow of taxi operations as they often restrict taxi operations in close proximity of ILS ground equipment.
- From a pilot's viewpoint, an LPV approach looks and flies like an ILS, but the WAAS approach is more stable than that of an ILS as the guidance is not provided via RF technology and therefore not susceptible to interference.
- In the US, aircraft equipped with an SBAS-capable GPS (TSO-C145/C146), and that equipment is used to satisfy the RNAV and RNP requirement as is the case for LPV-capable aircraft, the pilot/operator need not perform RAIM prediction if WAAS coverage is confirmed to be available along the entire route of flight.
- The LPV approach glide slope is based on the SBAS-based altitude versus the barometric altimeter which is subject to variations due to extreme temperatures or pilot error in the setting of the local altimeter setting.
- LPV Approaches may be added to runways that have traditionally not been the runway of choice for IFR operations, providing the lowest minima on alternate runways that are more preferable for current winds or other criteria

From the perspective of the airport, it provides a much lower cost (both acquisition and operational) relative to alternatives such as ILS while still providing a highly precise, stable and available approach capability to the airport with very high levels of availability. Airports that have an existing ILS may add LPV approaches in the near term as a backup to the ILS, and eventually as the cost of maintaining/replacing the ILS becomes increasingly prohibitive, LPV will serve as a replacement for ILS technology with some caveats. Most notably as a precision approach, the ILS supports not only Category I, but in addition Category II and III operations including autoland. The LPV technology as currently envisioned will not provide a Decision Altitude below 200' or auto-land capability. LPV is limited to Category I operations, however other technologies such as GBAS/GLS will provide Cat II and III capabilities.



According to Honeywell, whose SLS-4000 SmartPath® GBAS is the only FAA-approved CAT I GBAS in operation today, with systems operational in the USA, Germany, Spain, Switzerland, and Australia, Cat II approach operations supported by SmartPath® will be approved as early as 2016, and CAT III operations are expected to be approved as early as 2019.

Many Controlled Flight Into Terrain (CFIT) accidents have occurred in the final approach segment of traditional non-precision approaches that utilize step-downs to Minimum Descent Altitudes (MDA).

By definition, the vertical guidance provided by LPV enables a continuous descent final approach guidance to the crew as opposed to the “dive and drive” technique associated with Minimum Descent Altitude (MDA) and legacy Non-Precision Approaches (NPAs) such as VOR and NDB. Dive and drive refers to descending the aircraft to the MDA as early as the procedure allows (“dive”), and then “driving” to the Missed Approach Point maintaining the MDA in the attempt to visually acquire the landing environment so a landing can be made.

Continuous Descent Final Approach (CDFA) techniques have replaced “dive and drive” in the majority of airline operations but given the level of automation and accuracy provided by LPV approach, its advantages should be clear. LPV approach provides a continuous descent final to a Decision Altitude which when reached, requires the crew to have acquired the landing area visually so they can continue visually, or execute the missed approach procedure. There is no low altitude level segment prior to the missed approach point. So during the LPV approach the aircraft descends at a continuous rate upon acquisition of the glide path, in a stabilized manner along a very precise trajectory (generally within 2 meters, actual versus intended) until the DA is reached and visual contact with the landing environment established so the aircraft can be transitioned to landing visually. If the landing environment is acquired visually before or at reaching the DA, the approach is continued to landing. At the DA, if the landing environment is not in sight and a safe landing not achievable visually the missed approach procedure is executed so the time the aircraft is at near or at DA without being able to maintain the landing environment visually is limited. As outlined earlier, another safety-related advantage of LPV is around altitude indication and control in the cockpit. Because the vertical guidance relies on the altitude derived using the SBAS avionics versus the Barometric Altimeter, it is not subject to either improper setting of the altimeter or extreme temperatures that can cause errant barometric altitude indications on approach.



