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SatNavNews

FAA Navigation Programs AJM-32

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).

Inside ...

Delta Makes Inaugural GBAS Landing at Newark

Delta Boeing 737 lands at Newark using GBAS

On February 18, 2015, Delta made a perfect Ground Based Augmentation System (GBAS) Landing System (GLS) landing at Liberty Newark International Airport. Delta now joins United and British Airways as airlines who use the GBAS at Newark. On hand for this milestone event were FAA Eastern Region - Regional Administrator, Carmine Gallo; FAA Eastern Region - New York Area Program Integration Office (NY- APIO) Director, Marie Kennington-Gardiner; FAA Air Traffic Manager of Terminal Services for Air Traffic Operations in the Eastern Service Area North; Russell Halleran; Newark Liberty International Airport Chief Operations Supervisor, Harry F. Rater; and several Port Authority of New York and New Jersey (PANYNJ) representatives. PANYNJ Program Manager of Delay Reduction, Ralph Tamburro, remarked "Perfect GLS arrival by DELTA at EWR!!" Delta's number one and number two Boeing 737 captains, Rich Kaynor and Mike Spicuzza, were given the honor of being the pilots for this flight. Delta Technical Manager for B737 / B747-400 Flight Operations, Michael W. Mannino, noted "our GLS approach into Newark was a huge success!"

- Dieter Guenter, FAA AJM-32/NAVTAC

Tell Us Your WAAS Story

We're collecting testimonials about the benefits of Wide Area Augmentation System (WAAS) navigation from users. If you are a pilot, passenger, airport manager, controller, dispatcher, airline employee, or are involved in aviation in any capacity - whether you fly fixed-wing or vertical flight aircraft - we want to hear from you! Please send your stories and contact information to Mary Ann Davis at maryann.ctr.davis@faa.gov

GBAS on the Move

2014 saw an increase in both the operational use and interest in the Ground Based Augmentation System (GBAS). United Airlines, Delta Airlines, Emirates Airlines, Lufthansa, Cathay Pacific, and British Airways have all benefited from GBAS over the last year.

United Airlines

In November 2014, United Airlines hit a milestone of 1,000 GBAS Landing System (GLS) approaches at George Bush Intercontinental Airport (IAH) in Houston, Texas and at Newark Liberty International Airport (EWR) in Newark, New Jersey. This is the number of approaches at both airports combined since United gained initial GBAS operational approval. United Airlines is using GLS on a regular basis with Boeing 737s (currently operates 95 737 GLS-capable aircraft) and Boeing 787s (currently operates 14 787 GLS-capable aircraft). Additionally, all new 737s purchased by United will be GLS-capable. GLS capability comes standard on 787 aircraft. United flies an average of 65 to70 GLS approaches each month.

United Boeing 787

Delta Airlines

In December 2014, the Houston Airport System (HAS) announced "GBAS Groundbreaking Technology Continues to Take Flight at Bush Airport" as Delta Air Lines pilots, Captain Mike Spicuzza and First Officer Jim West, completed the airline's first GBAS landing in one of Delta's Boeing 737 aircraft. (More and more airlines operating from IAH are using GBAS).

Delta Airlines has made a conscious decision to implement GLS capability into their fleet. In 2014, Delta Airlines operated 42 GBAS-equipped 737 new generation (NG) aircraft. Delta is also investigating GBAS equipage for their Airbus fleet. Delta could have 177 GLS-capable aircraft (combination of Boeing and Airbus) by 2019.

Delta Boeing 737

Emirates Airlines

Emirates conducted their first GLS landing in Houston on December 3, 2014 with the Airbus A380. All of the Emirates Airlines' A380 aircraft (57 as of December 2014) are GLS-capable and fly the GLS approach where available. Currently, this includes approaches into Sydney, Australia; Frankfurt, Germany; Zurich, Switzerland; and now into Houston.

Emirates A380

Lufthansa

Lufthansa's first GLS landing in Houston was December 8, 2014 with the Airbus A380 aircraft. All of Lufthansa's A380 aircraft (12 as of December 2014) are GLS-capable and perform GLS approaches into Sydney, Frankfurt, and Houston.

