SatNavNews

Volume 75 Fall/Winter Edition

http://gps.faa.gov

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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).

William J. Hughes Technical Center evaluation of ARAIM

The Global Positioning System (GPS) has been an enabler of a safe and efficient aviation system since its adoption in 1994. GPS integrity, the confidence that the information provided by GPS is correct, needed enhancement to meet civil aviation requirements. To assure the integrity of GPS, aviation receivers implement a technique called Receiver Autonomous Integrity Monitoring (RAIM). RAIM allows aviation receivers to detect a GPS satellite fault and in many cases isolate the offending satellite and remove it from usage by the receiver. However, RAIM provides integrity only for horizontal operations, such as en-route and non precision approach. Additional integrity is needed to allow advanced capabilities, such as vertically guided approaches. Other integrity systems, like the FAA's Wide Area Augmentation System (WAAS), have been developed to provide the integrity needed to permit these additional operations.

GPS, and other Global Navigation Satellite Systems (GNSS), have evolved to improve their performance and have been upgraded to add an additional civilian signal. These improvements invite initiative to develop new integrity architectures. One such integrity architecture is Advanced RAIM (ARAIM). ARAIM addresses various weaknesses that exist with RAIM. For example, ARAIM increases the geometric diversity and integrity availability by using two core GNSS constellations (like GPS and Galileo, the European GNSS). ARAIM takes advantage of the second civilian signal by specifying dual frequency processing so the ionospheric error from GNSS signals is directly measured by the user equipment. The ionosphere is in most cases the largest source of error in a GNSS signal, and the ionosphere can also reduce the integrity of GNSS signals. Data provided for ARAIM use can include improved performance commitments from the GNSS constellation. RAIM uses static values for those performance commitments.

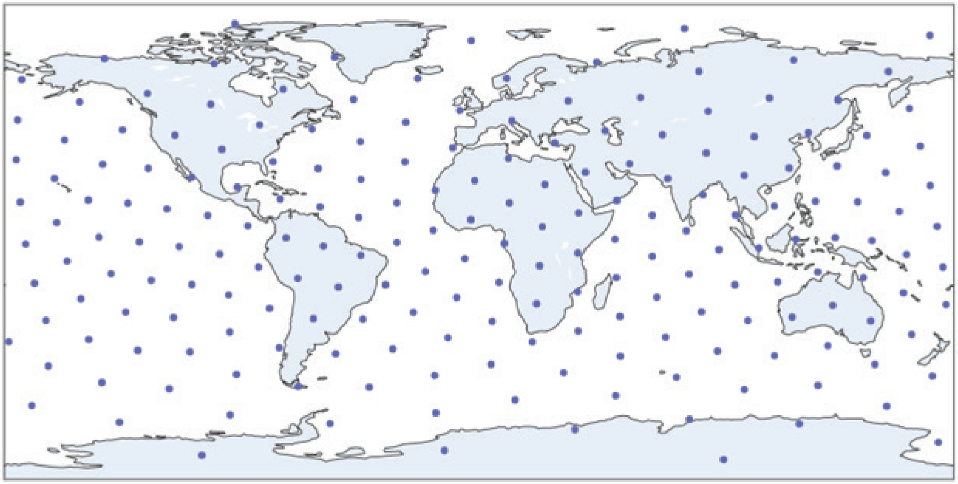


Figure 1 – MPE User Locations

"ARAIM allocates the integrity burden between the space, ground, and user segments."

ARAIM is a dual frequency multi constellation (DFMC) application that has the goal to allow LPV-200 approaches worldwide. ARAIM is an Aircraft Based Augmenation System (ABAS) since the algorithm to determine GPS integrity is in the aircraft receiver, just like RAIM. For example, the ARAIM could utilize the GPS and Galileo satellite navigation signals to achieve the worldwide LPV-200 goal. Those two GNSS constellations are compatible with each other and provide the necessary signals for a receiver to use in the ARAIM algorithm.

ARAIM is envisioned for aviation use, though any user that has strict integrity requirements could also implement ARAIM. As opposed to WAAS, a system that employs ground equipment to determine GPS integrity, ARAIM allocates the integrity burden between the space, ground, and user segments. The integrity needed for LPV-200 service is achieved by ARAIM because of the number of satellites available in the two GNSS constellations.

