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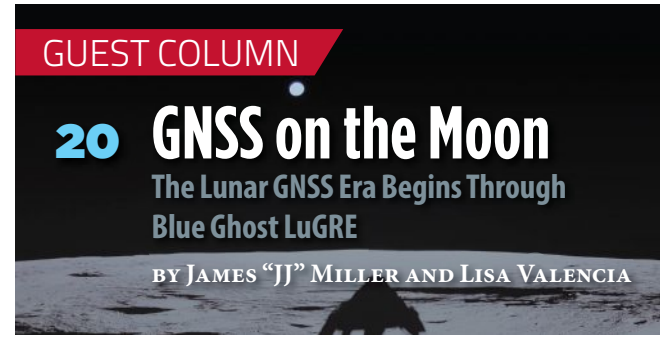
APRIL 2025

WingXpand

COVER STORY



Firefly Aerospace

GUEST COLUMN

ON THE COVER

On Feb.11, 2025, U.S. Air Force F-16 Fighting Falcons fly a presence patrol over the U.S. Central Command area of responsibility, which encompasses the Middle East, Central Asia and parts of South Asia, including Egypt, Jordan, Syria, Iraq, Israel, Kuwait, Saudi Arabia, Bahrain, Qatar, Oman, Yemen, Iran and Afghanistan. (U.S. Air Force photo by Staff Sgt. Jackson Manske)

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ONLINENOW

NEWS STORY

FCC to Meet on GPS Alternatives

BY DANA GOWARD
PRESIDENT
RESILIENT NAVIGATION AND TIMING FOUNDATION

Federal Communications Commission (FCC) Chair Brendan Carr announced in a March 5 blog post that the commission would be addressing GPS alternatives along with Next Generation 911 issues at its next meeting.

Pledging that "public safety and national security will be top priorities for us at the FCC" along with quick action on related issues, Carr said the commission's March 2025 open meeting will start "with an inquiry that explores alternatives to GPS."

Describing GPS as indispensable but not infallible, Carr's post showed a substantial appreciation of PNT and GPS alternative issues as well as much of the related policy history. It also cites President Trump, Sen. Cruz and Sen. Markey as advocating action to "ensure we have a resilient system in place."

In 2020, President Trump issued Executive Order 13905 on "Strengthening National Resilience Through Responsible Use of Positioning, Navigation and Timing Services." Designed to stimulate the adoption of open-market commercial solutions, it does not seem to have made the nation's PNT substantially more resilient in the intervening five years. This may be because GPS is free, and the government has provided time and navigation as free utilities for hundreds of years. Also, many GPS users may be unsure about the need for alternatives since the federal government has not yet acted to protect itself with an alternative system. Potential users are also reluctant to purchase commercial PNT services as they are unsure which commercial services will have the longevity to make the cost and effort of adoption and integration worthwhile.

Read the full column at **gpsworld.com/opinions/.**

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FCC Meets to Strengthen PNT

The fire at an electrical substation that shut down London's Heathrow Airport, Europe's busiest hub, for 18 hours on March 21 was one of many periodic reminders of the vulnerability of much of our critical infrastructure to a single point of failure (SPOF). A previous one was the CrowdStrike software bug that disrupted hospitals, airlines, banks and scores of other businesses and services around the world on July 19, 2024. Think of the impact on your home or business if the power went out for hours or days, and you did not have a backup generator and/or solar panels.

Our society's and economy's enormous reliance on global navigation satellite systems (GNSS) for positioning, navigation and timing (PNT) makes GNSS a huge SPOF. Hence repeated and urgent calls for increasing the resilience of GNSS and for developing complementary and/or alternative sources of PNT (or, to use the mantra of the National Space-Based Positioning, Navigation and Timing Advisory Board in recent years, to "protect, toughen and augment" GNSS).

Yet, at least two existing directives for strengthening PNT have not been implemented: The National Timing Resilience and Security Act of 2018 directed the U.S. Department of Transportation to ensure establishment of at least one terrestrial timing system as a backup for GPS signals, and President Trump's January 2021 Space Policy Directive 7 ordered the entire U.S. government to "identify and implement … alternative sources of PNT for critical infrastructure, key resources and mission-essential functions."

Awareness of the key importance and vulnerabilities of GNSS and of the urgent need to develop complementary and/or alternative technologies has reached the U.S. Federal Communications Commission (FCC). It dedicated its March 27 open meeting to hearing recommendations on "promoting the development of PNT technologies and solutions," which it deems "crucial for national security, public safety and economic stability."

The Notice of Inquiry (NOI) that the FCC issued in preparation for the meeting is a thorough and very useful compilation of relevant policies, programs, initiatives, reports and policy documents. I highly recommend reading it. Clearly, the commission did its homework — in the footnotes, it cited four *GPS World* articles among its sources — and demonstrated that it understands the key challenges for GNSS, the options for complementary/alternative systems and the relevant policy history. (See Dana Goward's March 7 article on this at **gpsworld.com/fcc-to-meet-on-gps-alternatives/**) The NOI also posed 94 questions to which the FCC seeks answers.

The FCC meeting, available on YouTube, was of great importance to the whole GNSS/PNT community. While the commissioners did not vote to support any existing or proposed PNT system, they engaged in a broad discussion of the issues and heard petitions from NextNav and the National Association of Broadcasters (NAB) related to the provision of nationwide PNT services. NextNav requested spectrum for its project to work with telecom providers. NAB sought to accelerate and mandate implementation of the new ATSC 3.0 television broadcast format, which includes signals for its Broadcast Positioning System. Regarding the latter, see my Q&A with the NAB starting on page 16.

Matteo Luccio | EDITOR-IN-CHIEF
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GNSS POSITIONING NAVIGATION TIMING
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EDITORIAL ADVISORY BOARD

I am pleased to announce that **Paul McBurney, Ph.D.**, has agreed to join *GPS World's* Editorial Advisory Board. He is currently CTO and co-founder of OneNav. Prior to that, McBurney was a GNSS architect at Apple. He was co-founder and CTO of eRide, a fabless semiconductor company specializing in high sensitivity GPS and sensor fusion that Furuno acquired in 2009. He also worked for nearly 10 years at Trimble Navigation, as well as Stanford Telecommunications. He received his Ph.D. in Electrical Engineering from Iowa State University in 1988 with a focus on GPS integrity monitoring. He has more than 50 patents in the areas of GPS, AGPS, and sensor fusion. Below are his comments on a few topics I proposed.

— Matteo Luccio, Editor-in-Chief

Could new clocks protect planes from spoofing of GNSS signals?

GNSS receiver builders would certainly take advantage of better oscillators. Poor clocks hurt performance, while stable clocks improve performance and provide a source of reliable information. A better oscillator by itself cannot prevent getting spoofed, but it can be an important component of an anti-spoofing regime not only for detection but also for mitigation. At OneNav, we started testing SiTime MEMs oscillators. We are using some SiTime devices that have nearly perfect reference frequency, with less than 100 ppb and amazing shock and temperature stability. They are not cheap, but they are improving the manufacturability for lower cost.

TV broadcasters have petitioned the Federal Communications Commission for permission to provide PNT signals. ***(See page 16.)***

In the 1990s, Rosum Corp. of Redwood City, California, first tried to do positioning using TV signals. They were famous for a while and most of their engineers are in GNSS now. The inherent advantages of the multipath mitigation in the signal structure are still unexploited, mainly because TV tower navigation suffers from poor positional dilution of precision as many towers are on the same hilltop. It's hard to imagine what changed in the manufacturing or business model to put this in the news again. It seems like a tough problem to adopt the silicon in a cell phone to receive this signal. It won't be an answer for resilience except domestically.

Some claim that quantum systems could transform navigation.

Even navigation-grade IMUs have relatively short viability with meter-level accuracy without GNSS. We are preparing some jamming and spoofing tests with the U.S. Navy's Stiletto program. The IMU is the limit of the project, and quantum IMUs would make a huge impact.

The Federal Aviation Administration is moving toward approving the use of controlled reception pattern antennas (CRPAs) on aircraft.

This is great news for everyone. It will herald a new movement toward more production, with lower cost and improved performance. We need this technology in everything that moves the public.

On February 24, the sun unleashed an X-class flare, triggering a radio blackout across the Pacific Ocean.

Once again, it's centered on the equator, where most of the heavy stuff with the ionosphere happens. Research on geomagnetic equatorial ionosphere is on the frontier of ionospheric research. Events like this are wild points that don't make it into the 3 sigma events. Single frequency receivers that rely on total electron content models for accuracy usually see some impact from these solar storms. The ionosphere has a subtle impact on people all over the world. Did anyone notice their navigation system acting any stranger than usual? Did anyone lose any money on the stock market because the timing accuracy degraded from 5 ns to 20 ns? Did a self-driving car have a blackout? I doubt it. But it's an important part of a data sheet. Companies such as Novatel and Trimble should comment on how they did.

VIAVI Solutions

Maintain Operational Capability for Personnel in D3SOE

Technological advances allow adversaries to jam and spoof GNSS, presenting soldiers with the possibility of operating in a denied, degraded or disrupted space operational environment (D3SOE).

The RSR Transcoder v2.0 from VIAVI Solutions uses a patented algorithm to provide near instant conversion of assured inputs such as M-code, SAASM, IMU/INS and other signals of opportunity into a universal L1, L2 C/A or P-code output that easily upgrades any legacy GNSS receiver with Assured PNT capability.

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Xona Space Systems

US Air Force to Test Xona LEO GPS Alternative

The Air Force Research Laboratory awarded Xona Space Systems a contract to demonstrate and refine its commercial PNT solutions for Department of Defense (DOD) missions. The agreement, facilitated through the Space Technology Advanced Research-Fast-tracking Innovative Software and Hardware (STAR-FISH) program, increases Xona's total contracted commitments to more than $20 million.

Under the contract, Xona will evaluate its PULSAR satellite navigation service across commercial user devices in scenarios where GPS/GNSS signals may be denied or challenged. Testing will focus on assessing resistance to jamming and spoofing, reducing multipath interference and implementing secure key distribution protocols. The initiative aims to expedite the development of advanced alternative PNT capabilities in commercial off-the-shelf equipment, aligning with DOD requirements for rapid deployment.

Xona has collaborated with GPS/GNSS hardware providers QinetiQ, StarNav and Locus Lock to integrate PULSAR-enabled devices. These partners will participate in performance demonstrations as part of the multi-year effort, which includes leveraging Xona's simulation tools and plans to utilize the first PULSAR satellite scheduled for launch in June.

ESA, EnSilica Partner to Enable Resilient GNSS

In partnership with the European Space Agency (ESA), EnSilica, a maker of mixed-signal application-specific integrated circuits, will design and develop a key silicon component to enable resilient multi-band GNSS capabilities. According to the company, these are vital to ensuring the world's critical infrastructure and services remain robust and secure in the face of evolving global threats.

The ESA NAVISP Element 2 program helps increase the competitiveness of participating European states in the global market for satellite navigation and enables these countries to be positioned to capitalize on emerging market opportunities across PNT technologies and services.

"As we and our infrastructure become ever more dependent on PNT services, it is important to have highly integrated, resilient and precise technology sourced in Europe and the UK," said Paul Morris, vice president of the RF and communications business unit at EnSilica. "This collaboration will allow us to accelerate such technology, starting with a next-generation radio design enabling our partners to focus on integrating their custom algorithms."


Blacklack3D / iStock / Getty Images Plus / Getty Images

EnSilica is working with support from ESA and the UK Space Agency, with the latter organization awarding the company £10.38 million ($12.8 million) in February 2025 for a development project under its Connectivity in Low-Earth Orbit program.

GMV Supports the Advancement of the Galileo Reference Centre

The European Union Agency for the Space Programme (EUSPA) has awarded GMV a framework contract to advance the Galileo Reference Centre (GRC), a key facility for monitoring and evaluating the performance of the Galileo satellite navigation system. Located in Noordwijk, the Netherlands, the GRC independently assesses Galileo's operations, signal quality and user-level service performance and compares its performance with that of other GNSS.

The upcoming GRC V2 version will introduce real-time monitoring capabilities, enhancing EUSPA's ability to oversee GNSS services. This evolution will support additional Galileo services, including:

- a signal authentication service designed to strengthen trust in Galileo signals
- a time dissemination service, enabling precise synchronization for critical infrastructure
- search and rescue capabilities to improve emergency response operations
- an Emergency Warning Satellite Service to facilitate public alerts for natural disasters and emergencies.

Key operational improvements in GRC V2 include:

- enhanced monitoring using data from multiple institutions
- real-time processing for faster user notifications
- seamless system upgrades without disrupting operations
- advanced cybersecurity measures integrated into a platform-as-a-service model.

The upgraded GRC is expected to be operational by 2026 without impacting ongoing functions.

ESA / P. Carril

Alternative PNT Systems for GPS-Denied Environments

The Air Force Life Cycle Management Center's PNT Program Office, Integrated Solutions for Systems (IS4S) and AEVEX Aerospace have completed flight tests for the Resilient-Embedded GPS/INS (R-EGI) Modular Open Systems Architecture (MOSA). The tests demonstrated R-EGI's ability to integrate third-party alternative PNT solutions to ensure reliable navigation in GPS-denied environments.

This achievement marks a step forward in developing R-EGI, demonstrating its ability to integrate a "plug and play" third-party alternative PNT capability that ensures reliable navigation in GPS-denied environments, according to IS4S.

The R-EGI system's open MOSA design enables seamless integration of government and third-party applications to address emerging navigation threats. Its Mission Capability Navigation (MCNAV) component allows for seamless integration of external alternative PNT solutions under challenging conditions.

During six test flights on a Special Operations Command C-146A Cougar aircraft, R-EGI operated successfully in GPS-denied environments, validating the system's resilience and capacity for real-time adaptability. Using AEVEX Aerospace's LynxVBN vision-based navigation system, it maintained approximately 10 m of positioning accuracy for up to 2.5 hours. Notably, LynxVBN was integrated into R-EGI's MCNAV software in one hour.