Lufthansa A380

Cathay Pacific

Cathay Pacific's first GLS landing in Houston was on January 30, 2015 with a Boeing 747-800 aircraft.

Cathay Pacific Boeing 747

British Airways

British Airways is flying GBAS-equipped B787s into Newark.

Brirish Airways Boeing 787

More and more airlines are equipping with GBAS-capable aircraft and will take advantage of flying GLS approaches into Newark and Houston. To fly GLS in the U.S. National Airspace System (NAS), non-U.S airlines will need an operational specification (Ops Spec) approval by the FAA. So far, British Airways, Cathay Pacific, Emirates, and Lufthansa have achieved this approval. Virgin Atlantic is also planning to go through the approval process for their 787 aircraft in order to fly GLS approaches into Newark.

Worldwide Operational Implementation

More GBAS locations around the world are reaching operational status and airline operations using GBAS are increasing as additional GLS-equipped aircraft are entering service for the various airlines. Boeing has confirmed that many of the customers who have ordered multiple 787s, 747-8s, or 737s have publically stated their intentions of using the GLS capability on these aircraft. Today, there are over 1,000 Boeing GLS-equipped aircraft in use and this number is growing by an estimated 25 airplanes per month. This estimate is based upon current production rates – one third of 737s are being equipped with the GLS option. GLS is standard on 787 and 747-8 aircraft.

The list below provides a summary of the airlines using GBAS and the airports where GLS approaches are flown on a regular basis.

U.S. Carriers

- Delta Airlines – Houston, Newark
- United Airlines – Houston, Newark

Non-U.S. Carriers

- Air Berlin –Bremen, Malaga
- British Airways –Newark
- Cathay Pacific – Houston, Sydney (plans for Newark in the future)
- Emirates Airlines – Frankfurt, Houston, Sydney, Zurich
- Lufthansa – Frankfurt, Houston
- Qantas – Sydney
- Swiss Air – Zurich
- TUIfly – Malaga
- Various Russian airlines (S7, Transaero, Utair, Sakhalin Energy, Gaspromavia Russia) - 15 GBAS locations in Russia have been approved with each airline using different airports (Domodedovo, Pulkovo, Tyumen, Ostafyevo, Nogliki and others)

The commitment to GBAS development and implementation continues to grow. This is visible by new airline interest and plans to implement GBAS in additional locations:

- Dubai, United Arab Emirates
- Chennai, India
- Gimpo, South Korea
- London Heathrow, United Kingdom
- Melbourne, Australia
- Oslo, Norway
- Rio de Janeiro, Brazil
- St. Helena, United Kingdom

Next Steps

The GBAS program is now focused on validating standards for a GBAS Approach Service Type-D (GAST-D) which will align with Category (CAT) III minima service. The program currently projects that a GAST-D GBAS system can be available in 2018.

FAA flight testing at the FAA Technical Center in Atlantic City, New Jersey and Single European Sky ATM Research (SESAR) flight testing at Toulouse, France, and Frankfurt, Germany has proved that a reliable alternative to an Instrument Landing System (ILS) signal can be produced with a Global Navigation Satellite System (GNSS) constellation and a single-frequency input signal.

SESAR is also exploring the potential for a future extension of the project for multi-constellation, multi-frequency GBAS. This would lead to an even more robust system suitable for use virtually anywhere in the world as a replacement for existing ILS. It is also expected to extend activities to validate enhanced functions which support curved approaches and displaced runway threshold capabilities.

Additionally, the Boeing eco-Demonstrator program is designed to speed up the development of new features to a higher technology-readiness level at which they could be considered mature enough for product introduction. The ecoDemonstrator 787 Flight Test Airplane successfully

Boeing tests GLS CAT III autoland approaches

completed GLS CAT III autoland testing at Moses Lake, Washington using Honeywell's prototype GBAS and a prototype Honeywell Integrated Navigation Radio (INR). The testing included 12 GLS approaches. Flight test data will be used to validate industry standards for new GBAS protocols and monitors designed to support CAT III operations.

New procedures were also tested on the ecoDemontrator that combined new and existing technologies. For example, a Required Navigation Performance (RNP) procedure to a GLS short final was demonstrated to show the reduction of track miles and community noise. Also, various glideslopes on final approach and displaced final touch down points were demonstrated to show the operational flexibility of GNSS landing systems to improve airport operations. Boeing is in the process of analyzing the flight test data to produce fuel, emission, and noise benefits of such procedures.