An important aspect of ARAIM is the Integrity Support Message (ISM). The ISM contains the Integrity Support Data (ISD) that describe a GNSS constellation's accuracy and reliability. Each GNSS constellation service provider generates and updates the ISD data. The receiver manages and uses each GNSS constellation ISM. The specific ISD parameters have not yet been finalized but candidate data includes the probabilities of satellite and constellation (i.e. more than two satellites fail due to a common cause) failure, and user range error and user range accuracy data, and other candidate data. The ISD will be finalized when the International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs) with the ARAIM requirements are completed.

To ensure the data provided in the ISM remains valid, external monitoring is needed. The external monitoring ensures the satellite and constellation failure probabilities provided in the ISM continue to be valid. External monitoring also characterizes the user range accuracy and user range error in the ISM. The WAAS Test Team at the FAA William J Hughes Technical Center (WJHTC) has begun to monitor these ISD parameters using evaluation tools and methods developed by the Technical Center and Stanford University. The results of this monitoring are published in a quarterly report available at the WAAS Test Team website *(https://www.nstb.tc.faa.gov/)*.

The current quarterly ARAIM report evaluates GPS with respect to the metrics listed above. The goal of the data analysis process is to determine whether the behavior of the observed data is consistent with the underlying assumptions and the commitments from the GNSS constellation service provider. The offline analysis uses two data sources: broadcast GPS data and post processed precise GPS ephemeris data. The broadcast navigation data consists of satellite orbit and clock parameters and includes User Range Accuracy (URA) values that indicate the expected level of accuracy. The precise data consists of GPS ephemerides and clock parameters. A subset of the GPS broadcast legacy navigation (LNAV) data is available from receivers in the International GNSS Service (IGS). Precise GPS ephemerides and clock are available from the National Geospatial-Intelligence Agency (NGA). The ARAIM quarterly report includes GPS performance data from January 1, 2008 to present. Future reports will add the Galileo constellation to the analysis. Also, additional metrics will be evaluated in future reports.

The broadcast navigation data as received from IGS sometimes contains defects (such as duplications, inconsistencies, discrepancies, and errors) that can cause false anomalies. A cleansing algorithm is applied to the IGS data to generate "validated" navigation messages, which have as many of these defects removed as possible. For each time step where precise data are available, the most recent prior validated broadcast navigation data are used to propagate the satellite orbits and clocks. At each data point for which both sources indicate a healthy signal and valid data within the fit interval, the satellite position error is determined by calculating the difference between the NGA-derived reference value and the calculated, propagated satellite position. The satellite position error is also projected onto the Earth to produce the maximum projected error (MPE) and projected along the lines of sight to individual user locations on Earth to produce user projected error (UPE). See Figure 1 for the MPE user locations.

The quarterly report includes additional analysis to ensure GPS continues to meet the performance commitments. Various analyses examining the statistical performance of GPS are included in the report. Parameters such as User URA, signal in space range error (SISRE), satellite position errors, satellite clock errors, and fault probabilities for GPS satellites and the constellation are all evaluated. The different types of views include statistical plots, such as probability, residual error over time, histograms, one minus cumulative distribution function (1-CDF) plots, and data tables, partitioned by satellite, block types, and composite. Block type means the different manufacturing versions of GPS satellites. For example, the current GPS constellation includes Block IIR, IIR-M, IIF, and III satellite types.

For GPS, an integrity error has occurred if the SISRE is greater than 4.42 times the broadcast URA for each satellite with the conditions that the URA is valid and no timely alert has been provided. URA is a statistical measure of GPS ranging accuracy and provides a level of integrity to the user. To ensure that no integrity error has occurred, the SISRE is evaluated. The monitoring of the URA parameter assesses the integrity of the ephemeris and clock data in the broadcast navigation messages, by evaluating the URA bounding performance of nominal, fault-free range errors.

The position and clock errors of each GPS satellite is also evaluated. The assessment breaks the errors into three components, the radial, along track, and cross track (RAC) errors. Clock errors for each satellite are also calculated. Figure 2 shows an example of the RAC, clock, and SISRE errors that is produced for the report. In this chart the center tick mark is the 68% mark of the error distribution and the upper and lower fences show the 95% area of the error distribution.

