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EUSPA REPORT ON GNSS AND SECURE SATCOM

HARVESTING EFFICIENCIES

From Brazil to Japan, GNSS Steers Ag Machines

+ GNSS FOR THE OTHER 99.9 PERCENT

MARCH 2025 | Vol 36 | No 3
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CONTENTS

VOL. 36 NO. 3 GPSWORLD.COM

MARCH 2025

COVER STORY

Chris Clifford, Agri Automation

20 HARVESTING EFFICIENCIES

From Brazil to Japan, GNSS Steers Ag Machines

BY MATTEO LUCCIO

Farming in the past century has been transformed by such innovations as tractors, electrification, chemical fertilizers and pesticides. In the 1990s, precision agriculture emerged. It reduces inputs of water, fertilizer, seeds, pesticides and fuel and increases harvests by mapping variations in soil characteristics and plant health and then using those maps to adjust the inputs using variable rate technology on sprayers. It also ensures that no part of a field is sprayed twice or missed and greatly reduces overlap in seeding and tilling. For this year's cover story on precision agriculture, we discuss the key challenges and the latest generation of farming hardware, software and services with:

- **Kirstin Schauble,** director of systems engineering, **ANELLO Photonics.**
- **Joey Koebelen,** founder and CEO, **Deep Sand Technology.**
- **Chad Huedepohl,** PA portfolio manager, autonomy and positioning division, **Hexagon.**
- **Ken MacLeod,** director of product management, and **Gordon Echlin,** director of business development, **Calian GNSS.**

SECONDARY FEATURE

Julian Luna and Sarah Wondra

26 GNSS for the Other 99.9%

News from the World of Consumer Applications

BY MATTEO LUCCIO, JESSE KHALIL AND BRIAN RICHESSON

ON THE COVER

The Burro autonomous agricultural vehicle — made by Agri Automation, a company based in New Zealand — uses the GEODNET RTK network to achieve centimeter-level positional accuracy. Image credit: Chris Clifford, Agri Automation.

CONTENTS

30 2025 SIMULATOR BUYERS GUIDE

In our 14th annual Simulator Buyers Guide, we feature simulator tools, devices and software from seven prominent companies that aid GNSS receiver manufacturers in product design.

OPINIONS AND DEPARTMENTS

ONLINENOW

WEB EXCLUSIVE

GNSS Disruption at Sea Level

An Interference Study in the Baltic Sea

BY MAKSIM BARODZKA CEO AND FOUNDER, GPSPATRON

GPSPATRON and Gdynia Maritime University have conducted a six-month study on GNSS interference in the Baltic Sea. Using terrestrial GNSS monitoring technology, the project examined the frequency, duration and characteristics of interference events affecting maritime navigation and other critical applications.

Read more at **gpsworld.com/opinions**

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Our Varied Routes to GNSS/PNT

We each arrived at our current involvement with the GNSS/PNT industry by a different path. For many, it was through engineering, perhaps initially thinking of focusing on completely different challenges than those posed by extremely weak RF satellite signals, intentional interference, or ionospheric scintillation. For others, it was through surveying, which they might have entered to make a living traipsing through open fields — well, *traversing* them — while working independently and in nature.

For others still, it was through one of the myriad applications of GNSS — from mapping the geographic distribution of the few remaining Amur leopards to guiding a tractor in the field, from commercial fishing in Alaska to conducting search and rescue missions, to training for military raids. Yet for others, it was through business, perhaps because they were tasked to route delivery trucks more efficiently or to track each vehicle in a rental fleet. Professor Richard Langley started out as an applied physicist and a radio tinkerer, building his first radio at the age of 14. My colleagues at North Coast Media got here via a career in journalism, with the steep subject-matter learning curve following their training in writing and editing.

I got here mostly through my passion for maps, charts and navigation. I first became interested in maps as a child — after twice getting lost. The first time, I was 5 years old and lost track of my mother as she entered a store in Berkeley, California, and I kept walking down the street. The next time, I was 7 and had insisted on walking home alone from school in Milan, Italy. I was determined not to let it happen again. So, when I was 11, I was the only kid I knew who walked around Pisa studying a map and a compass.

Next came the topographic maps I used for hiking. In my 20s, sailing around the Boston Harbor islands and off the coast of Maine, I learned to use nautical charts, sextants, radio direction-finders, sonar, radar, Loran C, and, finally, hand-held GPS receivers. I read my first technical article on GPS in 1985, when I was a graduate student in international security at MIT and Harvard, and the U.S. military was building the system. I studied its technical specifications and dreamt about its many possible future applications.