To date, flight testing and operational experience with the GLS has been excellent. Many GLS-guided approaches and landings have been conducted successfully at a variety of airports and under various runway conditions. Research and development efforts as well as operational experience have shown that navigation systems relying on GBAS can be considered as a promising solution for approach and landing in all weather and visibility conditions up to CAT III.

- Dieter Guenter, FAA AJM-32/NAVTAC

WAAS Benefits for Aviation

An article on the benefits of the Wide Area Augmentation System (WAAS) was recently featured in the EGNOS Bulletin #13/Q4 2014. As a courtesy to our SATNAV News readers and with permission from the European Satellite Services Provider (ESSP), we have included the content of the article here. Please note that the original article was published in December 2014 and WAAS approach procedure numbers have increased since that time. The most current procedure count can be found in the Satellite Navigation Approach Procedures Update article.

WAAS benefits for aviation, by FAA
(reprint from EGNOS Bulletin #13/Q4 2014)

The FAA is the operator of WAAS (counterpart of EGNOS in the USA), which was commissioned for civil aviation service more than 11 years ago. In this article, Bill Wanner, Navigation Systems Manager, kindly reviews the role of WAAS during these years, which is a reference for EGNOS.

The Federal Aviation Administration (FAA) commissioned the Wide Area

Augmentation System (WAAS) as a safety of life air navigation service on July 10, 2003. The agency has continually improved the system in the years since then. These system improvements have increased the WAAS service area, availability, and reliability. Each development kept the WAAS aviation users in mind so they would have the most reliable and accurate service available.

LPV approaches are very similar to ILS approaches, from the pilot's perspective.

WAAS provides consistent service to users throughout the service area for all phases of flight. The system delivers an accurate position solution, typically one to two meters, no matter where the user is in the WAAS service area. This accuracy is a significant improvement over the typical accuracy obtained using GPS alone. WAAS also provides timely integrity for the GPS signal. If a GPS satellite unexpectedly provides erroneous signals, the WAAS will detect this failure and mark that satellite as "not usable" within six seconds. The WAAS also provides integrity parameters that ensure that WAAS accuracy is within integrity bounds. With very high probability, the user is assured the information WAAS is transmitting will result in a safe and accurate position.

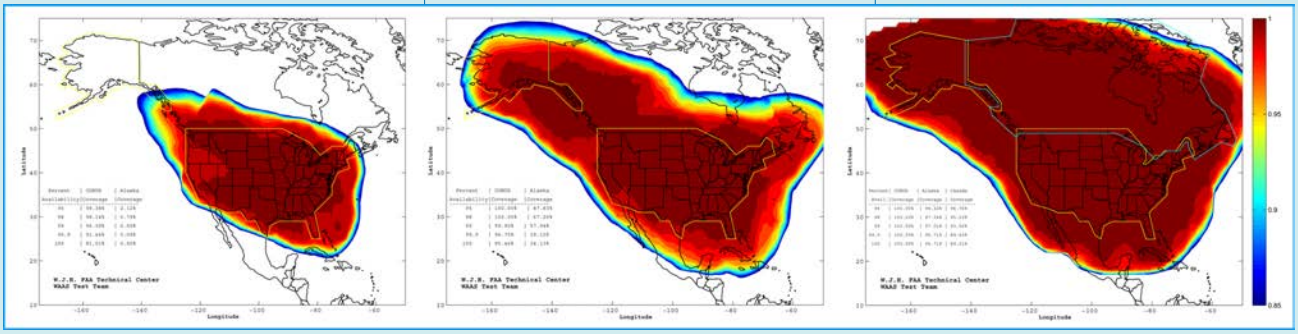
WAAS offers many benefits in approach operations. GPS alone does not meet the aviation requirements for availability, accuracy, and integrity for different phases of flight, such as final approach. WAAS allows pilots to use satellite navigation to perform a precision approach down to a 200-foot decision height with a one-half mile visibility.