The probabilities and rates of GPS satellite and constellation failures are critical fault parameters for ARAIM. The other key ISD is the mean fault duration (MFD). These parameters are expected to be included in the ISM and are based upon GPS commitments and are supported by observational history. The report documents the GPS service history to assess the GPS the probabilities and MFD. A running list of GPS constellation faults since 2008 are documented in the report.

ARAIM takes the well known RAIM concept to a new level for GNSS integrity. The technology takes advantage of additional GNSS constellations and advances in GNSS technology. Though the standards for ARAIM are not finalized, evaluation of ARAIM criteria can be analyzed. The WJHTC has begun to analyze ARAIM and publishes the results in a quarterly report. Plans are in place to add Galileo and other assessments to the report. The offline assessment of ARAIM is essential to ensure the commitments made by GNSS constellation providers continue to be valid.

- Bill Wanner, FAA ANG/WJHTC

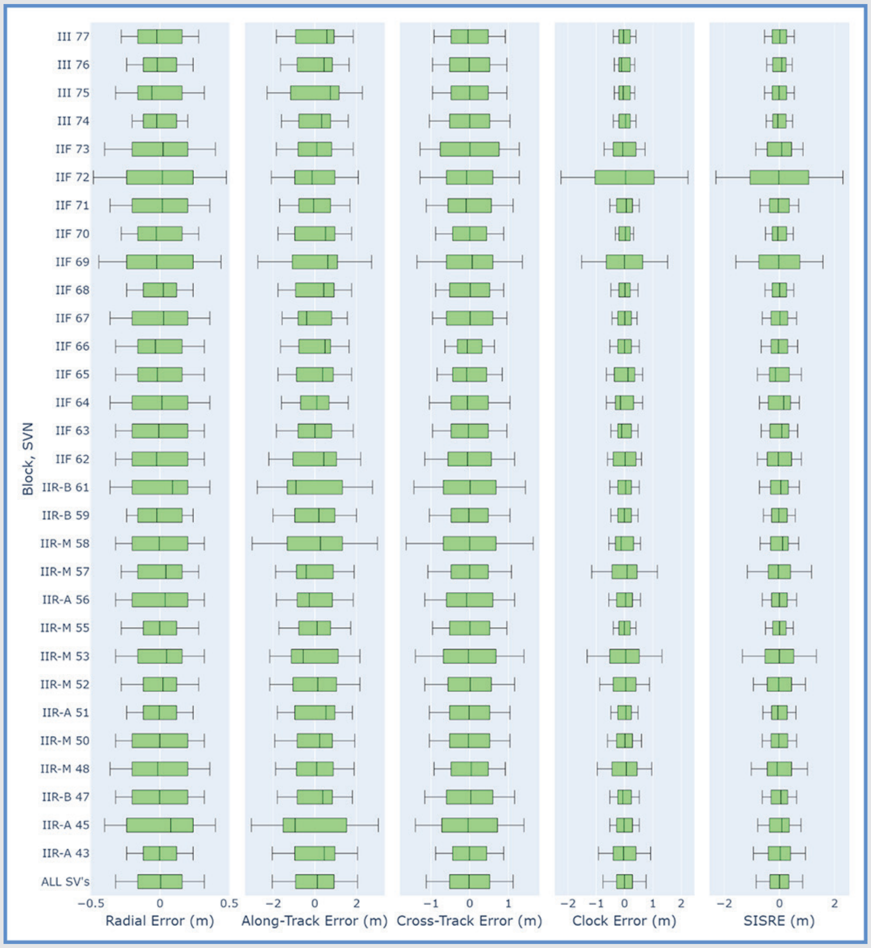


Figure 2 – Example of the RAC, Clock, and SISRE Errors Box Plot

WAAS LPV/LPs

As of 12/29/2022 there are:

4,112 LPVs

1,993 airports served

1,228 are non-ILS airports

734 LPs

537 airports served

436 are non-ILS airports

This graphic reflects the continued growth of satellite-based LPV/LPs approach procedures. For more detailed information please visit: http://www.faa.gov/about/office_org/ headquarters_offices/ato/service_units/techops/navservices/gnss/approaches/index.cfm

Space Force enhances GPS ground communications for greater resiliency

Reprint from *GPS World* December 19, 2022
By Tracy Cozzens

"The GONE initiative "has significantly enhanced communications for GPS . . . "

Kwajalein Atoll in the Marshall Islands is one of seven locations that received a GPS communications network overhaul. (Photo: USGS)

Modernized communications lines were installed at seven locations worldwide in an overhaul of the global communications network that provides command and control of the GPS constellation.