IS4S

The successful integration of alternative PNT technologies into R-EGI seeks to enhance the system's GPS resilience. It also sets a new benchmark for reliable, flexible navigation in GPS-degraded environments, said Mikel Miller, senior vice president for PNT at IS4S.

GNSS GLOBAL NAVIGATION SATELLITE SYSTEM **PNT** POSITIONING, NAVIGATION AND TIMING

1

1. INS

WITH THREE ADDITIONAL GNSS RECEIVER VARIANTS

SBG Systems has upgraded its inertial navigation systems — Ekinox, Apogee and Navsight — with new GNSS receiver options. The latest update introduces three additional GNSS receiver variants. These include:

- **Marinestar**, which supports Fugro Marinestar, delivering precise point positioning (PPP) with centimeter-level accuracy via L-band corrections without requiring a base station. It is optimized for marine applications.
- **HAS Ready / NavIC**, which includes Galileo E6 support for the upcoming Galileo High Accuracy Service (HAS), offering free decimeter-level PPP corrections globally. Additionally, it supports the Indian NavIC system.
- **Centimeter-Level Augmentation Service**, which is tailored for users in Japan; this variant utilizes QZSS L6 signals to provide free PPP corrections without external services.

All GNSS variants integrate seamlessly with SBG Systems' antenna portfolio and Qinertia post-processing software. Users select the appropriate GNSS variant at purchase to match their operational requirements. These enhancements aim to provide versatile solutions across diverse industries while ensuring reliable performance.

SBG Systems, sbg-systems.com

2. RECEIVERS

CAN ACHIEVE CENTIMETER-LEVEL ACCURACY

2

The GNSS receivers in the Teseo VI family use multi-constellation and quad-band signal processing on a single chip, achieving centimeter-level accuracy for various applications. The Teseo VI family includes the STA8600A and STA8610A models. These receivers are designed for automotive applications such as advanced driver assistance systems and autonomous driving, as well as industrial uses, including asset tracking, mobile robots and precision agriculture.

The Teseo VI+ variant can host enhanced positioning engines developed by third-party companies, providing real-time kinematics for centimeter position accuracy.

STMicroelectronics, st.com

3. GNSS MODULE

OPERATES IN CHALLENGING ENVIRONMENTS

3

The LG680P is a multi-constellation, quad-band GNSS module designed for high-precision positioning and to enhance signal quality and precision through concurrent reception of L1, L2 and L5 frequency bands. It supports Galileo E6, QZSS L6 and BDS B2b signals for precise point positioning, ensuring horizontal accuracy of up to 0.8 cm + 1 ppm without requiring local or broadband connectivity.

To ensure signal integrity in environments with electromagnetic interference, the module features professional-grade anti-jamming technology, including built-in NIC algorithms that suppress narrow-band interference. It supports external active antennas for enhanced signal reception and positioning accuracy. It is ideal for applications such as autonomous lawnmowers, delivery robots, surveying equipment and precision agriculture. Quectel complements it with two external GNSS antennas: the YEGR001W8AH geodetic antenna and the YEGD006U1A compact patch antenna.

Quectel, quectel.com

4. FIRMWARE UPGRADE

FOR SBG SYSTEMS' MEMS-BASED INS

4

The New Ellipse firmware upgrade for the Ellipse product line allows the system to now be used as an attitude and heading reference system or inertial navigation system. It is designed to enhance navigation, attitude and heave performance for stable and accurate positioning, even in challenging conditions.

It introduces advanced GNSS-denied capabilities, featuring newly integrated flags that trigger when GNSS jamming or spoofing threats are detected. This allows users to reject or re-enable external sensors — such as GNSS — without resetting the filter. The user-friendly interface allows for fast and flexible configuration using simple command lines, enabling users to tailor the Ellipse to their specific needs and applications.

SBG Systems, sbg-systems.com

5. LOCALIZATION SOLUTION

OPERATES IN GNSS-DENIED ENVIRONMENTS

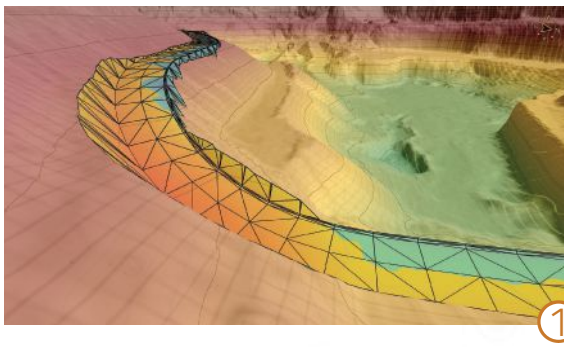

5

WayFinder is a localization solution designed for GNSS-denied environments. It integrates a GNSS/INS system, onboard processor, lidar scanner and two cameras, enabling precise navigation in areas with limited satellite coverage. The system features Lidar Boost, a software technology that enhances GNSS/INS performance by processing lidar data to compensate for missing or inaccurate GNSS updates in real time. This ensures high-accuracy localization and seamless transitions between GNSS-supported and GNSS-denied environments.

WayFinder enables precise navigation for autonomous vehicles in ports, mining and indoor automotive testing without fixed infrastructure. It also provides reliable positioning for surveyors in areas with limited GNSS coverage.

OxTS, oxts.com

SURVEY | LAUNCHPAD



1. SMART SURVEYING

INTRODUCES TOPOGRAPHIC DESIGN TOOLS

Virtual Surveyor Version 10 introduces Basic Topographic Design tools, allowing users to document terrain changes such as graded roads, water ponds and building surfaces. The software now features four subscription plans — Valley, Ridge, Mountain and Peak.

- **Ridge plan:** Focuses on surveying a single moment in time using one drone data set.
- **Mountain plan:** Adds Timelines to compare surveys across different times, visualizing changes through Time Steps.
- **Peak plan:** Includes advanced Topographic Design tools for planning future structures by creating new Time Steps. These tools allow users to design features such as roads or ponds directly on UAV-derived models, with automated alignment and volume calculations for cut-and-fill operations.

Version 10 introduces drawing guides, available in the Ridge plan and above, enabling precise drawing of points at specific intervals or angles. Walk Mode, included in all plans, allows users to explore 3D terrain at ground level for better visualization. Timelines, featured in the Mountain and Peak plans, facilitate the comparison of multiple surveys conducted at different times and the integration of future designs. These improvements seek to streamline processes for engineering surveyors, supporting applications in construction, mining and water management.
Virtual Surveyor, virtual-surveyor.com

2. LASER RTK

WITH A LASER RANGE OF UP TO 50 M

The Jupiter Laser RTK integrates GNSS, auto-IMU, laser and dual camera systems into a single unit. It incorporates a precise green laser that remains visible even in bright daylight. This feature allows for precise measurements of points in hard-to-reach, signal-blocked or potentially hazardous locations. It also features a night vision camera, allowing users to see feature points even in low-light conditions. The RTK system's laser range is up to 50 m, making it suitable for challenging surveying environments. It incorporates visual technology to offer surveyors an immersive experience during surveying and stakeout operations, improving working efficiency and productivity.
Comnav Technology, comnavtech.com

1. UAV SOFTWARE
WITH NEW MAPPING CAPABILITIES

Version 2.1.0 of AgEagle Aerial Systems' eBee VISION application software introduces circular and grid mapping features, allowing users to generate 2D or 3D maps using external post-processing software for more comprehensive geospatial data.

The eBee VISION 2.1.0 can continue missions in GNSS-denied environments and allows manual deactivation of GNSS to prevent jamming or spoofing. It implements the STANAG 4609 standard, the official format for motion imagery exchange within the NATO nations. This involves embedding UAV position and camera information into the videos recorded by the UAV and those broadcasted by the Ground Control Station. Its inclusion in the system seeks to enhance interoperability with third-party applications, which is key for military-grade UAVs.

It offers enhanced control over the Silent Tactical Landing feature. Users can now manually adjust the landing position on the map, with the system providing range estimates to inform operators of the UAV's reach. This functionality offers greater flexibility in mission planning and execution, particularly in tactical scenarios requiring precise landing control. The system is ideal for defense, public safety and utilities applications.

AgEagle Aerial Systems, ageagle.com

2. 'DRONE-IN-A-BOX' SOLUTION
DESIGNED FOR VEHICLE-MOUNTED DEPLOYMENTS

The DJI Dock 3 "drone-in-a-box" solution is designed for vehicle-mounted deployments and 24/7 remote operations in various environments. This system is compatible with the Matrice 4D and Matrice 4TD UAVs, which feature advanced cameras and IP-rated protection for challenging conditions. The UAVs are ideal for public safety, emergency response and infrastructure inspection.

This system supports flexible deployment options, including vehicle-mounted setups optimized for emergency operations and long-distance inspections. It enables horizontal calibration and cloud-based dock location adjustments. Two docks can be mounted on a single vehicle to facilitate dual-UAV rotations for enhanced efficiency. In fixed deployments, the D-RTK 3 Relay Fixed Deployment Version can be added to improve video transmission and satellite connectivity.

The Matrice 4D and 4TD UAVs have a wide-angle camera, medium tele camera, tele camera and laser range finder. The Matrice 4D features an advanced camera suite designed for high-precision mapping. The Matrice 4TD includes an infrared thermal camera for public safety and emergency response applications. The system includes a Flight Termination System to support regulatory compliance in strictly controlled airspace. This system can manually or automatically stop drone operations if necessary.

DJI, dji.com

3. SOFTWARE UPGRADE
ENABLES 24/7 BVLOS OPERATIONS

Casia G Release 4.0 is a software update that enables nighttime detection of aircraft, allowing 24/7 beyond visual line of sight (BVLOS) UAS operations. The update supports BVLOS flights up to 400 ft at night without requiring hardware modifications, offering detection of both cooperative and non-cooperative aircraft. The system detects aircraft at distances of up to 16.7 km with 360° coverage, ensuring safe nighttime operations. When multiple units are used, triangulation technology provides accurate range, altitude and satellite data for intruding aircraft. The update leverages existing hardware to detect navigation and anti-collision lights at night.

uAvionix, uavionix.com

4. MARINE RADAR
WITH W-BAND RADAR TECHNOLOGY

The MAS10 is a 77 GHz FMCW marine radar system designed to enhance navigation safety in congested environments under all weather conditions. The ultra-high-definition W-band radar provides centimeter-level resolution, enabling vessels to detect and identify small hazards in heavily trafficked waterways.

Unlike optical and infrared sensors, W-band radar technology penetrates fog, heavy rain and snow, ensuring reliable detection. It operates effectively in low-visibility scenarios, including complete darkness, intense sunlight and shadowed areas where cameras and lidar may struggle.

NavTech Radar, navtechradar.com

1. NEW 3D SCANNERS
AVAILABLE IN TWO VERSIONS

The Eagle Series line of spatial 3D scanners feature lidar and imaging sensors and are designed for various applications, including reverse engineering, digital twinning, asset management, extended reality, precision mapping and 3D printing.

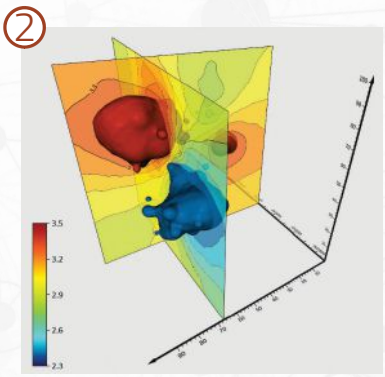
The series offers scanning capabilities with a range of up to 140 m and precision within 2 cm at 10 m. The lightweight scanner is designed for portability, with a built-in battery providing up to one hour of continuous use.

The scanners are available in Standard and Max versions. The Max model features four 48 MP cameras, enhancing scanning efficiency and producing vivid 8 K panoramic photos. With a point cloud frequency of 200,000 points per second, the Eagle Series is designed for applications requiring highly detailed spatial data.
3DMakerpro, store.3dmakerpro.com

2. UPGRADED MAPPING PACKAGE
WITH GOOGLE MAPS DOWNLOADS

Golden Software has upgraded its Surfer mapping and 3D visualization software. Users can now directly download georeferenced aerial and satellite imagery from Google Maps into projects. The latest version also improves 3D visualization tools, focusing on faster and more intuitive creation of visual models. Users can now colorize 3D drill hole intervals based on text keywords, making it easier to interpret subsurface data. Additionally, contour slices can now be added to the 3D view, offering a clearer representation of data layers.

Golden Software has released a beta version (30.0.135) that introduces multiple light sources for improved 3D viewing and customizable legends for better map presentation. These updates are designed to streamline workflows for professionals in industries such as environmental consulting, resource exploration and geospatial analysis, simplifying the creation of professional-grade maps and models efficiently.
Golden Software, goldensoftware.com



BROADCAST POSITIONING SYSTEM

TELEVISION BROADCASTERS PROPOSE NEW PNT SERVICE

Interview with Sam Matheny, CTO & Executive Vice President National Association of Broadcasters

More than 20 years ago, in these pages, we referred to television broadcast signals as "signals of opportunity" that might be used for positioning, navigation and timing (PNT). Since then, several other signals with a different primary purpose have also been considered as sources of PNT, and some have been used routinely for years now, such as WiFi routers for indoor navigation. On Feb. 26, 2025, the National Association of Broadcasters (NAB) filed a petition for rulemaking with the Federal Communications Commission (FCC) for television to transition to a new standard, ATSC 3.0, that enables what they call Broadcast Positioning System (BPS), as a way to enhance GPS resiliency. I asked NAB's chief technology officer and executive vice president, Sam Matheny, to answer a few questions about the organization's proposal. In next month's issue, we will present a different perspective on it.