In 2000, when looking for a career change and a job in journalism, I saw a posting for the position of managing editor of this magazine. I applied and 25 years later I am still in the business.

Throughout, I always have been impressed by the deep expertise of the scientists and engineers who created this fantastic GNSS that billions of people use multiple times a day yet take for granted. Those who discount, belittle or even mock the expertise of people who have spent decades studying complex subjects — from climate change to economics, from foreign policy to epidemiology, from education to urban planning — are profoundly unaware and misguided, when not hypocritical. We need experts.

Matteo Luccio | EDITOR-IN-CHIEF
mluccio@northcoastmedia.net

Professor Washington Ochieng proposed the following question:

When we discuss the security of GNSS/PNT systems, we nearly always focus on interference — i.e., meaconing, intrusion, jamming or spoofing. However, GNSS/PNT systems are embedded in systems of systems that also offer many other opportunities for cyberattacks. What should we do about it?

"Cyberattacks are a credible threat to all existing GNSS systems and certainly need to be taken into account when considering alternative resilient PNT solutions. In fact, Goal 3 of the recently released U.S. Department of Transportation PNT Strategic Plan identifies PNT cybersecurity as a critical element of PNT resilience. The National Institute of Standards and Technology (NIST) provided a report titled *Foundational PNT Profile: Applying the Cybersecurity Framework for the Responsible Use of Positioning, Navigation, and Timing (PNT) Services*. This cybersecurity framework was created for both users of PNT services to manage risks when using PNT signals or data, and for operators of alternative PNT services to leverage when providing PNT signals or services. It was created by applying the NIST Cybersecurity Framework (CSF) and provides approaches for cybersecurity for PNT by continuously monitoring for attacks (e.g., denial of service, jamming), false data, and other malicious behavior within the systems and across the PNT services, using data-driven methods and solutions. This *Cybersecurity Framework* should be routinely adopted by both users and providers of PNT services."

"As a GNSS receiver manufacturer and correction service provider, cyber attacks are a risk we must consider seriously that arises from our customers' integration of our solutions into complex systems. At the receiver level, it is important to make risk assessments to identify vulnerabilities across all components and implement a robust, multi-layered security strategy that includes physical, network and software components. At the core, our strategy incorporates cybersecurity considerations into our product/service development processes. We utilize the ASPICE framework for our engineering processes and we layer into that process the ISO21434 standard to ensure that we take steps all along the development path to consider cybersecurity. We selected this standard from the automotive industry due to the connected car use case, which is now in the front of cybersecurity development. ISO21434 covers the entire development life cycle — from system, to hardware and software, to verification and validation — in a way that many other standards do not.

As a correction service provider, we ensure our data streams are secure and reliable, maintaining the highest standards of accuracy and availability. We also use ISO27001 as an IT framework for our correction network infrastructure. Continuous monitoring and iterative improvements are crucial to maintaining a secure and resilient GNSS/PNT infrastructure. It is key also to prioritize redundancy and backup systems to ensure continuity and resilience, to develop a comprehensive incident response plan that allows for rapid action in case of a breach and to conduct regular employee training to promote cybersecurity awareness across all products and platforms."

I am very pleased to announce that **Professor Richard Langley** has agreed to join *GPS World*'s editorial advisory board. As most of our readers know, in our November 2024 issue, we published his 300th and final "Innovation" column and an extended tribute to him by some of his many friends and colleagues. He a is a professor in the Department of Geodesy and Geomatics Engineering at the University of New Brunswick (UNB) in Fredericton, Canada, where he has been teaching and conducting research since 1981, and the editor of *NAVIGATION: Journal of the Institute of Navigation*.

— Matteo Luccio, Editor-in-Chief

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SAFRAN
FEDERAL SYSTEMS

Safran Electronics & Defense

Empowering Defense Operations with Safran's Precision Timing Solutions

In defense operations, every nanosecond counts in critical detection missions, particularly in missile defense radar and distributed sensor systems. However, ensuring synchronized data exchange with highly-precise time and frequency across vast distances has long been challenging. Safran Electronics & Defense offers innovative navigation & timing solutions to tackle this pressing issue head-on.

The Problem

Missile defense radar and distributed sensor systems often suffer from data synchronization issues due to long distances between components. Traditional methods involving coaxial cables are cumbersome and present scalability issues. Maintaining accurate timing is essential for C5ISR systems to detect and track threats in real time.