From 2018 to 2022, GPS Product Support Delta — in conjunction with the Defense Information Systems Agency (DISA) — performed a complete overhaul of the global communications network required to provide command and control of the GPS satellite constellation. GPS Product Support Delta is under Space Systems Command of the U.S. Space Force.

The project, called GPS Operations Network Enhancements (GONE), connected multi-protocol label switching internet protocol (IP)-based routers to modernized communications lines at seven key GPS facilities, replacing older serial lines.

The GONE initiative "has significantly enhanced communications for GPS weapon systems," said Brian Botka, Product Support Delta GPS program manager.

"These upgrades not only increase communications speed and reduce overall down-time and adding a new paradigm in network resiliency with the networks capable of recovering in mere seconds from an outage or issue," said Sean Foley, DISA technical project manager. "The system upgrades will continue to improve service to the warfighter as well as enable increased resiliency and network diversity for DISA."

The modernized communications lines were installed at

- Schriever Space Force Base, Colorado
- Vandenberg SFB, California
- Cape Canaveral Space Force Station, Florida
- Facilities in Hawaii, Ascension Island, Diego Garcia and Kwajalein Atoll.

Throughout the COVID-19 pandemic, many of these locations were under strict lockdown or required long quarantine periods, making coordination and travel to remote locations more challenging.

Lockheed Martin was the contractor who supported Product Support Delta GPS on the GONE project. "This was a collaborative effort with Product Support Delta GPS and DISA that required significant logistical efforts due to the COVID-19 pandemic," said Christina Mancinelli, Lockheed Martin GPS Ground Programs director.

"With the GONE project completed, we are seeing a 75 percent reduction in communication line interruptions, and we expect that metric to continue to improve," Mancinelli said. "The migration of the GPS communication lines to the modern MPLS [multiprotocol label switching] routers and Ethernet-based connections continues the significant improvements in GPS ground capability, cybersecurity and reliability."

SSC is the USSF field command responsible for rapidly identifying, prototyping, and fielding resilient space capabilities for joint warfighters. It delivers sustainable joint space warfighting capabilities to defend the nation and its allies while disrupting adversaries in the contested space domain.

SSC mission areas include launch acquisition and operations; space domain awareness; positioning, navigation, and timing; missile warning; satellite communication; and cross-mission ground, command and control and data.

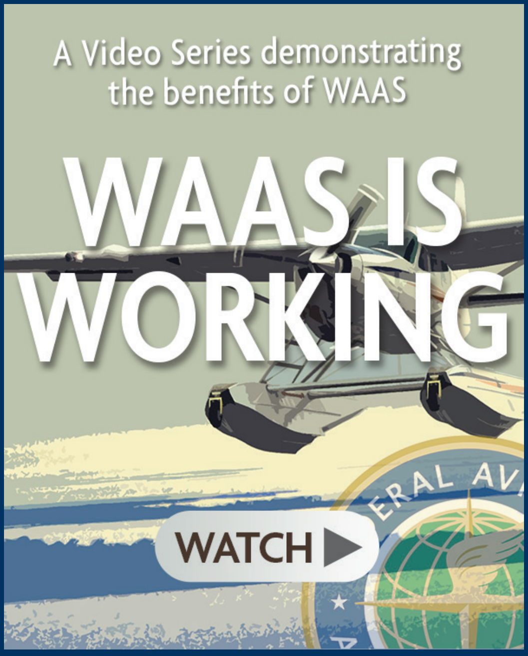
> "With the GONE project completed, we are seeing a 75 percent reduction in communication line interruptions"

WAAS is Working

A Video Series demonstrating the benefits of WAAS

Featuring: Horizon Air, the Goodyear Blimp, MedStar, Miss Virginia, Floatplanes in Alaska and Mid Atlantic Angel Flight

. . . 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 Amy Trevisan at: amy.ctr.trevisan@faa.gov



Satellite Based Augmentation System (SBAS) Interoperability Working Group (IWG)

Satellite Based Augmentation System (SBAS) providers from around the world, met in Antananarivo, Madagascar for the 37th meeting of the SBAS Interoperability Working Group (IWG) from November 2-4, 2022. The Agency for Aerial Navigation Safety in Africa and Madagascar (ASECNA) hosted the meeting, with warm welcomes from Madagascar's Minister of Transport and Metrology, the Honorable Roland RANJATOELINA, and from Louis Bakienon, the director of ANGA on behalf of ASECNA Director General, Mr. Mohammad Moussa.