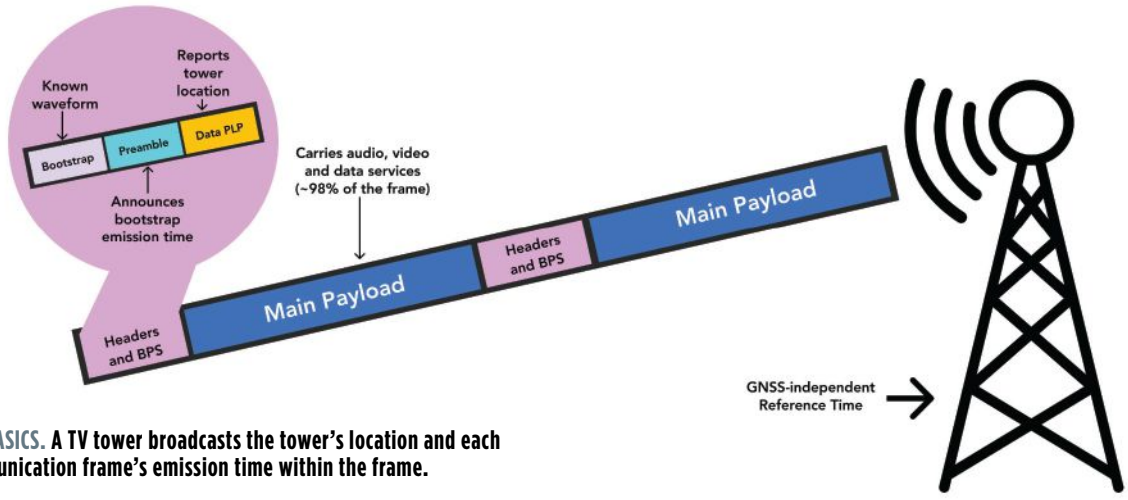
— MATTEO LUCCIO, EDITOR-IN-CHIEF

Briefly, what is the history of the relevant standards?

The Advanced Television Systems Committee (ATSC) is an international standards development organization. ATSC developed ATSC 3.0 as the "next-gen" standard, and the International Telecommunications Union (ITU) adopted it as a recommended digital broadcast standard in 2020. Broadcasters in the United States began experimental ATSC 3.0 transmissions in 2016, and there are currently more than 100 transmitters broadcasting in 80 markets. Other nations currently using or considering ATSC 3.0 include Brazil, India, South Korea, Canada, Mexico, Jamaica and Trinidad and Tobago. NAB's petition to the FCC requests permission to fully transition to ATSC 3.0 by 2030.

Briefly, what is the history of the BPS project/proposal?

BPS is a datacast application that uses ATSC 3.0. We at NAB authored a seminal paper on BPS in 2021 and built our first prototype in 2022. We put our second prototype on the air in 2023. We signed a Cooperative Research and Development Agreement (CRADA) with the National



All figures provided by National Association of Broadcasters.

BPS BASICS. A TV tower broadcasts the tower's location and each communication frame's emission time within the frame.

Institute of Standards and Technology (NIST) in 2024 and published our first joint paper earlier this year. The paper concludes that *"the stability of BPS time transfer is comparable to or better than GNSS, making BPS a viable complementary PNT solution when GNSS is unavailable."*

Our petition to the FCC highlights a transition to ATSC 3.0 that enables the nationwide deployment of BPS.

What is the motivation for broadcasters to implement BPS? What's in it for them?

BPS will further secure television broadcasters' role in the fabric of U.S. telecommunications. We also witnessed the innovation around GPS, with more than 7 billion GPS receivers being built into myriad devices. We'd like to see BPS experience similar innovation, which will bring new business opportunities. We believe that there is an opportunity for a public-private partnership with the government to deploy BPS for economic and national security.

What have your tests so far shown regarding the timing accuracy of your signals? How much more R&D is required?

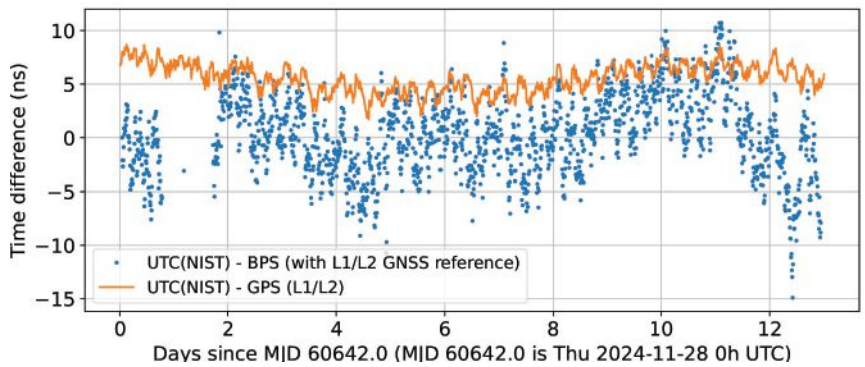
We've completed a wide variety of testing over the years, but probably of most interest is the work done with NIST. They ran common-view experiments using the BPS signal transmitted from KWGN, a TV station in Denver. Receivers were placed at two different facilities equipped with NIST timescale. Their Boulder facility is 30 km away with non-line-of-sight (NLOS) propagation, and their Fort Collins facility is 106 km away with line-of-sight propagation. A 21-day-long test showed that the time deviation (TDEV) statistics were better than 2 ns for all intervals. NIST also tested the stability of the NLOS signal alone at the Boulder facility and found that the TDEV statistics were better than 3 ns.

How can BPS help improve GNSS resilience and integrity?

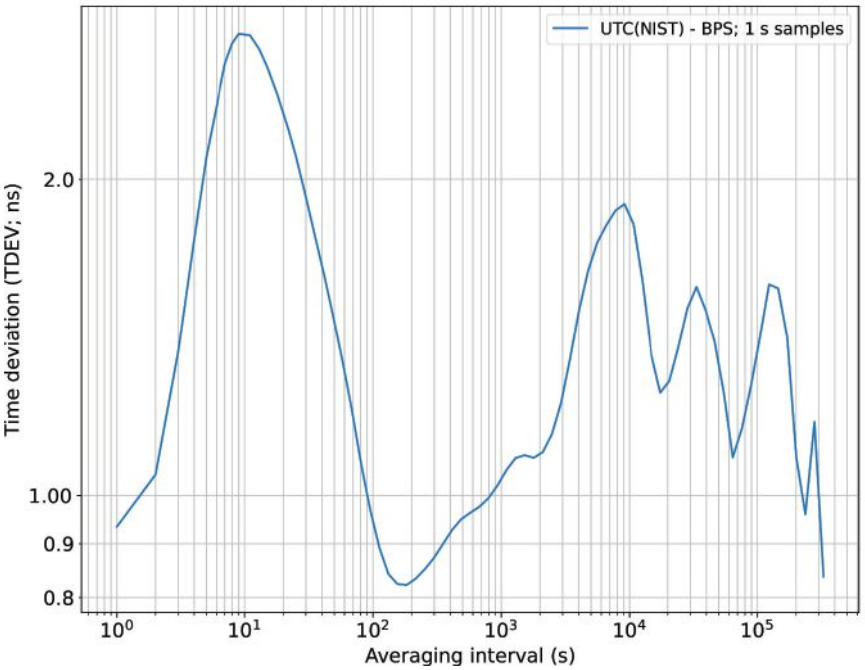
BPS functions completely independent of GNSS, so in the event of an acute GNSS disruption or catastrophic outage, BPS can be a resilient secondary source of timing for critical infrastructure (CI). Integrating BPS into CI applications also makes GPS a less attractive target for intentional disruption. Additionally, being independent means that BPS and GPS can work together in a hybrid mode, where, for example, BPS can help detect jamming and spoofing of GPS.

What are the main benefits of BPS?

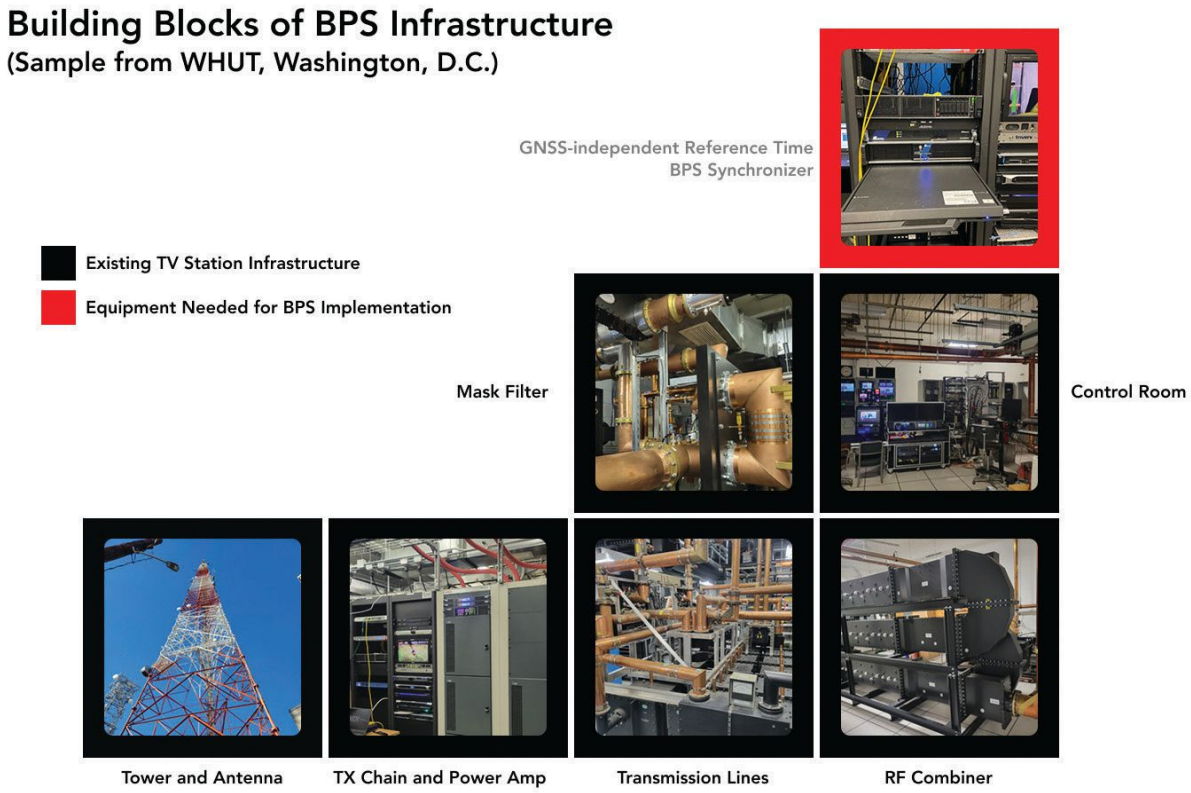
The key benefits of BPS include:



BPS TIME is comparable to dual band GPS (L1/L2) time. The data are recorded as 10-minute averages.



TIME DEVIATION (TDEV) statistics of BPS is less than 3 ns, even for the NLOS test scenario.



BPS INSTALLATION AT WHUT. TV transmission infrastructure is already built out. Only a BPS synchronizer and a reference timing source need to be added.

- **Existing infrastructure:** BPS leverages existing television transmission infrastructure making it low cost and easy to deploy. There are more than 1,700 full power TV stations on the air today. These stations, considered critical infrastructure, are designed to stay on the air on a 24 x 7 x 365 basis, including during emergencies.
- **Nationwide coverage:** Television transmissions are "high-power/high-tower" signals that provide nationwide coverage. Their broadcast power can be up to 1 MW and from towers up to 2,000 feet tall. The signals can be received NLOS, including indoors. The strength of these signals makes them difficult to jam or spoof.
- **Frequency diversity:** Television in the United States operates on 210 MHz of licensed spectrum divided into 35 6-MHz channels. There are multiple stations/channels in each market, which offer geographic diversity along with frequency diversity.
- **Passive receivers:** BPS is a broadcast service, just like GPS, and supports an unlimited number of simultaneous users with no bottlenecks or two-way connectivity dependencies.
- **Standards-based:** BPS is based on ATSC 3.0, an ITU-recommended digital terrestrial broadcast standard with the support of a global community and supply chain.
- **Independent:** BPS operates completely independent of GNSS and is a self-synchronizing network that does not rely on Internet or cellular connectivity.

What are the main initial use cases? What are some additional ones that might come later?

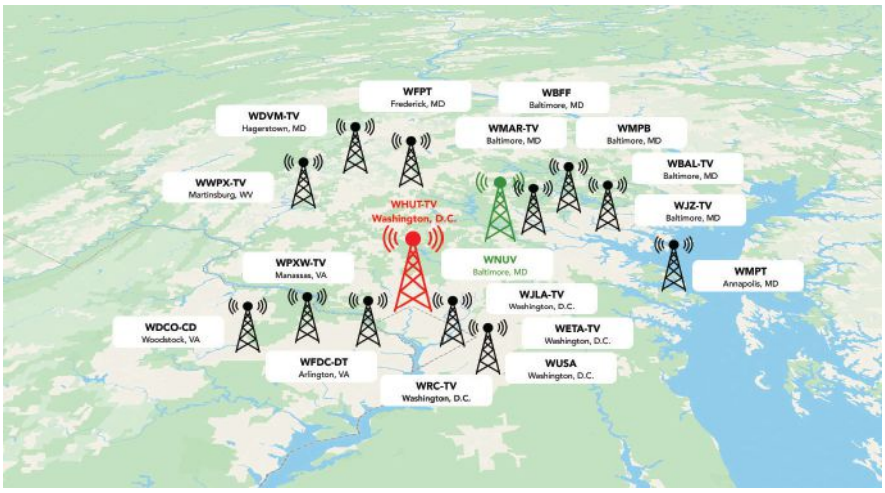
The initial use case is providing resilient time to CI, which includes the power grid, cellular communications, and financial and data centers. A 2019 NIST study estimated the economic risk of losing GPS at $1 billion a day, and in 2024 a National Security Space Association study said the impact of a disruption or loss would be incalculable, so addressing this CI need is vital.

Longer term, we see hybrid applications where BPS and GPS are used together. BPS can be leveraged for GPS health monitoring, which could be especially useful for transportation systems and can help identify and mitigate compromised GPS service. Going further, we see applications for positioning and navigation, plus other data services such as AGPS, GPS validation and RTK.

How will the BPS service be monitored after full deployment?

