FAA Navigation Programs AJM-32
http://gps.faa.gov

SatNav News

15 Year Anniversary of WAAS

An advanced technology concept in 1992 that became reality in 2003, is celebrating 15 years of operational performance providing benefits to countless users in aviation and beyond. The Wide Area Augmentation System has been delivering an extremely accurate and reliable navigation service for the United States and Canada since its activation.

The system has prevailed through the typical challenges of a program of its size and complexity to deliver the most advanced and reliable vertical guidance and horizontal system imaginable. As the following article by Julie Holley of NextGen Collaboration and Messaging highlights, the users AND benefits of WAAS keep growing!

What is WAAS?

The Wide Area Augmentation System, or WAAS, is used by pilots in all phases of flight from departure to arrival. WAAS procedures — a form of Performance Based Navigation that defines the "corridor" that an airplane will travel in — are especially helpful during take offs and landings, giving pilots a whole new level of access to airports across the country that may have once been out of reach. The accuracy of the location of the aircraft based on vertical location enables more efficient and timely air traffic control.

How does it work?

WAAS equipment works by providing extra information to an aircraft's GPS receivers to improve the accuracy and reliability of position estimates. So, what does this mean? GPS devices, like the ones we use in our cars, give us a close point estimate on the ground of where we are located at any given time on the road. However, they are not accurate enough for very precise vertical and horizontal movements of an aircraft during take off and landing procedures. An error of just a few feet during landing could make the difference between a safe landing and a missed approach.

The WAAS technology provides messages to the aircraft's flight management equipment, removing errors in the GPS signal and providing a much better estimate of the aircraft's location. This means pilots can take advantage of much more precise procedures without the need for Very High Frequency Omni-Directional Range antennas (VORs) or Instrument Landing Systems (ILS).

Advantages

WAAS offers advantages over many traditional procedures.

- There are currently about 3,900 Localizer Performance with Vertical guidance (LPV) and more than 660 Localizer Performance (LP) procedures — at more than 1,800 airports across the country — compared to 1,500 ILS procedures nationwide.
- LPVs are WAAS-enabled instrument approaches equivalent to a Category I ILS approach, the most commonly used instrument landing approach. LPVs provide the pilot with stable vertical guidance to minimums as low as 200 feet.
- As an added benefit, since WAAS uses GPS, procedures are available across the country. Traditional ground-based navigation aids only work within a particular geographic area. WAAS procedures are also more reliable. ILS equipment, for instance, can go out of service. WAAS is available wherever GPS is available.

The Life-Saving Impact of WAAS in Alaska

The impact of WAAS is no greater than in Alaska; where access to airports can make the difference between life and death.

"Eighty-two percent of the communities have no road service and are totally dependent on aviation for not only emergency services, but even more so in the delivery of day-to-day necessities," said Dennis Parrish of the Alaska Governor's Aviation Advisory Board. Some of these areas are so remote, the only way food, medication, and other vital supplies make it into the small towns is by airplane.

As a result of the lack of roads, Parrish said the demand and pressure to provide regular air service, Alaska has traditionally had the highest annual aircraft accident record in the nation. He credits WAAS for helping to change that. "The stabilized approach to airports with limited infrastructure, which this service provides, has saved many lives in our state," he said.

"Conditions up there are so severe and so different," said JoAnn Ford, an FAA engineer and Alaska Liaison for the agency's navigation programs. "With these smaller villages, all they may have is a small runway. There's no fixed based operator there; no lighting system; and no automated weather systems. So the ability to fly into the airport even though there's no control tower is key. With WAAS, they have a published approached, so they can gain access."

> "WAAS enables minimum en route altitudes, sometimes as low as the minimum obstruction clearance altitudes."

Ford says WAAS is helping not only during approaches and takeoffs but during the entire flight. In Alaska, pilots can't fly T-routes — designated routes from 1,200 to 18,000 feet — without WAAS. "WAAS enables minimum en route altitudes, sometimes as low as the minimum obstruction clearance altitudes," she said. "If you just have GPS, you don't have the ability to fly lower, out of icing conditions."

The WAAS Effect for Angel Flights

Steve Craven pilots a Piper Saratoga. As a volunteer for Angel Flights — a service that provides free airlifts for adults and children in need of specialized medical care— he says he relies on WAAS procedures to get in and out of airports in remote locations. It's

Steve Craven, pilot Angel Flights

not uncommon for Craven to fly to and from mountainous regions or in poor weather conditions as he helps patients make it to their appointments, often hundreds of miles away from their homes.