This was the first SBAS IWG meeting since February 2020 with six of the nine SBAS providers attending in person. The SBAS IWG provides an opportunity for the coordination of SBAS standards and operations as a means to promote interoperable development and deployment of SBAS systems and operations.

IWG-37 included one and a half days of parallel meetings of the Technology Subgroup (TSG) and the Operations Subgroup (OSG) and a day of plenary meetings. The OSG included an on-line interaction and coordination with industry and airlines. Several ASECNA members had representatives from their respective Civil Aviation Authorities, including Comoros, Madagascar, and Rwanda. Additionally, the IWG welcomed representatives from the Civil Aviation Authorities of Mauritius and Seychelles.

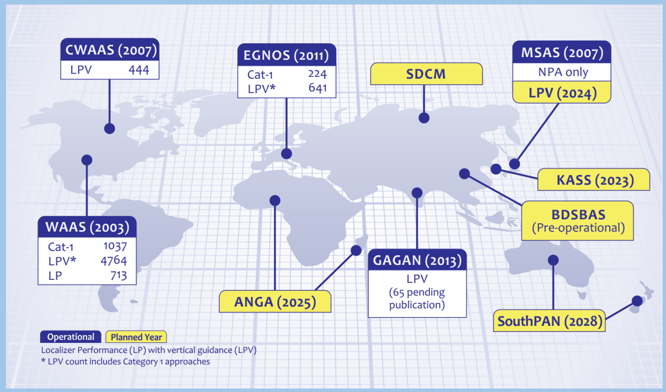
The plenary received briefs from SBAS providers on the status of current SBAS systems and the planned deployment schedules for new SBAS systems. SBAS providers continue to make progress with the deployment of new SBAS systems and services. Europe (EGNOS) and the United States (WAAS) both have contracts for the development and deployment of dual-frequency SBAS services using the SBAS L5 frequency around 2027. ASECNA (ANGA) is targeting initial L1 SBAS aviation services between 2025 and 2028, followed by dual-frequency services sometime after 2030. Australia and New Zealand (SouthPAN) are targeting certified L1 SBAS aviation services in 2028. South Korea sent a video presentation about KASS, which is making progress towards L1 SBAS certification in 2023.

The TSG reviewed status and progress since the last meeting and reviewed some options for future service enhancements. In particular, there was a review of progress for dual-frequency, multiple constellation SBAS equipment standards. The meeting reviewed options to update the DFMC SBAS Vertical Protection Level equation to account for correlated troposphere error. The meetings also reviewed some presentations on potential future changes, including discussion of SBAS authentication and improvements that might support lower minima. The meeting discussed how SBAS systems that decrease the fast correction update rate might operate in a test configuration. The current practice to send Message Type 2 content in a Message Type 0 will not be representative of these systems. Therefore, SBAS providers are exploring alternate content to place in the Message Type 0 during test operations.

The OSG discussed the operational implementation of SBAS, the deployment of SBAS services with updates on number of LPV procedures by EGNOS, WAAS, GAGAN and ANGA's update on initial demonstration services in Africa with a network of 11 GNSS stations, an uplink in Abuja and the use of Nigcomsat-IR Geo satellite. Follow on demonstrations are planned for 2023.

The SatNav Africa JPO provided their approach to the Africa SBAS business case with initial positive results for the Aviation

Identifier	SBAS
0	WAAS (US)
1	EGNOS (Europe)
2	MSAS (Japan)
3	GAGAN (India)
4	SDCM (Russia)
5	BDSBAS (China)
6	KASS (Korea)
7	ANGA (ASECNA)
8	SouthPAN (Australia and New Zealand)



"SBAS providers continue to make progress with the deployment of new SBAS systems and services."

market but also Agriculture, Maritime , and Geo-Information. EUSPA presented an interesting approach to provide EGNOS LPV services at non-instrumented runways and will start a pilot project in 2023 at 3 European airports.