NAB has developed a cloud-based network operations center

(NOC) to monitor the health of the BPS-enabled TV stations. As part of our leader-follower construct, TV stations in the BPS mesh network measure each other's emissions and send the data to the NOC, which can identify any issues.



BPS LEADER-FOLLOWER mesh network example. WHUT is configured as a leader tower, and WNUV is set up as a follower tower deriving traceable time from WHUT's signal. At full deployment, the remaining 12 towers in the DC-Baltimore area can also follow WHUT.

Which television manufacturers have expressed interest so far?

Hisense, LG, Panasonic, Samsung, Sony and TCL are already selling NEXTGEN TV sets. It is important to note that these televisions don't use BPS. They ignore the BPS data and pay attention to the audio and video payload. The reverse is true for a BPS receiver; it ignores the audio and video and simply uses the BPS data. Both services rely on ATSC 3.0, but they use different parts of the signal.

Have you talked to any GNSS receiver manufacturers yet?

Yes, we have healthy interest from numerous receiver manufacturers. They see BPS as a nice addition to their product lineups. Conversations have focused on performance and integration.

Are there any technical, commercial or legal arguments against BPS? Do you anticipate resistance to your proposal from any quarters?

We have not heard any such arguments against BPS. To the contrary, people have been intrigued and supportive of the concept. Recognizing that BPS requires transition to ATSC 3.0, some groups have expressed concerns over the television set upgrade cost for low-income viewers. However, ATSC 3.0 receiver accessories retail for less than $100 today, and prices will drop further with scale.

How does your proposal address backward compatibility?

NAB's petition calls for all television stations to transition to ATSC 3.0 and for all television sets to be equipped to receive ATSC 3.0. As mentioned earlier, millions of NEXTGEN TV sets are already being purchased, so our petition aligns with natural product replacement cycles, including low-cost converters for older TVs.

What is your arrangement and division of labor with NIST?

Our CRADA with NIST also includes Nexstar, one of our members. Nexstar operates KWGN where we deployed BPS. NAB provided NIST with BPS receivers and technical support. NIST scientists then performed independent measurements and analysis of BPS using their own techniques and processes. It has been a great experience for us to engage with and learn from the team at NIST. The effort has taught us a great deal about PNT and the capabilities of BPS.

Now that you have submitted your proposal to the FCC, what do you expect to be the timeline for approval, implementation and adoption?

The FCC follows a notice-and-comment process for adopting changes to its rules, which can take anywhere from several months to more than a year. The FCC previously convened the Future of Television Initiative to investigate issues associated with the transition, which should give us a bit of a head start. In NAB's petition, we ask the FCC to establish a timeline that would have the top 55 television markets fully transitioned to ATSC 3.0 by 2028 and the remaining markets by 2030.

How can the GNSS/PNT community help this project?

First, it can support the transition to ATSC 3.0 because BPS relies upon it. We need a full transition to recognize its potential. Next, it can continue to collaborate with us. We introduced BPS at the DOT Roundtable in 2022. Since then, we've collaborated with the PNT community on research, scientific papers, product design and deployments. We've built BPS together, and now we need to deploy it together.

GNSS on the Moon

The Lunar PNT Era Begins Through Blue Ghost LuGRE

BY JAMES "JJ" MILLER AND LISA VALENCIA

Historical Context of GNSS in Space

The latest historic chapter in GNSS for space users was launched, as one would expect, at an Institute of Navigation (ION) GNSS+ conference — the one in Miami in 2019 — by a handful of technical and policy experts well positioned to "Go for the Gold" — GNSS on the moon! Thus, liquid refreshments in hand, the Lunar GNSS Receiver Experiment (LuGRE) concept was born, amongst excited discussion and scribbling on napkins by Oscar Pozzobon (Qascom), Joel Parker (NASA), Frank Bauer (NASA), Alberto Tuozzi (Agenzia Spaziale Italiana or ASI, Italian Space Agency), Lisa Valencia (NASA) and James "JJ" Miller (NASA).

Long before this productive, informal brainstorming session, global navigation satellite systems (GNSS), such as the U.S. GPS, were originally designed for use on or near Earth, providing positioning, navigation and timing (PNT) services up to an altitude of about 3,000 km (the GPS Terrestrial Service Volume). Over the decades, experimental missions pushed GNSS use higher, and by 2006, GPS specifications defined a Space Service Volume, extending GNSS services out to 36,000 km (geosynchronous orbit). NASA missions then deftly demonstrated GNSS utility well beyond Earth orbit — notably in 2019 with the Magnetospheric Multiscale Mission spacecraft formation, which successfully tracked GPS signals roughly 192,500 km from Earth, setting the world record for farthest and fastest reception of any GNSS signals in the space domain.

Building on this success, NASA proposed conducting the LuGRE in 2020 by using a combination of GPS and Europe's Galileo signals at lunar distances. The flight opportunity for a lunar mission came through NASA's new Commercial Lunar Payload Services (CLPS) initiative, and by early 2021, Firefly Aerospace was awarded the mission to carry LuGRE to the moon. The LuGRE team was very fortunate from the start, competing for and winning the last of 10 payload slots, and the only space operations flight demonstration amongst nine other science payloads focused more on assessing the lunar environment.

AN IMAGE CAPTURED by Blue Ghost shows its shadow on the moon's surface, with Earth on the horizon.

Firefly Aerospace

The progress of this initiative reflects a broader national and international push based on NASA's role in implementing the 2021 U.S. Space Policy Directive-7, which directs NASA to work with the U.S. Space Force and other partners to extend GNSS capabilities farther into cislunar space to benefit both government and commercial users. Internationally, GNSS providers further cooperate through the UN-sponsored International Committee on GNSS to develop interoperable PNT standards for space users beyond Earth. So, ASI was a natural fit to become NASA's international partner. The Italian GNSS company Qascom was awarded the receiver development, while the Polytechnic of Turin provided academic support. This historic groundwork has thus set the stage for the recent LuGRE mission to achieve several accomplishments in lunar navigation, breaking three world records in the process.

Mission Overview: Blue Ghost Lander and CLPS

The LuGRE payload traveled to the moon aboard Blue Ghost Mission 1, a robotic lunar lander built by Firefly Aerospace under NASA's CLPS program. CLPS, started in 2018, is a public-private partnership model through which NASA contracts commercial landers to deliver science and technology payloads to the lunar surface. Blue Ghost Mission 1 launched on Jan. 15, 2025, via a SpaceX Falcon 9 rocket and touched down on March 2,

2025. This made Firefly the first U.S. commercial company to successfully land on the moon upright, delivering 10 NASA-sponsored payloads, including LuGRE. The lander targeted a site near Mons Latreille in Mare Crisium, achieving a precision landing within ~100 m of the aim point. Built as a solar-powered lander about 2 m tall and 3.5 m wide, Blue Ghost was designed for a mission duration of one lunar day (~14 Earth days). By leveraging CLPS, NASA rapidly deployed LuGRE and other instruments, demonstrating the effectiveness of commercial partnerships in advancing lunar exploration. Blue Ghost's successful landing and operations validated this approach and set the stage for upcoming CLPS missions in support of Artemis.

The LuGRE Payload: Objectives and Components

LuGRE is a technology demonstration aimed at determining whether Earth-originated GNSS signals can be reliably received and used for navigation at the moon's distance. The payload was jointly developed by NASA and ASI with engineering by Qascom. Hardware on LuGRE includes a specialized weak-signal GNSS receiver, a high-gain L-band patch antenna array with RF filtering and a low-noise amplifier. This design allows it to track faint GPS and Galileo signals nearly 400,000 km from their transmitters. LuGRE specifically listens on multiple frequencies — GPS L1 and L5, and Galileo E1 and E5a — to maximize signal acquisition opportunities. The experiment's objectives are threefold: (1) acquire and characterize GNSS signals in lunar orbit and on the surface, (2) demonstrate navigation fixes (position/time) using those signals at the moon, and (3) return data to inform the development of future lunar-specific GNSS receivers. All three of LuGRE's objectives were met. During the mission, LuGRE began collecting and processing data en route to the moon (during a ~45-day transit) and also on the lunar surface after landing. As one of the first demonstrations of GNSS use on another world, LuGRE set out to prove that combined GPS/Galileo signals could enable autonomous navigation for spacecraft far beyond Earth.

Benefits of GNSS for Lunar PNT

If proven reliable, GNSS-based navigation at the moon offers significant benefits for future lunar missions. First, it provides a common PNT framework for lunar explorers, akin to GPS on Earth, enabling precise real-time positioning and time synchronization for astronauts and robotic systems. This could allow lunar crews and rovers to navigate autonomously across the surface without constant ground support, reducing astronaut workload and dependence on Earth-based tracking. Accurate GNSS-derived position data improves safety and efficiency — for example, helping rovers avoid hazards and chart optimal routes or aiding astronauts in pinpointing resources, such as water, ice or scientific targets. Using existing GNSS signals also means that missions might rely less on cumbersome radio tracking from Earth or lunar beacons, simplifying mission operations.

In the long run, GNSS technology can support the development of lunar infrastructure: future base camps, power stations and landing pads could all reference a shared navigation grid, much as terrestrial infrastructure does. Additionally, leveraging well-known GPS/Galileo signals could reduce costs and technical risks, supplementing a proposed new lunar navigation satellite network.

LuGRE's results have affirmed these possibilities. During transit, LuGRE broke records by tracking signals at 395,900 km out in lunar orbit, proving multi-constellation GNSS can aid navigation to and around the moon. Shortly after landing, it further demonstrated an autonomous GNSS navigation fix on the lunar surface, 362,100 km from Earth. These achievements suggest that even existing Earth-centric satnav can be extended to serve lunar exploration, a promising development for upcoming Artemis endeavors.

NASA / Kim Shiflett

A SPACEX FALCON 9 rocket carrying Firefly Aerospace's Blue Ghost Mission 1 lander prepares for a launch to the moon on Jan. 14, 2025, from Launch Complex 39A at the agency's Kennedy Space Center in Florida.

Challenges of GNSS Reception on the Moon

Adapting GNSS to the lunar environment is challenging. The main difficulty is the weakness of signals by the time they reach the moon. GNSS satellites orbit around 20,000 km from Earth, beaming most of their signal power toward Earth's surface. At nearly 10 times that distance, only the spillover (side-lobe) signals reach the moon, arriving attenuated and sparse. This necessitates high-sensitivity receivers and high-gain antennas (such as LuGRE's) to even detect the signals, along with sophisticated algorithms to pull meaningful data from the noise. The geometry and coverage also pose issues: a receiver on the moon will often see a limited number

Firefly Aerospace

FIREFLY AEROSPACE'S Blue Ghost Mission 1 lander is carrying 10 NASA science and technology instruments to the moon as part of NASA's CLPS initiative and Artemis campaign.

of GNSS satellites above its horizon, potentially affecting the accuracy and availability of navigation fixes. Local lunar conditions add further complications. The moon's lack of atmosphere means no ionospheric delay, which is a positive for signal clarity. However, it also means that there is nothing to refract or scatter signals over the horizon — thus, terrain plays a crucial role. Rugged topography (mountains, crater rims) can block line-of-sight to GNSS satellites, and deep craters or polar shadowed regions might have very poor reception.

The pervasive lunar dust (regolith) can also be problematic because it may coat antenna surfaces or contribute electromagnetic noise, especially during landings or surface activities. These factors require advanced processing techniques and possibly integrating GNSS with other sensors to achieve reliable navigation. LuGRE's design and operations were tailored to confront these challenges. For instance, using dual constellations doubles the pool of satellites and signals available, and collecting data both in orbit and on the surface helps characterize how signal quality changes in different lunar conditions. The knowledge gained will guide the development of next-generation lunar GNSS receivers with improved robustness against weak signals and intermittent coverage.

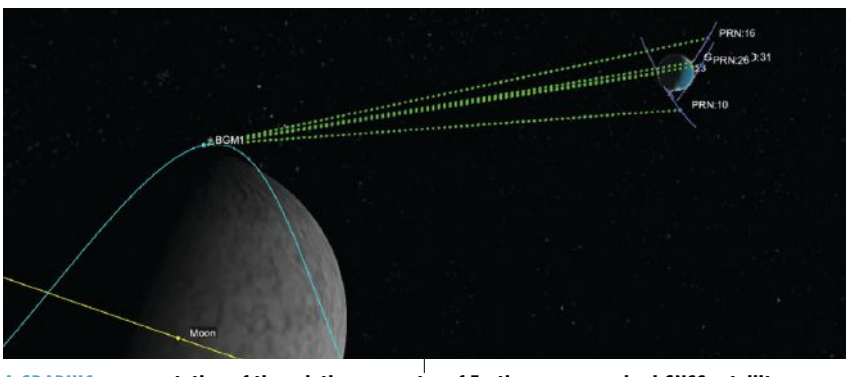
Implications for Artemis and Deep Space Navigation

LuGRE's success is a proof of concept that navigation aids from Earth can directly support moon missions. This is of immediate relevance to NASA's Artemis program, which aims to return humans to the moon and establish a sustained presence there. Artemis crewed vehicles (such as the Orion spacecraft) and the planned Gateway lunar station could potentially use GNSS signals during transit or in lunar orbit to autonomously determine their trajectories. On the surface, future Artemis astronauts and rovers could carry GNSS-enabled devices to know their precise location without relying solely on Earth-based tracking. This capability will become increasingly important as activities expand — from pinpoint landing of resupply craft, to coordinating lunar base operations to enabling the first long-distance treks by crew or robots on the moon.

By proving GPS/Galileo usability at the moon, LuGRE also paves the way for establishing a standardized lunar reference frame tied to existing GNSS, which all international partners can use for joint operations. In a broader sense, LuGRE is a stepping-stone toward more advanced navigation systems in deep space. It demonstrates techniques (such as combining multiple GNSS constellations and using high-sensitivity receivers) that could inform navigation around Mars or other distant targets. While Earth's GNSS signals won't reach Mars with useful strength, the lessons learned can drive the design of Mars-orbiting navigation satellites or better onboard autonomous nav systems for deep-space probes. In essence, the experiment is accelerating the development of a GPS-like interplanetary navigation capability, crucial for humanity's expansion deeper into the solar system.