Craven, who is the former chairman of Angel Flight in the Mid-Atlantic region, says these flights are particularly helpful for patients living in rural areas without access to state-of-the-art treatment facilities. "If someone has an appointment, at Sloan Kettering Cancer Center, they want to know they can get there," he said.

"Greater access makes all the difference in the world. In the past, without WAAS, we'd frequently have to cancel the flight because of a low ceiling." Craven has flown many patients to and from hospitals all along the Mid-Atlantic and Northeast states including face transplant patient Richard North who lives in a small town in a mountainous region of southwest Virginia. Following his surgery, North required twice monthly visits to his doctors in Baltimore.

Craven calls the airport he flew in and out of to transport North a "nasty little airport between the ridges." He says WAAS provided more consistent access to the airport. "Before WAAS, if I got a weather forecast and the ceiling was 500 or 600 feet, we could not get in. WAAS changed everything," he said. "It provides an approach with a glideslope we didn't have before."

WAAS for Air Carriers

WAAS is already benefiting airlines and air cargo companies in Alaska and Canada. "WAAS navigation changed the landscape for Alaskan air carriers," said Jane Dale, director of the Alaska Air Carriers Association. "In southeast Alaska, lower altitude routes available with WAAS enable carriers to fly instrument flight rules point to point," she said.

Although carriers have multiple alternatives to land at an airport, often the weather conditions do not allow for certain procedures, or instrument landing systems are down or not available. She said, "For regional jets, WAAS becomes important to them. They are transporting people, mail, supplies, and delivering things that one wouldn't think air carriers would carry." Dale says WAAS provides both safety and access to those using WAAS procedures.

> "Greater access makes all the difference in the world. In the past, without WAAS, we'd frequently have to cancel the flight because of a low ceiling."

Canadian North Airlines uses WAAS regularly and it's good for business according to Chris Drossos, director of flight operations and a pilot at the company. The airline's entire fleet of 737s is equipped to perform WAAS procedures. The aircraft transport people, cargo or a combination of both in Canada, parts of the United States and Mexico. Drossos says there are times when the airline cannot land at certain airports in Canada, especially without WAAS technology because of low ceilings and visibility due to poor weather conditions. Adding to the complexities, he says the airline serves a number of airports without instrument landing systems in place.

Conventional procedures are sometimes an option but he says WAAS is often the better choice during very bad weather. "It gives you

far more precise guidance than barometric VNAV [vertical navigation]. So for conducting stabilized approaches, it's a great gauge in maintaining a proper glide path particularly in conditions where the visibility and gusty winds are a problem. It keeps you on the profile," he said. "Normally we'd have to temperature correct these altitudes using a chart. Of course, the LPV glide path is unaffected because it's a geometric glide path, and it's not affected by an altimeter source."

Drossos says the technology helps the airlines save money. "We don't have to divert somewhere else and then possibly wait for the weather or have to wait for ground transportation, so our reliability for maintaining the schedule is far better with WAAS LPV," he said. "For some of the private airports we fly into, there's cost to install all the ground based NAV aids that would be required for an instrument approach procedure."

WAAS Success

The FAA began activating WAAS procedures in 2003, launching about 500 per year. At first, WAAS procedures featured a decision altitude of 250 feet. In 2008, the FAA reduced the decision altitude to 200 feet, which provides even better access to airports.

Deployment of WAAS equipment is now complete, and the FAA is looking to convert current Localizer Performance (LP) approach procedures to LPVs where possible. LP procedures are WAAS approaches that do not include vertical guidance. There are currently 668 LPs at over 400 airports across the country, typically at locations where terrain or obstructions make it harder to publish LPVs.

Enhanced Coverage

The FAA is also working to enhance WAAS coverage in the most remote parts of the country with a new satellite. "In order to enable WAAS technology, we not only utilize the entire constellation of GPS satellites in view, but we also have three geosynchronous satellites," said Ford.

This type of orbit allows a satellite to travel at the same rate as the Earth's spin, keeping it in relatively the same position above the earth at any given time. "That's what makes the difference as far as the accuracy, availably, and integrity of WAAS compared to just GPS alone," she said.

> "With the integration of GEO 5, the entire state of Alaska will have redundant coverage eliminating the risk of a service outage in northwest Alaska."