Figure 3 on this page provides a comparison of Instrument Approach Minima for a number of APV and non-precision approach types as ILS Cat I. LPV Approach capability can minimize missed approaches and diversions when weather is near or below other non-precision instrument approach minima which provides operators cost avoidance particularly at airports with weather conditions that frequently result in low ceilings or reduced visibility where ILS is either not installed or unavailable on the preferred runway.

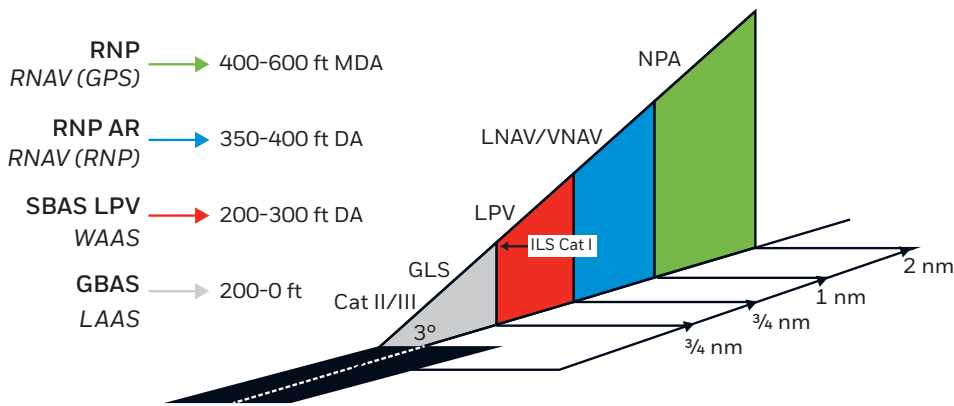


Fig. 3. Comparison of Instrument Approach MDA/DA Minima

In the absence of ILS (either not installed at the airport/ preferred landing runway or during an ILS outage), the LPV approach will provide the best minima amongst APV and non-precision approach procedure options, as low as 200' Decision Altitude in many cases. Roughly 26% of the FAA LPVs have a 200' Height Above Touchdown (HAT) today but understanding that to get to that level of minima, the Cat I ground infrastructure such as lighting must be present, the runway end likely has (or had at one time) ILS as well.

LPV APPROACH AVAILABILITY ON HONEYWELL-EQUIPPED AIRLINE TRANSPORT AIRCRAFT

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LPV Approach capability is certified and available today on the Embraer ERJ-135/140/145 as part of the FMS 6.1 Enhanced retrofit package.

The package includes the latest FMS software, upgrades to the GNSSU and antennas along with the latest displays software upgrades to deliver LPV functionality to this workhorse of many regional fleets.

With the certification of Epic Load 27.1 and the NG FMS in the summer of 2016, LPV approach became a selectable option on the E-Jet E1. The upgrade of the FMS with NG with the addition of airline transport features provides even more value particularly with North American and European operators. As a software option, it provides a key capability for updating the aircraft for service well into the next century as additional SBAS systems become operational.

Contact your Honeywell Avionics Technical Sales Manager for more information on LPV approach capability for these platforms.



ABBREVIATIONS AND ACRONYMS

APV

Approach with Vertical Guidance

EGNOS

European Geostationary Navigation
Overlay Service

GAGAN

GPS-Aided Geo Augmented Navigation
(India)

GLONASS

Globalnaya Navigazionnaya Sputnikovaya
Sistema (Russia)

GNSS

Global Navigation Satellite System

GPS

Global Positioning System

ILS

Instrument Landing System

LNAV

Lateral Navigation

LPV

Localizer Performance with Vertical
Guidance

MDA

Minimum Descent Altitude

MMR

Multi Mode Receiver

MSAS

Multi-functional Satellite Augmentation
System (Japan)

RNAV

Area Navigation

SBAS

Satellite Based Augmentation Systems

SDCM

System for Differential Correction and
Monitoring (Russia)

SLS

Satellite Landing System

SNAS

Satellite Navigation Augmentation System
(China)

VNAV

Vertical Navigation

WAAS

Wide Area Augmentation System

For More Information

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