Policy and International Collaboration

The LuGRE mission exemplifies how international and commercial



Agenzia Spaziale Italiana

A GRAPHIC representation of the relative geometry of Earth-moon-acquired GNSS satellites.

partnerships are shaping the future of space exploration. It was born out of a long-running collaboration between NASA's Space Communications and Navigation program and ASI, reflecting a shared strategic interest in extending GNSS interoperability to the moon and beyond. The receiver hardware was developed by Qascom with academic support from Politecnico di Torino, underlining the role of industry and academia in innovation.

This NASA-ASI partnership built on earlier joint projects, such as GNSS receiver experiments on the ISS and suborbital flights, which tested using both GPS and Galileo for space navigation. Europe's Galileo system, in particular, is a full partner in LuGRE. Its inclusion alongside GPS ensures that the experiment benefits from multi-constellation redundancy and also sends a message of GNSS interoperability, a key principle endorsed by the International Committee on GNSS. On the policy front, the mission aligns with U.S. space policy goals to develop services in cislunar space and encourages momentum in international standardization of lunar PNT frameworks.

Data from LuGRE will be made public, contributing to global research and possibly the drafting of new standards for lunar navigation that any nation's spacecraft can adopt. The CLPS program itself, which enabled LuGRE's delivery, represents a policy shift toward commercial sourcing of lunar services — fostering a market where companies such as Firefly, intuitive Machines, Astrobotic and others compete and cooperate to advance lunar science. As NASA leads the Artemis coalition with agencies from Europe, Asia and beyond, the LuGRE experiment offers a tangible product of cooperation: a foundation for shared navigation infrastructure at the moon. This collaborative, forward-looking approach will be critical as humanity returns to the moon not just to visit, but to stay.

Conclusion

LuGRE on Firefly's Blue Ghost lander has marked a milestone in space exploration: it demonstrated for the first time that navigational signals conceived for Earth can be harnessed on the lunar surface. By uniting cutting-edge technical work (in receivers and antennas) with visionary policy support (via NASA's CLPS and international GNSS cooperation), LuGRE showcases a path toward robust, autonomous navigation for the Artemis generation of missions. Achieving a GPS/Galileo fix on the moon is more than a symbolic first — it is a practical step toward a future where astronauts and robots navigate the moon — and one day Mars — with the same confidence as we do on Earth. The lessons from LuGRE will inform how we guide our spacecraft across the cislunar void, how we set up the positioning networks of tomorrow's lunar bases and how nations cooperating can build the navigation backbone for a new era of deep-space exploration. In short, LuGRE has opened the door for GNSS to become an integral part of the lunar toolkit, blending technology and policy into a giant leap for navigation beyond Earth.

Authors

JAMES "JJ" MILLER is a recent retiree of NASA, after serving nearly two decades as the NASA headquarters PNT policy lead, where he sponsored several GPS modernization efforts and managed the National Space-based PNT Advisory Board for 18+ years. JJ's final assignment was as the executive secretary of the National Space Council Users' Advisory Group, serving in the office of the vice president through two administrations.

LISA VALENCIA Lisa Valencia is a retiree of NASA (29 years) and Overlook Systems Technologies (5 years supporting NASA PNT). She was a technical advisor on several GNSS interoperable payloads, including two that flew on NASA's Flight Opportunities Program-sponsored UP Aerospace Spaceloft 15 (SL-15) sounding rocket and LuGRE.

Acknowledgments

BRADFORD PARKINSON, PH.D., for having inspired the entire team to push the limits of GNSS navigation. When GPS was designed in the 1970s, no one had expected that the technology would have been used on smart devices, as they had not yet been invented. Definitely, no one would have even thought about its usage on the moon. We would like to express our utmost gratefulness for the influence that Parkinson provided to the LuGRE team for pushing the boundaries of a system that was designed more than 50 years ago. *"Thank you, Dr. Parkinson. We dedicate the first PVT on the moon to you."*

Much appreciation to **BADRI YOUNES**, former SCaN Deputy Associate Administrator (DAA) who ensured NASA funding for LuGRE, and to **GEN. DAVID "DT" THOMPSON**, Vice Commander, Space Force, for his robust policy support of NASA's efforts.

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ASSURING PNT ON THE BATTLEFIELD

Achieving resilience with complementary solutions

BY MATTEO LUCCIO, EDITOR-IN-CHIEF

For our annual cover story on defense applications of GNSS, I discussed the topic with representatives of five companies. Predictably, the key challenge they reported facing is how to build resilience in the face of the growing challenge of jamming and spoofing. Their responses include controlled reception pattern antennas (CRPA), optical gyroscopes and a new satellite constellation in low-Earth orbit (LEO). One company is building uncrewed aerial vehicles (UAVs) with sensors customized for different missions. For the full versions of these interview transcripts, see **bit.ly/4kAB7Zr**.

WingXpand

WINGXPAND'S XRAI smart plane has long-range performance, modular payloads, and real-time AI that detects threats and anomalies as they happen, all in one system that expands from a backpack.

SEPTENTRIO

François Freulon, Director of Product Management

Septentrio, which was recently acquired by Hexagon, participated in Jammertest 2024. Jammertest is an annual event hosted at Andøya, Norway, that is likely the largest open PNT/GNSS resilience test in the world. According to the event's website, participants are "subjected to both simple and sophisticated spoofing and jamming attacks allowing actors from both public and private sectors to test their PNT systems and products for potential weaknesses against both unintentional and intentional attacks."

How realistic are Jammertest's scenarios? How well do they reflect the actual challenges?

They're pretty much aligned with the actual challenges. We have also recorded some jamming events in Norway, in the Baltic Sea, and so on. We have transmitted those data to Jammertest, and they have been able to replay them to improve their scenarios to better reflect the realities in GNSS-denied or warfare areas.

Does Jammertest only provide jamming or also spoofing and meaconing?

We have reported mainly spoofing events. There are already plenty of jamming scenarios using multiple jammers, multibands, narrow band, wide band and so on. Jamming is simple, but they are using very strong equipment, such as a 200 W jammer that can jam a large area. We have asked them to add more spoofing scenarios that we have seen in real situations. Jammertest lasts five days: three days of jamming and two days of spoofing and meaconing.

Are the Jammertest scenarios mostly similar to war zones, such as Ukraine, or a mixture of different types of challenges?

It's a bit of mixture. Some scenarios are similar to what we are seeing in contested areas in Ukraine, and other ones are focused on specific bands or constellations. It's very difficult to be in a real jamming environment because jamming is forbidden everywhere. So, generally, we are validating our anti-jam solutions in a laboratory or in specific contested areas. With Jammertest, they are authorized to jam for a whole week in the real world. They can do whatever they want. This is very beneficial because we cannot see that often.

Because of the high mountains on the island of Andøya, they're able to jam in one direction without interfering on the other side.
Correct.

What are the key technical challenges in dealing with jamming?
We need to support all the signals from the sky. So, the prerequisite is to have receivers that can track and acquire all the signals coming from space, because it's quite easy to jam one band, but it's much more difficult to jam all the bands — L1, L2, L5 and so on. So, the ability of a receiver to support all the bands and constellations helps a lot.

Next, a receiver must be robust and able to mitigate the interference in real time. It must reject the high power from the jammer while still recovering the signals from the satellites. All of that must be automatic, because on some receivers you can manually set anti-jam on a frequency, but the jammers are dynamic and some more advanced jammers change their frequency opening, so they are more difficult to mitigate. So, you need to have a receiver that can protect in real time and be automatically adaptive to the interference. That is what we do at Septentrio.

Septentrio

SEPTENTRIO STAFF DROVE a van from Belgium to Norway with about 20 receivers from the company and its main GNSS competitors to compare the results in real time.

What's the relationship between what you do in the receiver and using a CRPA antenna?
They are complementary. CRPA antennas do not cover all the bands in view, so they protect only a limited part of the spectrum.

What do you do differently from your competitors?
You need to cancel interference from the receiver signal, so you cannot mitigate it by software. You need to remove it in the hardware. We have designed a chipset that removes interference at the arrival of the signals from the antenna. We call this automatic notch filtering. It enables position computation with clean signals.

ANELLO PHOTONICS

Mario Paniccia, Business Development and Marketing

ANELLO Photonics signed a contract on Oct. 21, 2024, with the U.S. Space Force and one on Jan. 21, 2025, with the U.S. Navy to develop its optical gyroscope technology and its sensor fusion engine.

Tell me about your recent six-month contract with the U.S. Navy to demonstrate your optical gyroscope and sensor fusion technology for navigation at hypersonic speed without relying on GNSS.
At hypersonic speed, the missiles and the projectiles create a plasma over the vehicle, which doesn't allow for RF signals to go in or out of the system. So, those

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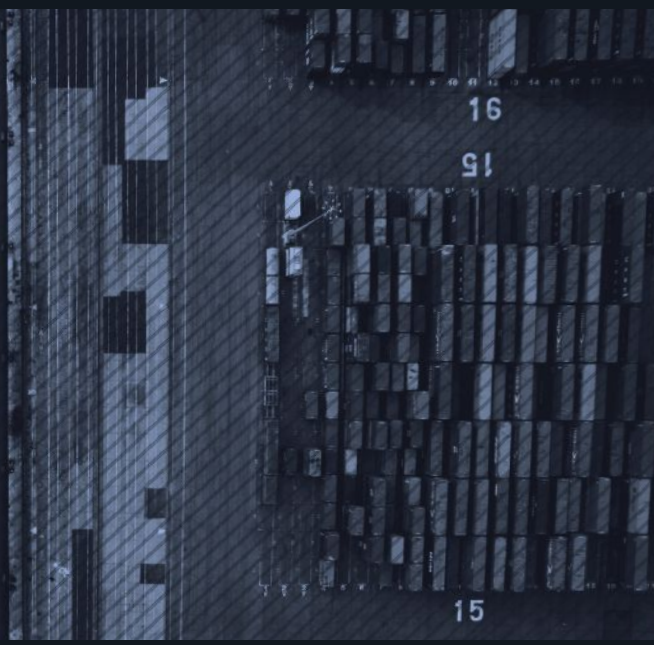
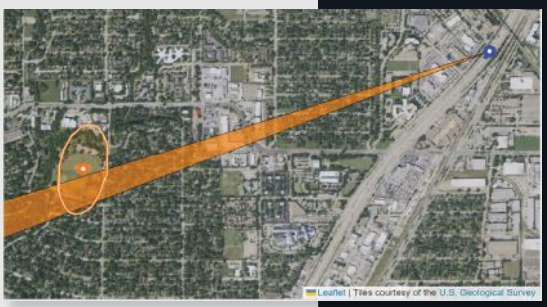
IS YOUR GPS SPOOF-PROOF?





Situational Awarenes GUI

UHU1000

Northstar

THE LEADER IN DETECTION AND MITIGATION OF GPS SPOOFING & QRC ANTENNAS

UHU Technologies is focused on locating and mitigating GPS interference so that critical platforms can stay safely on course. We use advanced, multi-element digital signal processing to spatially identify and separate legitimate GPS satellites from fake or spoofed GPS signals.

Our patented technology has proven to be impervious to spoofing—which guarantees business as usual.

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systems cannot rely on GNSS at all. Once they hit hypersonic speed, they lose all communications. Our X3 optical gyroscope IMU has an angular random walk (ARW) of 0.05°/√hr. The Navy is asking us to improve on that. The first phase was the design phase, to figure out how we can get 10 times, 20 times or even 100 times better. With better performance, you can get better accuracy over longer distances.

The first phase is a design phase, where we're going through different scenarios, and then the next phase will be to build it. I can't give you the numbers, because they're a secret, but we're talking about 10 or 20 times better than what we have today, and possibly 100 times better.

They still care about size, weight and power (SWaP). So, this is not about going 10 times better and 10 times the size. It's either 10 times better with the same size or 10 times or 100 better but a little bigger. So, this is what the hypersonic solution is about, and taking advantage of our integrated silicon photonics technology, our low power and low noise electronics, and our product's small footprint.

ANELLO Photonics

THE ANELLO MARITIME INS is equipped with three ANELLO silicon photonics optical gyroscopes for navigation in demanding maritime environments.

Tell me about your other recent contract, for a laser gyro for the U.S. Space Force.

This one is about making very small things. We have a silicon nitride platform based on ring resonators. We have a very low loss silicon nitrite process that is about 100 times lower than anybody else in the world has. We have published some papers with Stanford and with Caltech on resonators based on this low loss process with very high Q's (more than 400 million). This one was a six-month design phase to see how we could build a very small ring-based gyro based on our low loss nitride platform. Small here means on the order of 10 mm. The analysis was looking at various configurations and designs — including combinations of rings, exceptional points and the various tradeoffs of these various designs. Our current study for the U.S. Space Force is similar to this study, and this is also probably four or five months in. Then there'll be a design phase, then a phase two that will be funding to build that device and validate it via a lab POC. This is navigation-grade or tactical-grade, but it's for very, very small, low power form factors.

Briefly describe the resonator.

If you have a small, high-Q resonator, light goes in and gets coupled in and resonates. Because it goes around so many times, even though it's small, because of the finesse, you can get very good accuracy in terms of low ARW. The question is, how do you deal with the noise? How do you deal with the design, the coupling, the laser line width? Because of the low loss of the nitride, you can get these high-Q devices. When you get to hundreds of millions of Q, you can get large effective path length, which means you get very good sensitivity. Now, the complexity is that with a high-Q resonator, you need to tune that laser to the

resonance frequency of the ring. It's a completely different system than the fiberoptic gyro, which uses a broadband source and one coil. Here you have a resonator, and often you put light in both directions and you get them coupling. Then, you must subtract out thermal effects from rotation, but it works and can be very, very sensitive.