The FAA currently has three geosynchronous satellites (GEO) orbiting the earth. In March 2018, the WAAS GEO 5 became operational which is particularly helpful in Alaska. Greg Thompson, WAAS Program, says WAAS provided coverage over the entire state, but the northwest portion was only covered by one satellite prior to GEO 5.

"With the integration of GEO 5, he said, the entire state of Alaska will have redundant coverage eliminating the risk of a service outage in northwest Alaska."

- Julie Holley, NextGen Collaboration and Messaging Office

Talking about EGNOS benefits with...BOEING

Reprint from EGNOS Bulletin, Issue 26 Q2 2018

David Zeitouni is a Technical Fellow in Boeing Commercial Airplanes where he has worked in the Flight Deck, Flight Crew Operations and Integration Group since 2010. He is currently a member of the ICAO Instrument Flight Procedures Panel & the ICAO Performance-Based Navigation Study Group. He also served as a United States Air Force military pilot and graduated from the Air Force Academy

Credits: BOEING

When did you first hear about SBAS and LPVs in the US?

Prior to working for Boeing, I worked for a company called Universal Avionics Systems Corporation. Universal was an early adopter of SBAS technology. As their FMS (Flight Management Systems) Systems Engineering manager, we certified the first Part 25 (large aircraft) SBAS and LPV FMS. Working for Universal gave me great experience with SBAS and LPV. We had customers ranging from single pilot aircraft to regional operators. I had direct experience with the benefits and value of SBAS.

What about EGNOS, were you following its beginnings or did you find about it recently?

While developing SBAS at Universal in the mid 2000's, I became aware of not just WAAS, but the other operational and in development SBAS. As we developed our LPV capable FMS and SBAS receiver, we conducted interoperability testing with all the SBAS systems (WAAS, EGNOS and MSAS) at the time. The FMS I helped certify in 2007 was interoperable and able to utilize EGNOS when safety of life services were enabled. I've been promoting the benefits of SBAS for many years within my organizations and within the industry groups I participate.

As pilot, have you ever been able to fly a LPV approach yourself? If so, what was your experience? Was it as good as everyone says?

In my US military career, I was not able to fly an LPV. The Air Force had not adopted or retrofitted LPV technology onto the aircraft. During development of SBAS and LPV systems at Universal, I was able to fly LPV approaches as a pilot and passenger. I'm hooked. The GNSS augmented approaches (LPV and GLS) are awesome. They provide the precision of ILS without the instability or quirkiness due to interference. So, yes, I think LPV is as good, actually better than everyone says.

Could you please tell us about your role at Boeing?

Currently, I'm a technical fellow for Boeing. I work in Boeing Commercial Airplanes division in the Flight Deck engineering organization. My organization is responsible for defining, specifying and developing all of the features and functionality within the flight deck. This includes everything from the flight deck door and bulkhead forward. My specific role is primarily related to Communications, Navigation and Surveillance equipment and functions. With my background in FMSs, I focus on navigation related technologies, but our organization's larger reason for existing is to define the human/ machine interface for the Boeing flight deck. My background as a transport pilot is also instrumental in understanding the role of the pilot in the modern flight deck and integrating the capabilities like LPV into our aircraft so that the pilot can use them without causing confusion or adding unnecessary workload. Working on GNSS augmented approaches, especially LPV, has been a primary task of mine in recent years. Integrating LPV approaches into the Boeing flight decks requires some work. When we get it right, the pilot is able to follow LPV guidance just like ILS or GLS providing access to thousands of LPVs in North America and Europe.

We always heard that WAAS was born for general and business aviation which are today their most frequent users. However, Europe seems to be reaching medium size and large airports, which is attracting the interest from regional and commercial airlines. Has Boeing received any request for LPV from customer airlines?

It's true that WAAS LPV was adopted early by the GA and business aviation, but not because there is something special about LPV for GA and business aircraft. Airlines only upgrade equipment when there is a very good business case to do so. The majority of airlines operate to airports with ILS procedures to all the main runways. So, there hasn't been a great need for airlines to retrofit with LPV. As LPV proliferates with projections for significant increases in coverage areas in the coming years, the business cases are shifting. Airlines that operate to airports without ILSs are also seeing the benefit of LPV. Additionally, having an alternative if the ILS is out of service is a benefit. So, yes, Boeing is starting to see interest for LPV from customers. It's still sparse, but interest none-the-less.