WAAS has opened up thousands of runways to aviators who previously did not have access to a precision approach capability. The FAA has published 3,498 Localizer Performance with Vertical guidance (LPV) approaches, 2,321 to runways with no ILS capability, by November 13, 2014. LPV approaches are very similar to ILS approaches, from the pilot's perspective.

The figures below show the evolution of WAAS service. The dark red color in each picture shows where WAAS LPV is available 100% of the time. Outside that dark red color, the WAAS availability reduces until the color is blue. The blue color indicates where the WAAS LPV service is available 85% of the time. WAAS LPV service is available less than 85% of the time in the white area of the pictures.
The left picture shows WAAS LPV service coverage on September 4, 2003. The center picture shows WAAS LPV service coverage on September 28, 2007. This is the performance after new reference stations in Alaska, Canada, and Mexico were added to WAAS. The right picture shows WAAS LPV service coverage on September 24, 2014. It clearly shows that LPV service is available 100% of the time in a large portion of North America. The current level of service compared to previous service is attributable to several system changes that increased the robustness of WAAS.

WAAS enables the FAA to reduce operations costs by decommissioning ground-based navigational aids. For example, the FAA is moving from a VOR-based route structure to a Performance Based Navigation (PBN) route structure. Aircraft can fly direct routes instead of the VOR defined routes. The new routes that WAAS enables are called "T" and "Q" routes. T routes are low altitude Area Navigation (RNAV) routes (less than 18,000 feet) and Q routes are RNAV routes at higher altitudes (18,000 - 45,000 feet). These routes also can be flown using GPS without being augmented by WAAS. Also, the number of operational VORs in the NAS can be reduced. The FAA is now developing the plan to reduce the number of VOR transmitters in the United States, as well as the number of Instrument Landing Systems (ILS).

WAAS enables the FAA to reduce operations costs by decommissioning ground-based navigation aids.



Evolution of WAAS Service - 2003, 2007, 2014

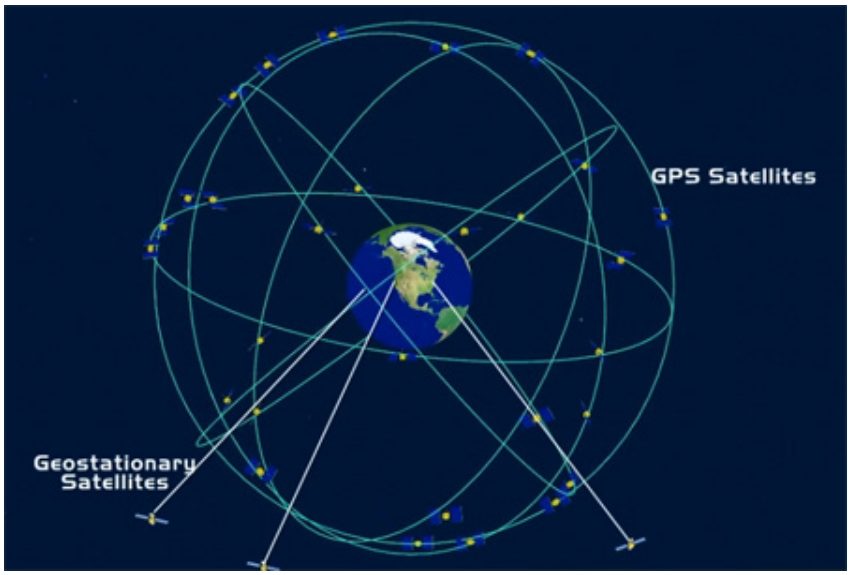
The FAA's policy calls for any new Category I precision approach to be an LPV approach. Aviation use of WAAS continues to grow. More than 100,000 aviation-certified WAAS receivers have been sold, as of September 30, 2014. The FAA estimates that nearly 80,000 aircraft are equipped with the WAAS-LPV capability. FAA analysis also shows an increase in the number of approaches during instrument meteorological

conditions (IMC), and those increases are being attributed to the substantial number of LPV approaches available. Many LPV approaches are published to runway ends that do not have an existing ILS, yet even the runways with an ILS offer greater access and flexibility to pilots who fly LPV using WAAS. For example, a runway with ILS and LPV instrument approach procedures would still support a precision approach if the ILS is out of service.