Another aspect of the OSG was the integration of non working group members (OEMs, airlines, avionics manufacturers) to provide and exchange information on SBAS integration and implementation in a specific Guest Session. Airbus, ATR, and Boeing provided short updates on their LPV implementation with forward fit capability .

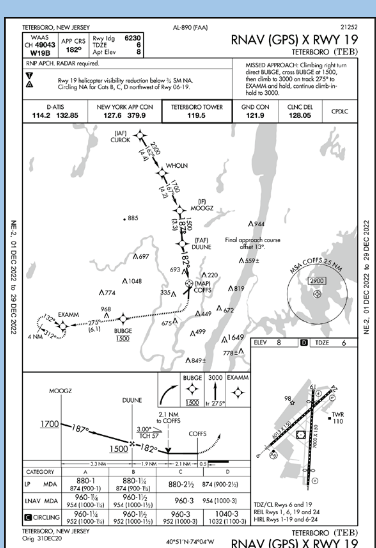
Airbus has LPV capability for A330/A350/A380/A220/A320. ATR 42/72 aircraft models 500/600 have LPV capability. Boeing has planned SBAS implementation for B777X, B737-10 and B737MAX with iMMR or GLU2100 equipage. The most detailed airline implementation strategy was presented by Delta Air Lines outlining aircraft type and locations where the specific fleet can operate. Additionally, they addressed equipage numbers and outlined crew training aspects highlighting A220 and A350. SBAS/LPV flight crew training is conducted during initial and recurrent training in the respective simulators and SBAS/LPV cockpit procedures are similar to GPS, RNAV (GPS/GNSS), RNP and GLS approaches with only two small differences in the selection process. In Japan HAC, a member of the JAL group, will start using LPVs after they are certified for use in Japan. The current projection is September 2024.

The Guest session was closed with presentation of avionics manufacturers addressing their capabilities for GNSS and SBAS avionics, for Collins the GLU-2100 used on Airbus and certain Boeing aircraft and for CMC with the CMA 504 another forward and retro-fit options for Boeing and Airbus airframes.

ASECNA is planning to hold an outreach event to encourage SBAS adoption for aviation in Africa. While not an SBAS IWG meeting, SBAS IWG members are invited to attend. ASECNA will hold the outreach event in conjunction with an SBAS flight demonstration event in Abuja, Nigeria in the first quarter of 2023. For more information please use the following email contact : *event@satnav-africa.com; MPwajok@nama.gov.ng; jolawode@nama.gov.ng; hjibrin@nama.gov.ng; lasisi@nigcomsat.gov.ng; contact@anga-africa.org*

- Dieter Guenther FAA AJM-32/NAVTAC

Noise mitigation at Teterboro



Area Navigation (RNAV) procedures are frequently used for mitigation of noise since aircraft can usually be routed more precisely using RNAV than other Air Traffic Control (ATC) procedures.

Teterboro Airport (TEB) is in New Jersey just northwest of New York City and near numerous noise sensitive areas. Most of the traffic into TEB is general aviation—principally business aviation. Noise has been a continual difficulty for years.

TEB has Instrument Landing System (ILS) and RNAV (LPV, LNAV/VNAV, and LNAV) approaches to Runway 19 providing vertical and non-precision guidance to the runway. However, these approaches are straight in and fly over noise-sensitive areas north of the airport. To mitigate some of the noise and still retain predictable flight paths, the FAA has designed an RNAV approach to Runway 19 at TEB (RNAV(GPS) X RWY 19) that is offset to the right of the runway centerline. This offset helps reduce noise in some of the areas that are under the flight path of the straight-in approaches.