Photo: 777 Flight Deck
Credits: BOEING

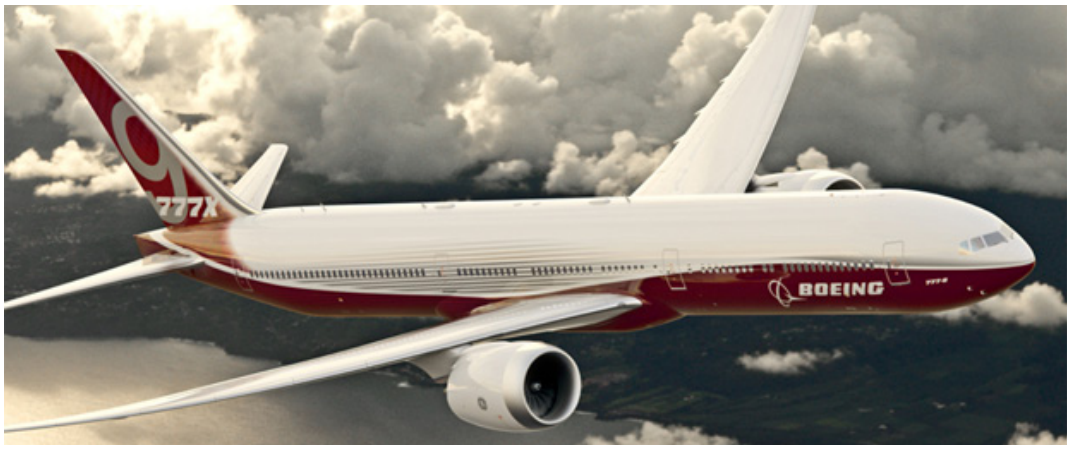
Surely you are aware that other big manufacturers like Airbus, Embraer, Bombardier or ATR are offering LPV options for their new and some legacy models. Is Boeing planning to offer such capability in the short term?

The short answer is yes, Boeing is working on LPV. We have to make the case on each different model and program, but it is happening. Our next new derivative, the 777X, will have LPV as a customer option. That will be followed by the 737 MAX. In cases where changes to production aircraft are not possible, we are investigating retrofit options.

> "Airlines that operate to airports without ILSs are also seeing the benefit of LPV (...) having an alternative if the ILS is out of service is a benefit."

Which models will be first to benefit from such developments and what is the tentative date for entry into service?

Benefit is very individual to a specific operator. An airline that doesn't operate on North America or Europe will probably not see much benefit for LPV in the near term. We are within the next two years or so for the 777X and 737 MAX. There are no specific dates for other models at this time.



Credits: BOEING

What will be, in your opinion, the main advantages or benefits of having LPV on Boeing aircraft?

Again, the advantages will depend upon your operation. For some, it is having a precision approach where no other precision approaches exist. For others, it's the backup to ILS or the benefits of geometric (non-temperature restricted barometric) approaches. Anytime, an operator can fly a precision 3-D approach instead of a 2-D dive and drive is better/safer.

> "In a few years, we will look back and see that we did make a rapid change from standard GPS to SBAS."

We are aware that the FAA has recommended SBAS for ADS-B Out as it offers an improved availability with respect to GPS and that EASA is likely to follow the same approach. Is Boeing considering such recommendation?

Yes, Boeing is well aware of the FAA SBAS recommendations for ADS-B. The number of reasons to have SBAS on the aircraft is growing (i.e. GAGAN mandate for Indian registered aircraft). Boeing is actively working on forward fit and retrofit SBAS packages for most of the current commercial models.

Any final message for our readers?

In the modern world of consumer electronics where technology changes at a rapid pace, aircraft technology is very slow by comparison. Most commercial aircraft fly for 20+ years and often have minimal changes made to them in their active lifetime. When you consider those facts, getting SBAS and LPV on commercial aircraft is now happening at a quick pace. In a few years, we will look back and see that we did make a rapid change from standard GPS to SBAS quickly by commercial aviation standards. It's easy to wish it would move faster, but we're getting there.

The 19th International GBAS Working Group (IGWG)

On May 15, 2018, the Polish Air Navigation Service Provider (PANSA) and Krakow airport hosted the 19th International GBAS Working Group (IGWG). The IGWG discussed the implementation, technical and operational aspects of using the GBAS Landing System (GLS).