There are many non-aviation users of WAAS, even though the FAA developed it for aviation use. The system's repeatable and precise positioning supports applications for farming, boating, hiking, surveying, and other many uses. Many GPS chip manufacturers now include WAAS in their chip designs. These GPS/WAAS chips are in many consumer GPS products such as cell phones, automobile navigation units, and other products. The FAA recognizes that WAAS has become a national utility that makes GPS better, even though the FAA does not keep track of non-aviation uses of WAAS.

The future of WAAS includes updating the system with the latest technologies. The FAA will update the WAAS reference station receivers to receive the full set of signals transmitted from GPS satellites. Other components of the WAAS will also continue to be upgraded to ensure the availability of replacement parts in case of component failure.

The FAA also will ensure the WAAS geostationary satellite constellation, currently at three satellites, continues to provide the WAAS corrections to users. The FAA is pursuing new satellite leases with satellite providers as the current geostationary satellite constellation ages. Other future enhancements to WAAS include providing a dual frequency capability that will take advantage of the two civilian GPS frequencies, L1 and L5. When the L5 signal is ready for operation and is being transmitted by a proper number of GPS satellites, the WAAS will be ready to provide dual frequency service to users. Other future enhancements include adding other Global Navigation Satellite System (GNSS) constellations, such as Galileo.



WAAS GEO satellites orbit 22,236 miles (35,786 kilometers) above the equator and orbit at a pace that matches the earth's rotation. This keeps the GEO satellite footprint over the same area of the earth. GPS satellites are in a lower orbit, about 12,500 miles (or 20,200 kilometers), and orbit in six, different orbital planes.

WAAS has been operational for more than 11 years. The system continues to provide accurate and reliable augmentation to GPS. The FAA will ensure that the current level of service will continue and future service will become even better than it is today.

- William Wanner, Manager, Navigation Systems Verification and Monitoring Brand, FAA

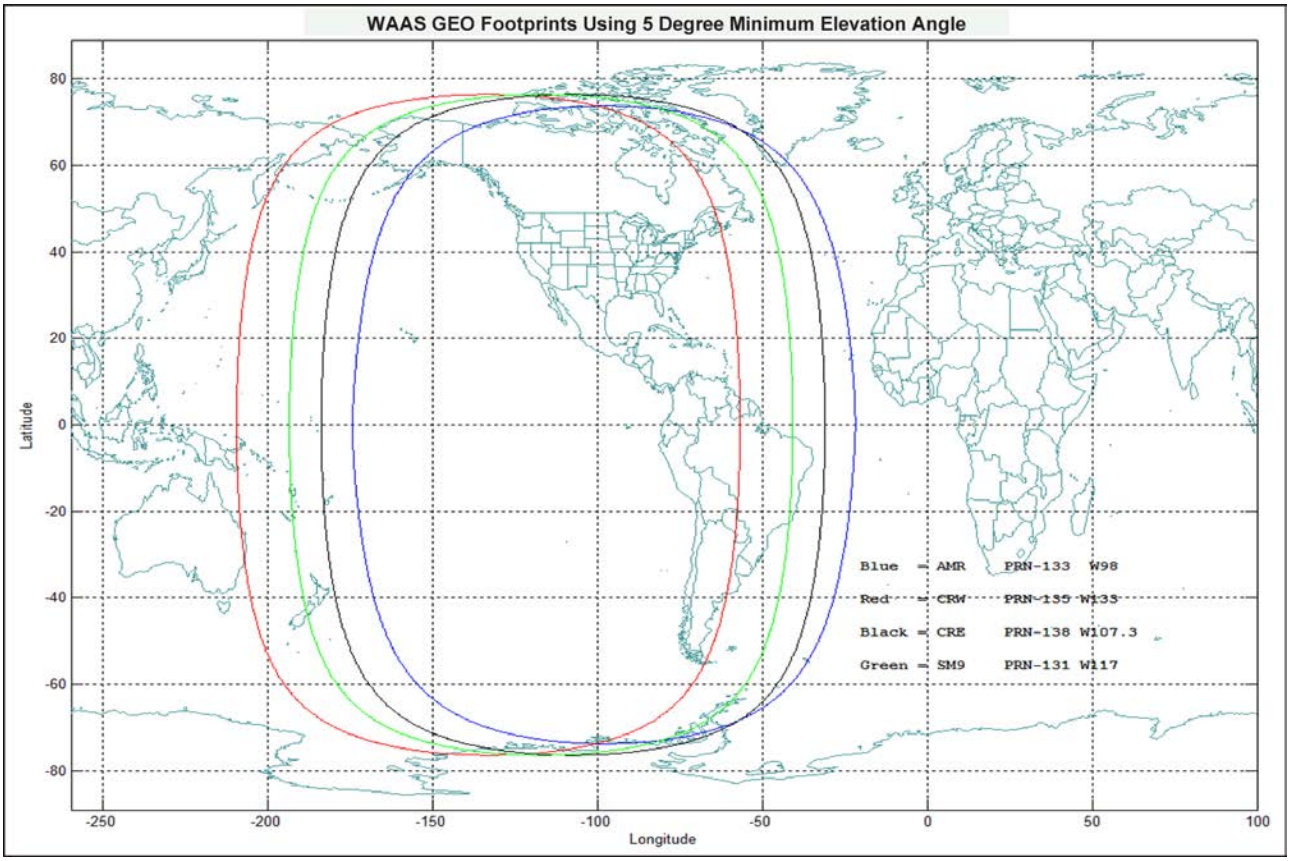
EGNOS Bulletin #13/Q4 2014 and all past issues are also available for download in PDF form at http://www.essp-sas.eu/egnos_bulletin.