When you start looking at the rings and the micro rings, this is about making very small devices with high performance and that is scalable — granted, DoD likes to fund it, because they're putting these on lots of things. From our perspective, it could open up large markets such as the consumer market someday. Think about it: You have a 10 mm^2 device that's high precision. You integrate everything on that single integrated photonic chip — the electronics, the photonics — and now you have a tiny chip that can go in everything from phones to watches to handhelds and gaming.

In what is the Space Force putting them?

They want to put it in lots of high-precision stuff. But the Space Force also deals with missiles and hypersonics. The hypersonic program was specifically for a hypersonic group that requires high precision, low power, small form factor gyros that can be used broadly across platforms.

XONA SPACE SYSTEMS

Brian Manning, Co-Founder and CEO

Xona Space Systems is developing a network of small satellites in low-Earth orbit (LEO) to provide high-precision navigation services aimed at intelligent and autonomous technologies.

What's your current constellation and what are your plans for it?

We launched our first demonstration satellite in 2022. It demonstrated a lot of the core aspects of the technology and showed that we can provide high performance satellite navigation from a small, low-cost satellite, which was something that really hadn't been done before. Our first production-class satellite is on track to be launched in June. With that satellite, we'll be able to start demonstrating the full capabilities of the service. This is the first one designed to provide service directly to our customers' receivers and start to run real demonstration capabilities.

> "We only need to put a few hundred satellites in orbit, but there are about two billion new GNSS devices shipped every year. So, typically, the receiver end is the hard end."

From there, we're starting to ramp up with volume launches in late 2026, starting to have the first level of capability online in 2027. The final system will be about 250 satellites. We're targeting having that up, ideally, within the next five years.

Once your satellites are up there, what's the plan for receivers?

We took a very deliberate approach to the receiver end. One of the biggest challenges that we found that most people underestimate when deploying a new service is that the user equipment is the hard part. We only need to put a few hundred satellites in orbit, but there are about 2 billion new GNSS devices shipped every year. So, typically, the receiver end is the hard end. We started by talking to as many as possible of the manufacturers of GNSS user equipment to understand what capabilities they have, what flexibilities they have, what type of signals they can receive, what frequencies they can receive, etc. We ultimately designed the signal and the service around that so that it can be as little as a software or firmware update to an existing receiver without needing to change the hardware.

We're working with probably a dozen receiver manufacturers now. Quite a few of them have demonstrated that they can receive our signals and fully use our service with just firmware changes. We are pushing the envelope as to what can be done and the capabilities of GNSS.

In general, we've seen a pretty high uptake and ability for even very small, low-cost ASICs to be able to make software firmware changes to utilize our signals.

What are the primary defense use cases or missions for your signals? I assume that they would complement GNSS in areas where GNSS signals are denied.

If you look at the challenges facing defense forces when it comes to navigation, there are the obvious

ones, such as jamming and spoofing. You see what is happening in Ukraine and even in Israel. Things that affect the defense forces also affect all the civilian applications in the same area. The other legitimate concern is that GPS is such an incredibly valuable system that it has painted an equally massive target on its back. It is such a single point of failure for so many critical systems, for not only the military, but also the economy and logistics and everything else that it supports, and there's not really anything that can provide that level of performance as a backup if it goes down.

So, those are two of the very big gaps that we're working to help fill by providing a service that is much more resilient to jamming, has more security capabilities on board, and something that faces different threats and is in different orbits from GPS and can provide a backup that can be rapidly replenished. It's very much the Starlink approach to GPS. Instead of a small number of very big satellites, there is some natural resiliency in proliferating into many small satellites.

Would integrating your signal into current military GNSS receivers only require a software update?

It depends on how you look at integrating and into what systems you're planning to integrate it. The military GPS User Equipment (MGUE) program has very specific requirements designed to support very specific systems. I don't know what the volumes are on producing those devices. When the military would like to start producing systems in the volumes of tens of thousands or hundreds of thousands or millions, they often look to the commercial world. We see our service being incredibly valuable for UAVs, handhelds and other small devices that require a small SWAP and/or a low cost using commercial off-the-shelf (COTS) chipsets and need to integrate a high-performance service that can be tailored specifically for DOD and government use cases. The next conflict is more likely to be fought with a million small devices in addition to the hundreds or thousands of big bespoke ones. That's where we can really help fill a big gap for the DOD.

WINGXPAND

Michelle Madaras, Co-Founder and President

WingXpand builds autonomous smart planes with automatic AI threat detection for both defense and civil missions. As part of an ongoing U.S. Army contract, the company is collaborating with RTX's Raytheon, a provider of defense solutions, on a portion of these efforts.

What are the intended defense missions for your UAV?
Many of our military customers are using our system for perimeter security. We have additional capabilities for intelligence, surveillance and reconnaissance. Our system is modular, so it will host whatever sensor or payload you need to use. We recently won a new contract with U.S. Army Special Operations to refine the modularity of our payload. In addition to our current baseline offerings, they require additional sensors, payloads and drop mechanisms. So, we're developing a tool that can have a wide variety of applications, for both our defense and our commercial users.

Have any of the U.S. armed services already acquired your systems for deployment?
Yes, the Air Force and the Army are using our systems today. We've also done a little work with the Navy. We have an exemption to policy with the Army, the Navy and the Air Force today, meaning that they can procure our systems because we comply with the National Defense Authorization Act. We've had reviews of our systems. They went through all our critical subcomponents to make sure that those parts were not made by a foreign adversary. We also have airworthiness certifications with the Air Force and the Army.

Do you use commercial off-the-shelf (COTS) components? Do you discuss with your client their operational needs and come up with a solution, and then put it together and acquire the components?
That is correct, yes. We really try to take a hand-in-hand approach with our customers. We ask them, "How do you want to use this? What are your range requirements? What are your security requirements? What are your operational requirements?" Then we synthesize that information. Even early in the business, my co-founder and I found that for many of the drone solutions and subcomponents out there, you need to be a high-level professional to be able to put all these systems together. That's something that we felt was very difficult for many customers. They knew that they wanted drones, but they either didn't know exactly how to do that piecemeal or needed a trusted partner that could give them the solution that they were seeking as a holistic answer, as opposed to a point solution.

What kind of threats do your systems detect?
In addition to making our airframes, we make autonomous detection and alerting software. It's done at the edge, meaning a processor within the aircraft does the real-time detection and alerting. It also handles our full autonomy of the aircraft in flight. As part of a contract, we delivered real-time, early wildfire spotting using that edge AI detection. Another example that we're doing is for vehicle detection and tracking on behalf of the Army. We have a couple of other projects. I can't get into specifics here, but it's using both artificial intelligence and machine learning to recognize what the optics are seeing and then conduct real-time actions based on operator input.

WINGXPAND'S MODULAR smart planes, such as the xRAI (pictured), are designed for seamless hardware and software upgrades.

WingXpand

Your choice of sensors depends on the mission and the client, correct?
Yeah. Our website has some of our current baseline sensor offerings. We do build our own AI detection models for specific sensors. Sometimes, baseline AI and machine learning

repositories already exist out there in the world for the sensor that you want, and sometimes they don't. When it doesn't, we can use synthetic data combined with other data sources that are made available. Maybe our customers have those data sets, maybe they don't, but we really use all the tools at our disposal to organically create these detections. We are also able to import third-party applications on our autonomous systems.

What is your collaboration with Raytheon? What is your division of labor with them?

We won three of the Army's xTech competitions for small businesses: xTechSBIR Autonomy, xTechSpecial Forces and xTechSearch 7. The autonomy one was for our software, the Special Forces one was the modular payload I described earlier, and the Search 7 was for our airframe. They've gone toward developing different parts of WingXpand's overall unmanned system. When we won xTechSBIR Autonomy, we already had an ongoing relationship with Raytheon, and this was a way for us to bring them on board. They're one of the first apps in our app store. So, while we do detections today for vehicles, early signs of fire and other anomalies, Raytheon has a lot of experience using IR for thermal AI detection, so they're helping us with those detections. Now, in addition to standard RGB, we can also do those things in thermal, which is very cool and state of the art.

HEXAGON AUTONOMY & POSITIONING DIVISION

Neil Gerein, VP of Product, Aerospace & Defense

Hexagon, a very large company, makes a wide range of sensors that capture and display data about physical reality. On March 19, 2025, it acquired Septentrio, a manufacturer of GPS/GNSS positioning technology for autonomy and mission-critical applications.

It is often said that jamming and spoofing have increased significantly in the last few years, especially in and near conflict areas, such as Ukraine and the Middle East. Does Hexagon have any independent data on that? What do you hear from your customers?

We hear from our customers all over the world, and everyone is being affected. There are instances of GNSS jamming and spoofing almost daily, particularly in conflict areas such as Ukraine and the Middle East, just like you see in all the news reports. We know this from our customers, because they're using our equipment, and the situational awareness data out of our OEM7 receivers as well as our GAJT equipment enable them to know, yes, we're being jammed. Here's what the jamming environment looks like. Yes, we're being spoofed, and it continues to escalate and it continues to change.

Is GNSS anti-jamming technology (GAJT) a DOD term, an industry term or a Hexagon term?

That's a Hexagon trademarked term. You hear "GAJT" more and more because the product line has been available and used in the field for many years now.

The term "assured positioning, navigation and timing" is often used ambiguously. How do you define the term? Does it mean 100 percent assured in 100 percent GNSS-denied environments? Besides inertial navigation, what technologies does it require?

Everybody you talk to will have a slightly different definition of assured positioning. The way we see it is that you must trust that your positioning solution is reliable, accurate and resilient, no matter the environment. Nothing is ever 100% assured. In regions of conflict, the adversary is constantly escalating, so you need to have a layered approach.

When we talk about assured positioning, navigation and timing (PNT), it means that we protect GNSS and that we protect the RF environment using anti-jam antennas. We also use non-GNSS versions of PNT to augment the solution. A classic solution is using inertial sensors to aid navigation. With assured PNT, we are also always monitoring the RF spectrum for situational awareness, understanding what the threat environment is and then adapting to that by constantly advancing our technology.

What about non-GNSS sources of PNT?

We have found that our customers are using any and all technology available — from barometric pressure to radars to ultra-wide band positioning signals of opportunity. Our navigation engine can take in generic inputs for additional aiding, so they don't necessarily have to be inertial sensors. We can bring velocity and attitude updates from other devices into our sensor fusion engine. We've always had these generic-type interfaces going into our GNSS receivers because there's just such a plethora of relevant technologies, and every little bit helps.

You say that the new GAJT-310 "features advanced anti-jam technology." What does "advanced" mean in this context?

It's an increasingly competitive world regarding anti-jam technologies, and we don't give away our trade secrets. That being said, it's an extraordinarily fine-tuned solution for getting the right level of anti-jam performance in the right size, weight and power (SWaP). It's a much smaller form factor than our previous GAJT products and much lighter.

The advanced technology that must go into that is the advanced signal processing — to be able to get the SWaP down — as well as advanced manufacturing methods to put that into a package such that every single one that comes off the factory floor performs the same. So a small, three antenna element solution with the right level of performance for the right platform.

What are the key differentiators between CRPAs from different manufacturers? What is special about Hexagon's CRPA implementation?

Ours is unique in that it is receiver-agnostic, meaning that you can go to your local sporting goods shop and buy a GNSS receiver there, disconnect its antenna and hook it up to the GAJT-310, and it'll work. You don't need to have a specific military receiver to hook it up to. Our GAJT antennas have always been receiver-agnostic. They're designed so that, in the field, if somebody already has a receiver installed in their vehicle, they can very easily add the GAJT on top of that.

Also, because we come from a long heritage of selling many solutions across many industries, we bring a very stable supply chain, and we're able to get our receivers into customers' hands with great speed and expediency. That means that for urgent operational requirements in conflict zones we will react very fast and be able to supply our customers. Everything that comes out the door has the NovAtel brand quality behind it — so every unit performs the same, and our customers get advice from our application engineers and our pre-sales team as to how to install them and get things working.

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Spoofing Mitigation for Public Transport Navigation

How Galileo's OSNMA data authentication function helps secure GNSS receivers

BY JOSEP LABORDA
CEO AND MANAGING PARTNER, FACTUAL CONSULTING

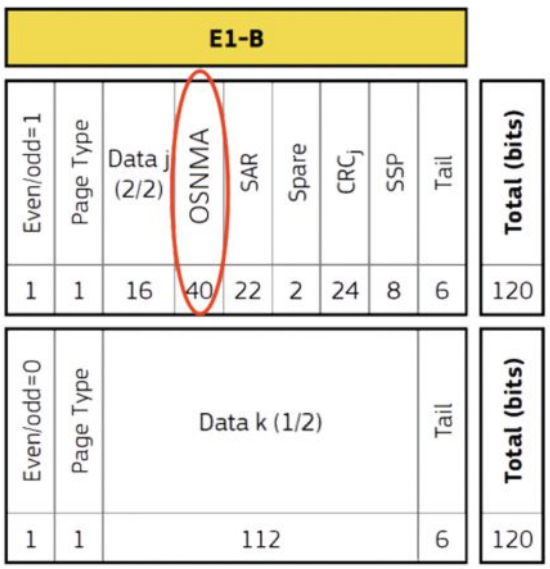
Public transport systems today rely heavily on global navigation satellite systems (GNSS) for various critical functions, from real-time tracking of buses and trains to providing accurate location information for passengers.

However, the vulnerability of GNSS signals to spoofing — where malicious actors transmit false signals to deceive receivers — poses a serious threat. Imagine the chaos if a spoofing attack were to disrupt the timing of trains or misdirect autonomous buses. The consequences could range from operational inefficiencies to severe safety hazards. This is where Galileo's key differentiator, the Open Service Navigation Message Authentication (OSNMA), comes in.

OSNMA is a free data authentication function for Galileo Open Service (OS) users available worldwide. It assures GNSS receivers that the Galileo navigation message is genuine and has not been tampered with, acting as a "digital signature."

OSNMA authenticates geolocation data from the Galileo Open Service via the I/NAV navigation message on the E1-B signal component, which is transmitted alongside the data used by GNSS receivers to compute position, velocity and time solutions. By integrating OSNMA, receivers can detect spoofed signals and respond accordingly.