Approximately one hundred thirty (130) participants from thirty (30) nations to include international service providers, industry stakeholders, airport operators, airlines and aircraft manufacturers attended the IGWG and associated working sessions which also included many new participants. Notably, representatives from ten major airlines and eight regulators attended the meeting. First time participants included a large delegation from China, as well as representatives from India.

In their welcome comments Mr. Tadeusz Grocholski, PANSA COO and Mr. Radosław Włoszek, CEO of Krakow airport indicated the importance of GBAS for the rapidly growing traffic of Krakow airport and their main airline customers.

Continued commitment to GBAS development and implementation by participants was impressive, and visible in airline presentations from Delta Air Lines, United Airlines, Cathay Pacific, Ryanair, CargoLux, Japan Airlines and All Nippon Airlines. NPPF Spectr, LLC provided an update of their impressive GBAS implementation within Russia with over 100 locations supporting 10 different aircraft types.

Boeing and Airbus remain strongly committed to the use of GLS and reported an increasing GLS customer base and increased number of sales of GLS equipped aircraft. Boeing reported delivery of over 3,500 equipped aircraft with an additional 5,000 GLS equipped aircraft on order. Boeing also confirmed that they were implementing GBAS Approach Service Type D capability required for Category III (CAT-III) operations on aircraft including the 777-8/9, 787, and 737 Max starting in 2020. Boeing is also supporting airline request for approval to conduct CAT-II operations using the current GAST C ground systems designed to support CAT-I operations. Airbus reported that about 100 customers were choosing the GLS option on aircraft, including A320, A330, A350 and A380 families. Airbus is supporting work in GBAS Extended Service Volumes, GLS CAT II operations using GAST-C ground systems, and GLS development in the scope of SESAR. Dassault Aviation, attending the IGWG for the first time, also briefed their interest in GBAS and other GNSS technologies.

The status reports of service provider plans, users and manufacturer updates as presented on the first day of the working group were impressive, important and informative. Participants appreciated the possibility to get a concentrated overview of the worldwide

state of the activities in a single day. Honeywell briefed on deployment status for the CAT-I SLS-4000; multiple airports internationally are in some phase of installation and operational approvals. Status of Honeywell GBAS avionics, the iMMR and VIDL-G was also briefed. Rockwell-Collins and CMC also outlined the development of GAST-D capable avionics suites. Indra Navia briefed their potential timeline for CAT-III GBAS development work, and announced that they had started a dialogue with the FAA to explore a possible pathway to System Design Approval for their GAST-D GBAS ground station. Both Honeywell and Indra Navia are involved in several SESAR work packages. NEC was unable to participate in person but sent a statement updating their status to be shared at the meeting. NEC is delivering their CAT-I GBAS to Haneda Airport in March 2019 and planning to be in operational service two years later after operational validation is complete.

The key value of the GBAS working group continues to reside in the parallel strings of technical and operational sessions, where data collection and evaluation, siting experience and interference mitigation, ionospheric activities, operational plans and future operations are not only exchanged but actively coordinated.

The key value of the GBAS working group continues however to reside in the parallel strings of technical and operational working sessions on day two and day three, where more in depth briefings can take place. More than two-thirds of the participants attended the operational working sessions. Major aspects of the operational working groups were discussions on the newly coordinated means to allow expanded service volumes, an important step for GBAS operations at airports with a requirement for extended final approach segments. Another topic of particular interest was the progress towards implementation of the ability to perform CAT-II operations using a GAST-C GBAS system, which is in Europe also a SESAR Operational Demonstration. Both Honeywell and Delta Air Lines briefed on their status towards achieving this goal, while DFS reported the activities on the ATC integration side. Progress was reported on RNP-to-GLS approvals in the U.S., Europe, and Asia. There are several SESAR work packages dedicated to pursuing enhanced arrival procedures enabled by GBAS.

The technical sessions, which included Data Collection and Evaluation and Ionospheric Aspects, remained active. The ionospheric aspects session received a brief on the progress of the ICAO Ionospheric Gradient Monitoring Ad-hoc group which is assessing the capability of GAST-D GBAS to support operations in low-latitude areas. The session also received briefing on data analysis and research work done by low-latitude states such as Brazil and Japan. The development of a European Ionospheric Threat Model and evaluation of a dual frequency GBAS ionosphere monitor were also shared. The Data Collection and Evaluation session focused on radiofrequency interference monitoring and mitigations and VDB compatibility studies. Updates on EUROCONTORL'S PEGASUS data processing software, were also shared.