Maintaining the WAAS Constellation

The role of geostationary earth orbit (GEO) satellites within the Wide Area Augmentation System (WAAS) is critically important. GEO satellites are the vehicle by which the Federal Aviation Administration (FAA) is able to broadcast WAAS signals over the GEO footprint, which includes WAAS service volumes - contiguous United States (CONUS), Alaska, and the marine regions surrounding CONUS. While Canada and Mexico are outside the WAAS service volume, they also receive and use the WAAS broadcast signal. Currently, the WAAS uses three GEO satellites to serve the WAAS coverage volume.

GEO satellites are selected based on the ability of their orbital locations to provide optimal coverage and sufficient overlap. If one GEO satellite fails, the coverage of the others will provide sufficient continuity of service for WAAS users. The lead time for launching a GEO satellite in a desired orbit location is about four to five years. This is why the FAA is already planning for the next generation of WAAS GEO satellite leases.

The FAA is currently working with industry to identify GEO satellites that can host a WAAS payload. To spread the costs associated with the launch, operation, and maintenance of a GEO satellite, there are often several tenants that share the service of one GEO. Also, the WAAS payload must be developed to ensure compatibility with the host satellite. These considerations reveal why advanced planning and timing is so important.



The footprints of the current WAAS GEO satellites are shown here. As leases on these satellites expire and the GEO satellites reach the end of their useful life, new leases will be secured to meet WAAS service requirements.

The FAA awarded a "WAAS GEO 5/6" contract in September 2012. Since that time, the FAA has been working with Raytheon to develop and integrate the GEO 5 satellite payload and associated GEO Uplink Subsystem (GUS) pair into WAAS. GEO 5 is expected to be operational in October 2017. On March 27, 2015, FAA authorized Raytheon to proceed with the procurement of GEO 6 satellite payload and its associated GUS pair. GEO 6 is expected to be operational in 2019. GEO 5 and 6 will replace current operational satellites nearing the end of their lease terms.

In January 2015, the FAA issued a market survey to industry to assess what other GEO satellite opportunities will be available starting in the time frame from 2017 to 2022. The market survey also specified the desired GEO satellite orbital locations to ensure coverage over the WAAS service volume. Using the information gathered from the survey, the FAA can develop next steps. FAA will use the market survey responses to shape its GEO replacement strategy. For more details on the recent market survey that was conducted, please visit https://faaco.faa.gov/index.cfm/announcement/view/19198