The RNAV (GPS) X RWY 19 approach has both GPS LNAV and WAAS LP lines of minima. Although the LNAV and LP approaches are not vertically-guided, both approaches have a Vertical Glidepath Angle (VGA) that allows most aircraft, especially those with WAAS avionics, to follow advisory vertical guidance to the runway. So, the approach reduces noise but retains most of the benefits of vertical guidance.
This is a link to the National Business Aircraft Association (NBAA) description of the approach, including a video of community leaders encouraging the use of the approach:
https://nbaa.org/aircraft-operations/airports/teb/local-officials-urge-pilots-to-use-community-friendly-alternate-teb-approach/

New RNAV RNP procedure enables safer approaches and landings at Eagle County Airport

Reprint from *Aviation Today* October 26, 2022
By Woodrow Bellamy III

In August 2021, I participated in an inspection flight of a new approach procedure at one of the most challenging airports to land at in the U.S., Colorado's Eagle County (KEGE) with Hughes Aerospace CEO Chris Baur in a TBM 850 equipped with Garmin avionics. Using the RNP and point-in-space landing capabilities of the aircraft's advanced navigation systems, Hughes was able to deploy a new RNP AR approach into Eagle County that went live earlier this year.

Equipped with one runway measuring 9,000 feet, the approach to land at Eagle County is challenging because the mountainous terrain and nearby airports that surrounds it making the missed approach procedure challenging for even the most skilled professional pilots. In 2010 as the most famous example, Eagle was ranked as the world's eighth most extreme airport in a special feature broadcasted by The History Channel.

The airport is situated within a valley inside the Rocky Mountains, with an elevation of more than 6,500 feet above sea level.

Located 37 miles from Vail, the lone runway at Eagle County is surrounded by mountainous terrain with publicly available procedures that require pilots to use decision heights of more than 1,700 feet and three miles of visibility. Using RNAV RNP, Baur and Hughes Aerospace have established a new approach procedure with a decision height altitude of 282 feet and a half a mile of visibility.

"This approach has the lowest minimums of any published instrument procedure at Vail/Eagle County Airport. The other instrument procedures have significantly higher ceiling & visibility minimums, lack runway alignment, may position the aircraft closer to terrain, and have a challenging missed approach," Baur told Avionics International.

Flying the approach in the TBM showed how much easier its descent angles and better avoidance of the terrain. The runway is situated within a valley area of the Rocky Mountains, where the mountainous terrain can range from 11-12,000 feet or more.

Pilots must fly over and through a gap in the mountains and slowly descend down into the valley where the lone runway sits to land at Eagle. Visibility can be quickly reduced by surprise snow storms or squalls. Lateral movement of the aircraft is also limited as you descend down into the valley because of the surrounding mountains and terrain.

Hughes Aerospace's newly deployed RNAV (RNP) Q approach procedure to Runway 25 at Eagle County takes advantage of advanced navigation systems featured in modern cockpits, such as the Hughes TBM 850. It means smoother descent angles for pilots, allowing them to smoothly coast in between the mountains surrounding the downward glide slope into the runway, landing a few hundred over the runway center line.

According to reports on the use of the new approach several airline pilots on the first day of its becoming available through special FAA authorization, Baur said, it prevented several aircraft from diverting.

Many aircraft today are equipped with contemporary avionics capable of supporting Performance Based Navigation (PBN). Extracting the value of these avionics is achieved through the extensive use of PBN, reducing

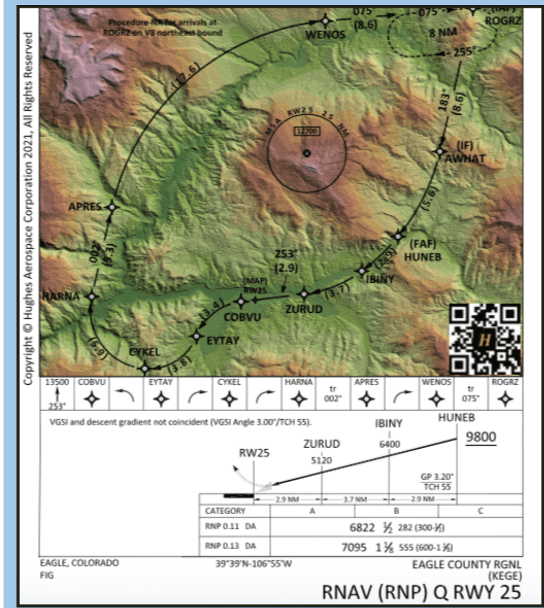
A view of the RNAV RNP approach developed by Hughes Aerospace into the runway at Eagle County Airport. (Photo: Hughes Aerospace)

The cockpit of the Hughes Aerospace TBM 850.

pilot-controller workload, mitigating terrain & obstacles in a trajectory vs linear based lateral navigation as well as vertical navigation," Baur adds.