The introduction of OSNMA has minimal impact on GNSS receivers, as the additional computational load required for cryptographic processing remains well within the capabilities of low-cost receivers — a crucial factor to consider, given that cost is a critical factor in public transport procurements. Furthermore, and just as importantly, OSNMA does not impact navigation performance, which is essential for managing public transport fleets efficiently. OSNMA is compatible with all types of receivers decoding the E1-B signal component. This approach ensures full backward compatibility, meaning that standard OS receivers can continue ignoring the OSNMA dedicated fields of I/NAV and keep functioning with the same performance level. Only OSNMA-ready receivers will decode these fields and be able to authenticate Galileo navigation data. In fact, OSNMA is becoming a readily available feature in many GNSS receivers already deployed through simple firmware updates.



I/NAV **Nominal Page with bits allocation.**

OSNMA SIS ICD

By enabling GNSS receivers on buses and trains to verify the authenticity of Galileo signals, OSNMA can ensure that the navigation data being used is genuine and untampered. For public transport operators, this means enhanced trust in the systems on which they rely daily, leading to more resilient and reliable operations.

JULIA: Advancing the Uptake of EU Space Data and Services in Public Transport

JULIA — short for Joint developments for Urban resiLIence connecting users to public transport through spAce technology — is a project funded by the European Union Agency for the Space Programme (EUSPA) under the Horizon Europe program and coordinated by Factual. It seeks to integrate EU Space services and data into the global public transport sector by utilizing Galileo, the European global navigation satellite system, and by leveraging Earth observation data from Copernicus.

JULIA assesses the benefits of using multi-constellation, multi-frequency GNSS receivers integrated into INIT's COPILOT last generation on-board computer, deployed on both regular as well as Demand-Responsive Transit

(DRT) bus services, in cooperation with the project partners Nemi (DRT tech provider), Arriva (bus operator) and OASA Transport for Athens (bus and train operator), as well as trains, with FGC and Hellenic Train (train operators). JULIA demonstrates how Galileo differentiators, such as OSNMA (and also High Accuracy Service — HAS), reduce friction in location accuracy while enhancing the security and efficiency of public transport operations. By exploring their benefits across the public transport value chain, JULIA raises awareness and fosters understanding of their potential. Ultimately, this will encourage the adoption of Galileo technology in the public transport sector.

> **"Real-time positioning of vehicles allows fleet operators to detect incidents such as significant delays, detours and breakdowns as soon as they occur."**

The OSNMA Public Observation phase started in November 2021 and concluded in early June 2024 with the last testing activities led by EUSPA, which is now preparing for the forthcoming OSNMA Initial Service declaration. This timing aligns very well with JULIA, which began in January 2024 and has since explored relevant use cases and conducted preliminary tests with its partners across Spain, Slovenia and Greece.

As OSNMA reaches maturity, providers of positioning and wireless communication technologies and services, such as u-blox, are releasing firmware updates for OSNMA support, starting with the u-blox ZED-F9P high-precision GNSS module used in INIT's COPILOT in JULIA. By incorporating OSNMA support, the industry is setting a new standard for GNSS security and reliability.

JULIA will provide evidence of OSNMA effectiveness in public transport through the following applications:

- **Trustworthy distance-based fare systems** calculate fares based on the distance traveled by a passenger, offering a fair and flexible pricing model that can adapt to varying trip lengths. However, the accuracy and reliability of these systems depend largely on precise and trustworthy positioning data. Imagine a bus system in a bustling urban area that uses distance-based fares. Without OSNMA, a spoofing attack could make it appear as though the bus is traveling a shorter distance than it actually is, leading to undercharging. Over time, this could result in significant financial losses for the operator. With OSNMA, the system can detect and reject spoofed signals, ensuring that fares are calculated accurately and fairly.
- **Reliable vehicle tracking with Galileo.** Buses, trams and trains transmit their position in near real time, which allows the operator to track them. The GNSS position can be used to display its live geographic position through an app and provide users a better estimated time of arrival. Real-time positioning of vehicles allows fleet operators to detect incidents such as significant delays, detours and breakdowns as soon as they occur. This enables them to proactively inform passengers and take necessary actions, minimizing disruptions and improving the overall passenger experience. Historical aggregated positioning data can help the operator identify whether any segments of the route or the schedules must be modified to optimize the speed of the service. GNSS can also improve low-demand railway lines by providing an accurate and cost-effective way to track trains and manage their movements. In contrast to traditional signaling systems that require physical infrastructure, GNSS can provide position information to trains in real time, allowing for efficient and safe train control. Furthermore, enhanced vehicle tracking will contribute to operational safety such as bridge warnings (for buses) and speed warnings (for buses, trams and trains) for the driver and at the control center (through INIT's MOBILE-ITCS). In addition, this will enable active speed adaptation measures (for buses, trams and trains) that require precise and authenticated GNSS position data that interacts with the on-board units embarked on the vehicles. By ensuring the authenticity and integrity of GNSS signals, OSNMA will safeguard these critical functionalities, protecting against spoofing attacks that could disrupt operations, misinform passengers or even compromise safety.

GNSS data authentication is also crucial for mission-critical applications, such as advanced driver assistance systems and autonomous driving, where the integrity of positioning data is paramount. By ensuring this integrity, OSNMA will help build public trust in modern transport systems. Passengers are more likely to embrace innovations such as on-demand shuttles or driverless buses when they are confident in the security of these systems.

JOSEP LABORDA is co-founder and CEO at Factual, a Barcelona-based innovation and strategy consulting firm specializing in mobility. He has been involved in more than 30 European research and development projects in the fields of connected, cooperative and automated driving, the intersection of space technology with mobility, road safety, decarbonization of mobility, mobility as a service, and mobility data management, including the latest trend on common European data spaces. A leading mobility expert, Laborda advises the European Commission and EIT Urban Mobility, and cooperates with Cities Forum in his independent capacity. He is a partner and member of the board at Nemi, a bus-on-demand startup, and co-founder and partner at Lane Patrol, a tool to assess the safety of cycling infrastructures.

From Shorelines to Seafloors

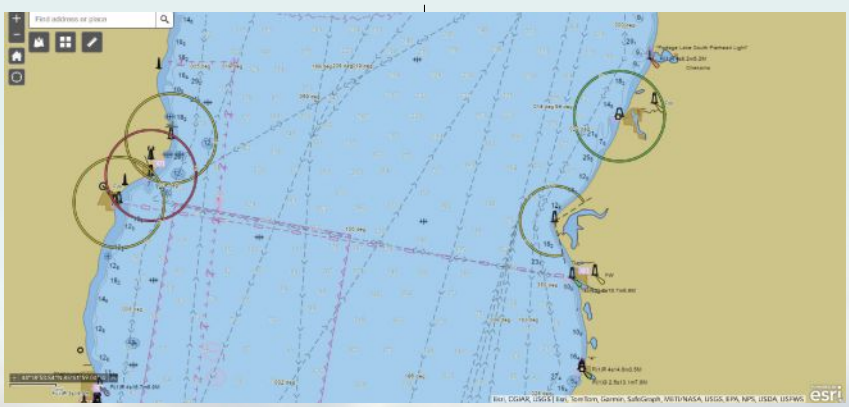
NV5 Celebrates Two Decades of Geospatial Data Collection for NOAA

BY JESSE KHALIL, ASSOCIATE EDITOR

NV5 is celebrating two decades of delivering critical geospatial services to the National Oceanic and Atmospheric Administration (NOAA).

Over the past 20 years, NV5 has completed more than 220 contracts across 30 states, covering more than 50,000 square miles. These projects involve topobathymetric surface modeling of shorelines, bays, estuaries, lakes, wetlands, rivers and streams to provide detailed data for various applications. The information generated helps NOAA protect and restore natural resources and habitats, update nautical charts and understand the effects of environmental and human-induced changes over time.

The company employs airborne remote sensing technologies, such as topobathymetric laser scanning, to capture near real-time changes in nearshore topography and bathymetry. Additionally, NV5 integrates marine vessel-based technologies, such as multibeam echo sounding, to map offshore bathymetry, including sand resources, essential fish habitats and historic shipwrecks.



NOAA

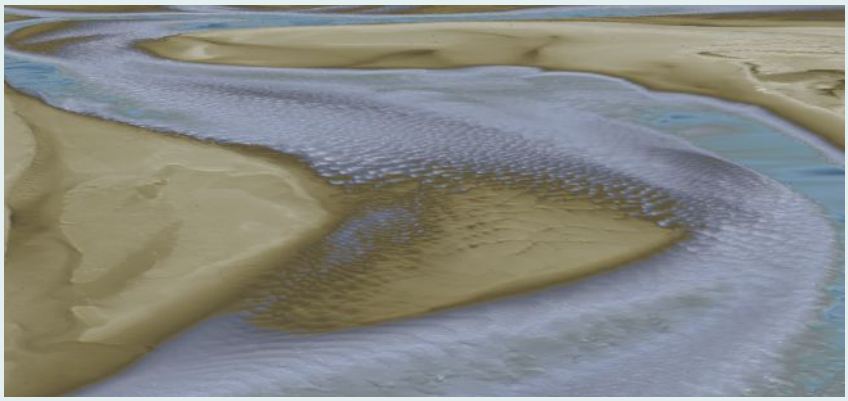
A screenshot from the NOAA ENC Viewer of the updated nautical chart of southern Lake Michigan, created using multibeam bathymetry and backscatter data.

"Our collaborations with NOAA over the past 20 years have yielded many important insights and baseline data that helps the agency with its core mission of climate monitoring, coastal restoration and supporting marine commerce – all of which supports our nation's economic vitality and affects more than one-third of America's gross domestic product," Dave Bernstein, vice president of hydrospatial operations at NV5, said.

In one notable project, NV5 conducted a large-scale hydrographic survey in southern Lake Michigan for NOAA's Office of Coast Survey. The survey covered 481 square nautical miles from northeast Chicago to Michigan City, Indiana — an area that had not been surveyed since the late 1940s. Using multibeam bathymetry

NV5

Lidar point cloud and lidar-derived bathymetric surface topobathy in Key Biscayne, Florida.

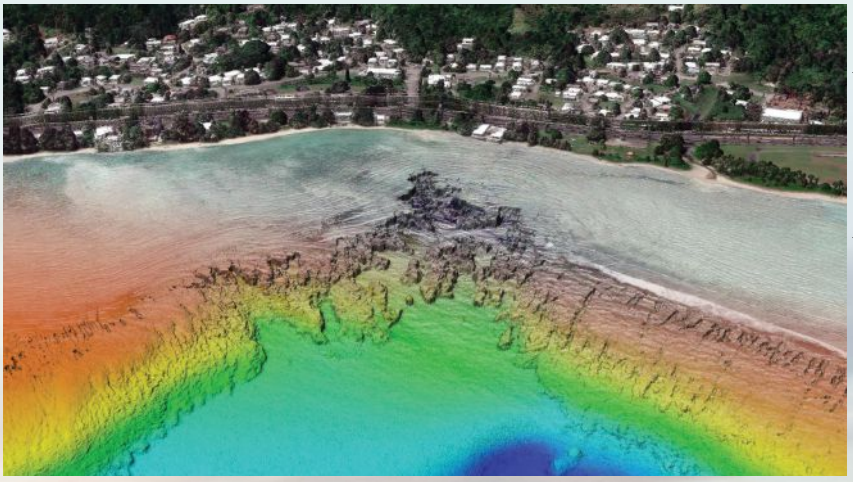


NV5

The National Geodetic Survey Remote Sensing Division's Coastal Mapping Program requires the collection of airborne topographic/bathymetric lidar and digital camera imagery data to enable accurate and consistent measurement of the national shoreline following Hurricane Sandy's landfall.

and backscatter data, NV5 updated NOAA nautical charting products to improve maritime safety along the Michigan, Indiana and Illinois shorelines. Under NOAA's Office for Coastal Management contract, NV5 also provided certified hydrographer expertise aboard the Pisces (R226), a NOAA fisheries research vessel. These efforts included overseeing the collection and processing of hydrographic data for marine habitat mapping.

NV5 has also contributed to NOAA's Coastal Change Analysis Program through projects that utilized aerial multispectral imagery and machine learning techniques. In Rhode Island, NV5 partnered with the National Estuarine Research Reserve System to study salt marsh habitats and produce change mapping products. Similarly, high-resolution land cover products were created for Brown County, Wisconsin, and key watersheds to assess urban growth, map wetlands, delineate wildlife habitats and monitor land cover changes over time. Other initiatives include mapping eelgrass habitats along coastal Massachusetts using multispectral aerial imagery and analyzing satellite imagery for wetland changes in the Great Lakes region.



Partnership between NV5 and Woolpert

A view looking south at the Submarine Canyon on Asan Point, Guam. The image was created from the lidar bare earth model and lidar point cloud colored by elevation and RGB values from imagery respectively.

Through these diverse projects, NV5 continues to provide NOAA with essential geospatial data that supports its mission of environmental stewardship and maritime safety while contributing to national economic vitality.

NV5

A view looking northeast from Virginia Key shows the topobathymetric surface of the intertidal zone near Fisher Island, Florida.

Nicholas Klein / iStock / Getty Images Plus / Getty Images

TIMING


Adtran

Italy Launches First Time-as-a-Service Platform

The Turin and Piedmont Internet Exchange (TOP-IX) has introduced Italy's first Time-as-a-Service (TaaS) solution, utilizing Adtran Oscilloquartz technology. This initiative, developed in collaboration with Italy's National Institute of Metrological Research and other partners, serves as a significant milestone in the country's digital infrastructure. The service is built on Oscilloquartz edge grandmaster devices deployed across TOP-IX's dedicated fiber network, offering precise timing and synchronization to industries such as finance, health care and logistics.

Central to this TaaS platform are Adtran's OSA 5410XG and OSA 5412 grandmaster clocks. The OSA 5410XG is designed for high-speed applications, featuring multiple 10Gbit/s ports and a compact form factor that allows for rapid scalability to meet growing bandwidth demands. Both devices incorporate Syncjack technology, enabling real-time performance monitoring for uninterrupted synchronization even under external threats.