- Mary Ann Davis / Ranjeet Shetty, FAA AJM-321/NAVTAC

New GPS IIF Satellite Goes Operational

On March 25, 2015, the ninth Global Positioning System (GPS) IIF satellite was launched and is expected to be operational by the end of April. GPS IIF satellites were first introduced into the GPS constellation in 2010 and additional IIF satellites will be introduced in the future. IIF satellites are being developed and launched as a part of the sustainment activities for the GPS constellation; but, they also add new capabilities. Most notable of these capabilities is the provision of the L5 signal. As noted by the GPS.GOV New Civil Signals web page, L5 is "broadcast in a radio band reserved exclusively for aviation safety services. It features higher power, greater bandwidth, and an advanced signal design". The name, L5, refers to "the U.S. designation for the radio frequency used by the signal (1176 MHz)". The availability of L5 will improve GPS accuracy, interference mitigation, and signal robustness." The IIF satellites also include improved atomic clocks. To learn more about the GPS constellation and IIF satellites, please visit the GPS.GOV Space Segment page.

GPS IIF satellite - Image courtesy of GPS.gov multimedia library

- Mary Ann Davis, FAA AJM-321/NAVTAC

Satellite Navigation Approach Procedures Update

The tables shown here reflect the continuing growth of satellite-based approach procedures as compared to the inventory of instrument approach procedures based on conventional NAVAIDs. 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

	Procedures (Part 139 Airports)	Procedures (Non-Part 139 Airports)	Total Number of Procedures
RNAV (GPS) Approach **LNAV Line of Minima**	1,765	4,180	5,945
RNAV (GPS) Approach **LNAV/VNAV Line of Minima**	1,370	2,039	3,409
RNAV (GPS) Approach **LPV Line of Minima**	1,377	2,157	3,534
Non-ILS runway	*52*	*1,586*	
ILS runway	*1,325*	*571*	
RNAV (GPS) Approach **LPVs w/200' HAT**			914
RNAV (GPS) Approach **LP Line of Minima**	81	505	586
GPS Approach **GPS Stand-Alone Procedures**	11	104	115
GLS Approach	11	0	11

(Data as of April 2, 2015)

Instrument Approach Procedures (IAPs) Based on Conventional NAVAIDS

ILS	1,277
ILS (CAT II)	153
ILS (CAT III)	118
NDB	716
VOR	1,236
VOR / DME	936

(Data as of March 5, 2015)

More information is available on the FAA Inventory Flight Procedures (IFP) Inventory Summary at https://www.faa.gov/air_traffic/flight_info/aeronav/ procedures/ifp_inventory_summary/

On the Web

Where can you find FAA Satellite Navigation program information between editions of the SATNAV News? On our website, at http://gps.faa.gov, you can read about GPS, WAAS, and GBAS; browse an archive of past SATNAV News editions; and download a variety of fact sheets.

What's New?

Three-dimensional animations have been added to our GPS - How It Works web page and to our WAAS - How It Works web page. Please visit our website at http://gps.faa.gov to learn more.

- Mary Ann Davis, FAA AJM-321/NAVTAC

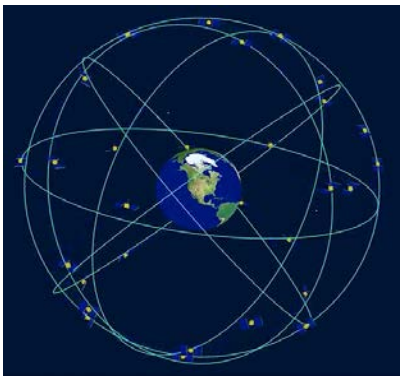


Image from: "GPS: How It Works" animation

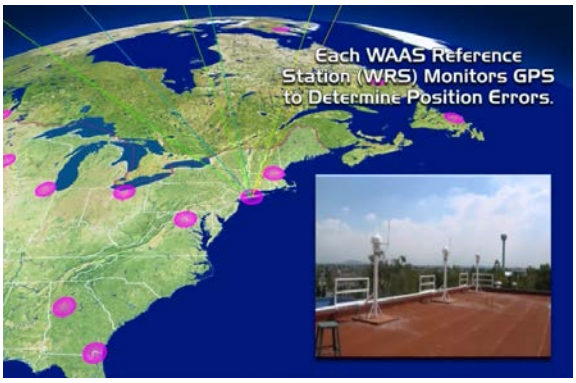


Image from: "WAAS: How It Works" animation