Furthermore, the new approach features the strategic use of radius to fix legs to overfly the lowest possible terrain path from the initial approach fix to the runway. For RNP AR qualified pilots, it becomes a much smoother approach with shallower bank angles into the RF leg turns.

Lowering the landing minimums from decision height in the previously available approaches at KEGE are the



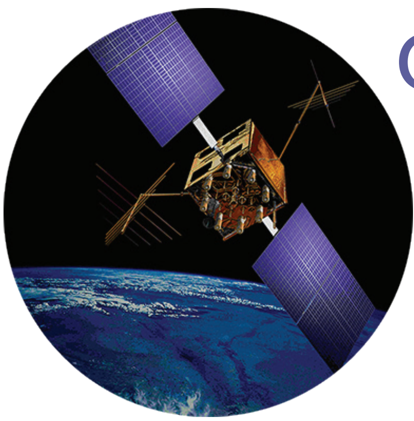
The RNAV RNP approach developed by Hughes Aerospace

clear star of the near approach though. Eagle County is located in the state that receives the fourth-highest amount of snowfall annually in the U.S., often causing lower ceilings enforced by air traffic control at the airport.

According to an article published by the Eagle County airport's authority in February, the airport set monthly passenger record numbers in 2021, recording its highest number of enplanements from the airport's lone runway since 2008. Some of the factors the airport attributes traffic growth to include the addition for summer service to Atlanta and Chicago, long with year-round service to Denver.

In 2022, the airport is experiencing continued growth in traffic. American Airlines, United and Delta Airlines conduct the most airline operations of all U.S. carriers to Eagle County, according to the article.

"The automation allows the pilots to focus on monitoring the performance, detecting and reacting to an undesired aircraft state immediately. This is in contrast to 'being the performance' potentially becoming task saturated while flying & navigating a legacy process," Baur said.

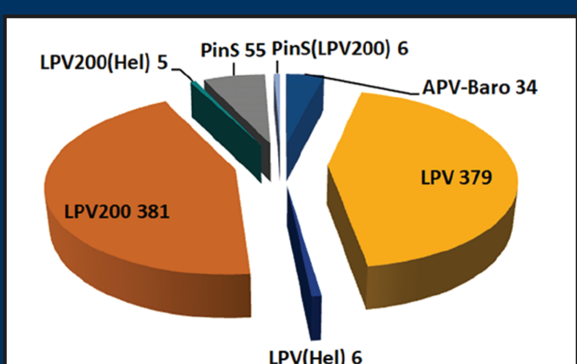


GPS Information

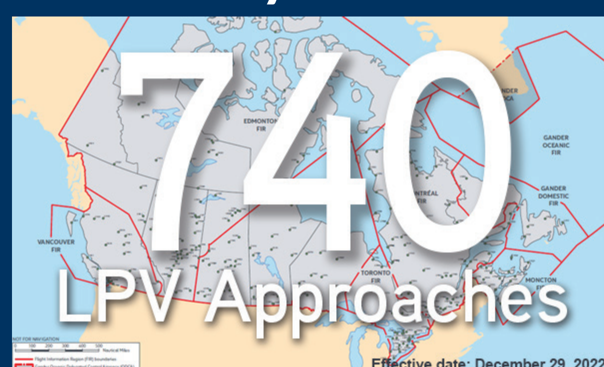
December 14, 2022: Cybersecurity and Infrastructure Security Agency (CISA) released a new Insights titled *CISA Insights: Global Positioning System (GPS) Interference*, which provides a summary of a January 2022 GPS interference event, recommended actions GPS users should take now to make their system resilient and avoid degradation of services, as well as guidance on how and when to report GPS interference.

Download/share the *CISA Insights: Global Positioning System (GPS) Interference*

LPVs Internationally



The number of LPVs in Europe is also growing. The graphic shows LPV procedures in Europe as of November 3, 2022. https://egnos-user-support.essp-sas.eu/new_egnos_ops/news-events/egnos-bulletin



Canadian WAAS LPVs provided by NAV CANADA
as of December 29, 2021
(click for map)