This solution offers advanced features such as jamming and spoofing detection, multi-band GNSS receivers and timing assurance capabilities. TOP-IX's TaaS service provides a reliable alternative to GNSS systems and seeks to strengthen Italy's national timing infrastructure while addressing the growing demand for ultra-reliable timing across critical sectors.

SparkFun Unveils GNSS Disciplined Oscillator

SparkFun Electronics

SparkFun Electronics has introduced its first ultra-high-precision GNSS timing product, the SparkPNT GNSS Disciplined Oscillator (GNSSDO). Designed for applications requiring sub-nanosecond timing and frequency precision, the GNSSDO is built around Septentrio's multi-constellation, multi-frequency, L1/L2/L5-ready mosaic-T module.

The device integrates Septentrio's mosaic-T GNSS timing receiver, Espressif's ESP32-WROVER processor and the SiTime SiT5358 disciplined 10 MHz oscillator on a single circuit board. It is housed in a custom extruded aluminum case with machined end panels and slotted flanges, making it suitable for installation in weatherproof enclosures or server racks. Its time pulse accuracy is 5 ns, which improves to under 1 ns with an optional subscription to Fugro AtomiChron via L-Band. Event accuracy is less than 20 nanoseconds.

To ensure reliability and security, the Septentrio mosaic-T module provides robust performance even under challenging conditions such as GNSS jamming or spoofing. The system's multi-constellation and multi-frequency capabilities, combined with AIM+ technology, are designed to enhance resilience. Additionally, the integration of SiTime's Super-TCXO offers clock frequency stability and accuracy during GNSS outages.

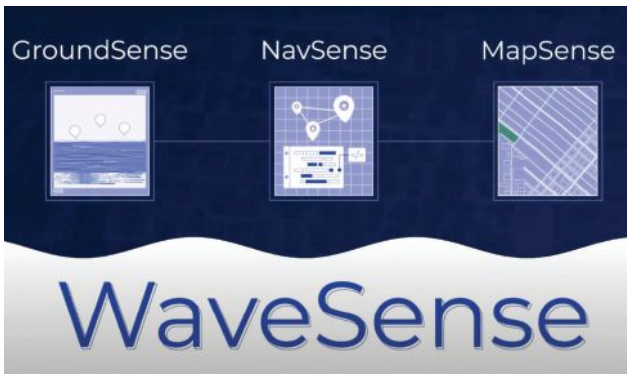
AUTONOMOUS SOLUTIONS

Advancing Ground-Penetrating Radar for Challenging Environments

Hexagon | NovAtel has signed a memorandum of understanding (MOU) with GPR Inc. to integrate GPR's WaveSense ground-penetrating radar sensors into NovAtel's SPAN GNSS/INS solution. Through this partnership, the companies will assess the integration of NovAtel's SPAN system with GPR's subsurface mapping technology, which is designed to enhance positioning solutions for applications that require high reliability and centimeter-level accuracy,such as autonomous systems, mining and other mission-critical operations.

NovAtel SPAN GNSS+INS technology provides reliable position, velocity and attitude (PVA) data by combining GNSS signals with inertial measurement unit data. According to the company, this approach ensures continuous accuracy during short GNSS interruptions caused by environmental factors, including foliage or buildings. By incorporating WaveSense's ground-penetrating radar as an additional input, the system can maintain accurate PVA solutions even during extended GNSS outages due to obstructions, signal interference or jamming, according to Hexagon. This integration can be particularly beneficial in GNSS-denied environments or areas lacking clear surface structures.

WaveSense's technology operates by scanning up to 10 ft below the ground, mapping unique subterranean features. These stable underground patterns serve as a reliable reference for navigation because it can remain unaffected by adverse weather conditions such as snow, rain or fog. This makes the integrated solution particularly valuable in GNSS-denied environments or areas lacking clear surface structures from civil to defense applications.



GPR Inc.

Under the terms of the MOU, NovAtel and GPR will collaborate on specific use cases to demonstrate the combined capabilities of SPAN and WaveSense in demanding real-world applications. Following these demonstrations, the partnership may advance toward a full product definition and supply agreement, according to the companies.

Hexagon Completes Acquisition of Septentrio, enhancing access to technology

Hexagon has finalized its acquisition of Septentrio NV. By integrating Septentrio's GNSS platforms with Hexagon's existing portfolio, the company aims to enhance access to high-accuracy and high-performance positioning technology designed for size, weight and power efficiency.

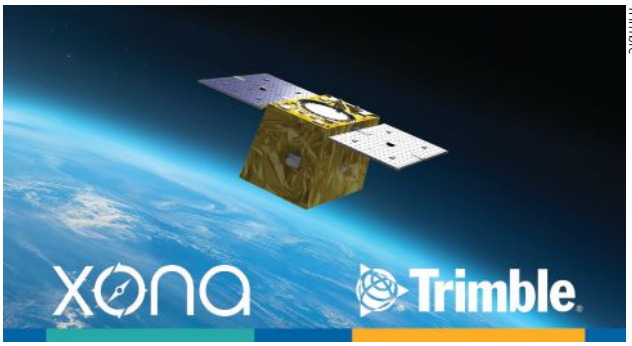
According to Gordon Dale, president of Hexagon's Autonomous Solutions division, the collaboration will enable the delivery of advanced solutions for autonomy and mission-critical applications across various industries.

The combined expertise of both companies is expected to accelerate the adoption of autonomous systems while addressing the needs of emerging sectors such as robotics, UAVs and other mission-critical technologies. Septentrio, headquartered in Leuven, Belgium, will maintain its existing business model of providing GNSS technology to a broad base of original equipment manufacturers.

Hexagon/Septentrio

SPACE & EARTH

Xona Space Systems, Trimble to Deliver Navigation Services



Trimble

Xona Space Systems and Trimble have collaborated to integrate Trimble correction services with Xona's PULSAR high-performance navigation service.

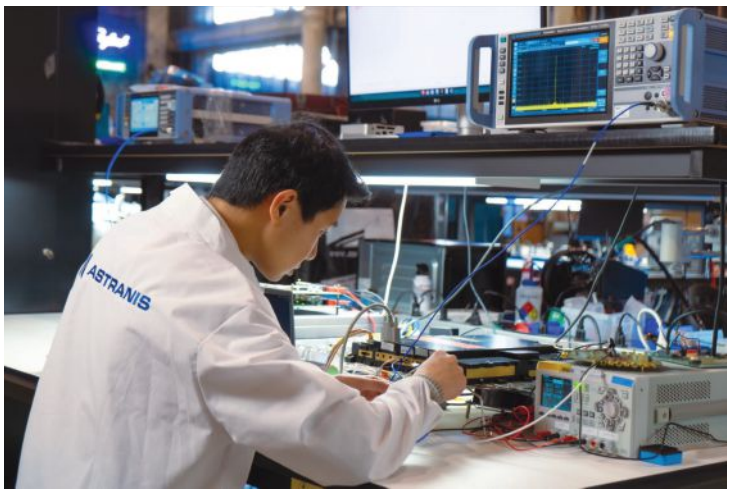
Initial satellite launches are expected in late 2026, with service starting in 2027 through the PULSAR satellite network. This seeks to enable secure, high-precision positioning for applications ranging from geospatial to low-power mass mobile and IoT. Xona has received an investment from Trimble Ventures to support this new and developing collaboration.

Xona PULSAR, powered by Xona's planned network of small satellites in low-Earth orbit, is being developed to deliver robust and secure high-precision positioning and navigation services directly to current GNSS hardware. The PULSAR service, which will include high-precision correction services through this collaboration, has the potential to provide scalable, cost-effective solutions for industries with demanding positioning and navigation requirements, such as civil construction, surveying and mapping, and automotive and IoT applications. Xona's signals are also expected to enable operations inside low-rise buildings, as well as improve resistance to jamming and interference compared to current GNSS capabilities.

Astranis Tests Resilient GPS Technology for US Space Force

Astranis has completed a critical demonstration for the U.S. Space Force's Resilient GPS (R-GPS) program, showcasing its ability to transmit core GPS waveforms using software-defined radio hardware. Conducted ahead of schedule and within budget, the demonstration highlights Astranis' ability to adapt its flight-heritage high-orbit satellite hardware to meet the Space Force's new resilience requirements.

The test took place at Astranis' headquarters in San Francisco using flight-like software-defined radio and positioning, navigation and timing algorithms provided by Xona Space Systems, a partner and subcontractor for the R-GPS program. Astranis transmitted a GPS Course Acquisition navigation signal through its resilient GPS payload and demonstrated signal acquisition and recovery of Legacy Navigation messages with an off-the-shelf GPS receiver. According to Astranis, this validated that its resilient GPS design, Nexus, complies with GPS specifications "out of the box," ensuring compatibility with existing user equipment without requiring costly upgrades.



Astranis

Astranis was selected in September 2024 as one of four contractors to design next-generation, resilient GPS satellites under the Space Force's initiative. The company received its authority to proceed on Sept. 19, 2024, and has since exceeded program objectives ahead of schedule. The R-GPS program aims to augment the existing GPS constellation with smaller, cost-effective satellites to enhance resilience against threats such as jamming or spoofing.

The company is advancing its satellite design in preparation for the Space Force's goal of launching the first eight R-GPS satellites by 2028. The company's approach leverages its MicroGEO satellite design and software-defined radio technology to deliver resilient capabilities while maintaining compatibility with legacy equipment.

DEFENSE

Collins Aerospace Kickstarts Full-Rate Production of MAPS GEN II Navigation System

Collins Aerospace

Collins Aerospace, a division of RTX, has received approval for full-rate production of its Mounted Assured PNT Generation II system (MAPS GEN II). This follows the fifth delivery order of the navigation solution, which is designed to resist jamming and spoofing attempts. The system will be deployed across thousands of U.S. Army and Marine Corps combat ground vehicles, as well as military watercraft, Collins Aerospace shared in a statement.

MAPS GEN II integrates sensor data from multiple sources, including satellite navigation and secured PNT information, to provide reliable guidance for both crewed and uncrewed ground vehicles. The system consists of Collins Aerospace's NavHub-100 navigation system and multi-sensor antenna system (MSAS-100), offering enhanced protection against emerging threats to GPS such as electronic warfare. By fusing data from various inputs, MAPS GEN II is engineered to offer accurate positioning even in contested environments.

This advanced system supports a wide range of mission types, including combat operations, artillery fires, air and missile defense, ship-to-shore movements and logistics in contested areas. Its modular open-system architecture allows for scalability and integration of additional sensors or capabilities at lower lifecycle costs. This flexibility ensures its adaptability to evolving military needs while maintaining high-performance standards.

WingXpand Enhances Smart Plane Capabilities with AI and VTOL Technology

WingXpand, a company specializing in autonomous smart planes, is developing new technologies to enhance operational capabilities in defense and civil missions. As part of an ongoing U.S. Army contract, the company is working with RTX's Raytheon to improve its systems.

The company's aircraft utilize artificial intelligence (AI) algorithms for real-time threat identification. The open systems architecture allows for integration of various applications and payloads, providing mission flexibility and adaptability to evolving threats. The collaboration is expected to enhance the effectiveness of WingXpand's technology, potentially improving surveillance and reconnaissance operations for military units, according to the company.

WingXpand has also introduced a vertical takeoff and landing (VTOL) capability for its xRAI smart plane. This feature allows the aircraft, which can be carried in a backpack, to operate in confined spaces and challenging environments.

ADVERTISER INDEX: COMPANIES FEATURED IN THIS ISSUE

Editor's Note: This ad/edit index is for reader convenience only. The publisher accepts no responsibility for errors or omissions.

UNB STUDENTS PREPARE FOR SECOND SATELLITE MISSION

The CubeSat team at the University of New Brunswick (UNB) is developing a second satellite after its first, VIOLET, failed to communicate with Earth. The team is refining its design based on lessons learned from the initial mission. VIOLET, deployed in 2024, was created through a partnership between UNB, the Université de Moncton and the New Brunswick Community College as part of the Canadian Space Agency's CubeSat Project. This initiative provides students with hands-on experience in designing, building, testing, launching and operating miniature satellites.

GPS SAVES 190 AIRLINE PASSENGERS

GPS technology played a crucial role in preventing disaster during an EasyJet flight, *The Daily Mail* reported. As the Airbus A320 descended toward Hurghada, Egypt, it approached dangerously close to a mountain range, flying at an altitude of 3,100 ft — just 770 ft above the peak of the mountain. The Ground Proximity Warning System, which relies on GPS-enabled terrain data, alerted the cockpit with warnings such as "pull up, terrain ahead." This alarm prompted the pilot to perform an emergency maneuver by pulling up the joystick to level off the plane, narrowly avoiding collision and saving all 190 passengers on board.

'GULF OF AMERICA' NAME CHANGE LEAVES DECISIONS FOR MAP CREATORS

With the U.S. government now recognizing the Gulf waters as the "Gulf of America" and not the "Gulf of Mexico," TomTom is introducing a U.S. geopolitical view for its users in the United States; they will see "Gulf of America." Translations will be available in English, Spanish, French and German, and users searching for "Gulf of Mexico" will find the "Gulf of America." Map users outside of the United States will see the default map view showing the "Gulf of Mexico." Users searching for "Gulf of America" will find the existing "Gulf of Mexico" feature. All users will be able to change the view based on their preferences.

NEW 'SURVEYOR' APP FOR IMPROVED MAPPING ACCURACY

Apple launched the Surveyor app, a tool designed to enhance the accuracy of Apple Maps by collecting real-world mapping data. According to Apple, Surveyor relies on partner companies and users to gather data along assigned routes. The app focuses on capturing detailed information such as street signs, traffic signals and roadside features, which are then transmitted to Apple for precise map updates. By leveraging community-driven data collection, Apple aims to refine its mapping ecosystem and keep critical details current.

PHOTO CREDITS: students, Canadian Space Agency • plane, Injenerker / iStock / Getty Images Plus / Getty Images • Map, TomTom • app, Apple

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