The Krakow Airport and PANSA sponsored a dinner at the aviation museum of Krakow, which highlighted Poland's aviation history throughout the years. The museum includes many remarkable aviation examples from the early days of flying, World War I, World War II, and more modern aircraft in use today.

Sorry – No GLS Retrofit

Participants were extremely satisfied with the outcome of the working group meeting, and agreed that the IGWG continued to fulfil a

Participant's at the 19th International GBAS Working Group (IGWG) in Krakow, Poland, May 15-18, 2018

recognized function in GBAS development and implementation work. The meeting's format seems well adapted to the participants' needs, allowing for coordination between ANSPs, airports, airlines and Original Equipment Manufacturers. The working group addressed relevant issues for GBAS, and enabled exchanges of data and information which can be effectively used by participants in formulating their business strategies and implementation plans.

The next International GBAS Working Group is tentatively planned for the Americas in Spring 2019. The final location and dates will be confirmed at a later date.

- Dieter Guenter FAA AJM-32/NAVTAC

WAAS by the numbers

Did You Know . . .

For this issue's "Did You Know" column, the SatNav News staff has put together a timeline of WAAS from first concept to operations today to a look into future benefits.

The SatNav News is produced by the Navigation Programs AJM-32 branch of the Federal Aviation Administration (FAA). This newsletter provides information on the Global Positioning System (GPS), the Wide Area Augmentation System (WAAS) and the Ground Based Augmentation System (GBAS).

Satellite Navigation
Approach Procedures

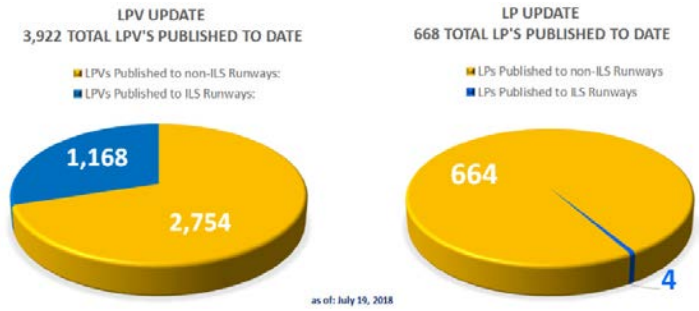
WAAS LPVs

The table to the right reflects the continuing growth of satellite-based approach procedures. For more detailed information about satellite-based instrument approach procedures, please visit our GPS/WAAS Approach Procedures web page. *http://www.faa.gov/about/office_org/ headquarters_offices/ato/service_units/techops/navservices/gnss/approaches/index.cfm*

Satellite-based Approach Procedures

RNAV (GPS) Approaches	ILS Runways	Non-ILS Runways	Total
LPV Line of Minima	1,168	2,754	**3,922**
<250' Decision Altitude			*1,073*
Exactly 200' Decision Altitude			*1,023*
LP Line of Minima	4	664	**668**
LNAV Line of Minima	1,219	4,820	**6,039**
LNAV/VNAV Line of Minima	1,147	2,662	**3,809**
GPS Stand-Alone Procedures	1	52	**53**
GLS Approach	11		**11**

(Data as of July 19, 2018)



EGNOS LPVs

The number of LPVs in Europe is also growing. The table to the right shows LPV procedures in Europe as of May 24, 2018, as included in the EGNOS Bulletin Quarter 2 (Source: EGNOS Bulletin, Issue 26 Q2 2018)

Follow this link to the most recent EGNOS Bulletin Issue 26 Q2 2018: *http://egnos-user-support.essp-sas.eu/new_egnos_ops/content/quarterly-bulletin*

Country	Airports – SBAS APV procedures	# SBAS APV Procedures
Austria	0	0
Belgium	5	9
Croatia	4	6
Czech Republic	5	9
Denmark	4	8
Estonia	1	2
Finland	1	2
France	69	105
Germany	23	37
Guernsey	1	2
Hungary	0	0
Ireland	1	1
Italy	11	21
Netherlands	2	3
Norway	17	26
Poland	1	1
Portugal	2	3
Romania	1	2
Slovak Republic	2	4
Spain	4	9
Sweden	6	10
Switzerland	8	10
United Kingdom	14	31
Total	**182**	**301**

Canadian WAAS LPVs

Numbers provided by NAV CANADA as of March 29, 2018