The Solution

Safran introduces two groundbreaking solutions: HATI and the Z-Family. HATI, a licensable firmware, seamlessly integrates with existing FPGA designs and distributes time and frequency signals through standard optical fiber cables. It requires no additional hardware and ensures sub-nanosecond timing accuracy over distances of up to 50 miles. Alternatively, the White Rabbit Z-Family offers dedicated hardware for precise time distribution, implementing the White-Rabbit protocol to ensure high-accuracy timing within Metro Area Network distances and beyond.

Why Choose Safran

- **Easy Integration:** HATI can be installed on existing FPGA or PTP cards, eliminating the need for additional hardware.
- **Versatility:** Compatible with 1GB or 10GB Ethernet links, HATI adapts seamlessly to your existing network infrastructure.
- **Ruggedness:** Dynamic compensation of weather-induced asymmetries ensures reliable performance in any conditions.
- **Accuracy:** Achieve stunning sub-nanosecond resolution for timing synchronization, which is necessary for mission-critical applications.
- **Reliability:** Safran's solutions can manually distribute time and frequency over long distances without requiring amplifiers or frequent calibration.
- **Resiliency:** Incorporating failover mechanisms, our solutions ensure uninterrupted operation despite timing source failures.
- **Intuitive Management:** A user-friendly web UI, extensive SNMP monitoring and advanced management features streamline operations and maintenance.
- **Advanced Management:** Smart alerts, SNMP monitoring, topology discovery, and comprehensive logging ensure seamless integration with existing network management tools.

HATI sub-nanosecond time sync in phase array antennas also eliminates separate clock cables for each element, cutting costs and weight, and enhancing reliability. This is crucial for large systems with numerous cables.

Conclusion

Safran's precision timing solutions modernize defense operations, providing unmatched accuracy, reliability, and versatility. With HATI and the White Rabbit Z-Family, your systems are always synchronized, empowering you to stay ahead of threats in today's dynamic defense landscape. For more information, visit **www.safran-navigation-timing.com.**

SAFRAN

ISRO

THE NVS-02 NAVIGATION SATELLITE being encapsulated into its payload ahead of its launch on Jan. 28, 2025.

Indian Navigation Satellite Stranded in Transfer Orbit

The Indian Space Research Organisation (ISRO) has encountered a significant setback with its recently launched NVS-02 navigation satellite. Launched on Jan. 28, 2025, the satellite currently is stranded in a transfer orbit due to a critical failure in its onboard propulsion system, ISRO stated in a report. The issue occurred when the valves admitting the oxidizer to fire the thrusters for orbit raising failed to open, which prevented the satellite from reaching its intended orbital position.

The NVS-02 satellite, part of India's Navigation with Indian Constellation (NavIC) program, was launched using a Geosynchronous Satellite Launch Vehicle Mark II rocket from the Satish Dhawan Space Centre. The launch placed the satellite into a geostationary transfer orbit with a perigee of approximately 165 km and an apogee of approximately 37,582 km.

The launch placed the satellite into a geostationary transfer orbit with a perigee of approximately 165 km and an apogee of approximately 37,582 km.

ISRO noted in its statement that other systems on the spacecraft were working well, including a successful deployment of its solar panels.

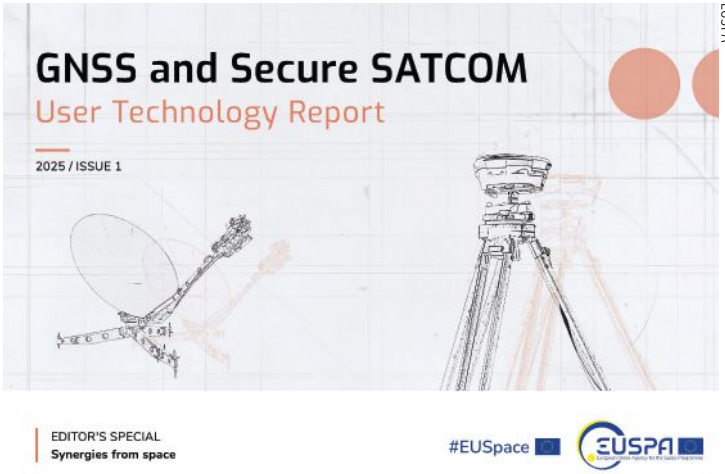
"The satellite systems are healthy, and the satellite is currently in elliptical orbit. Alternate mission strategies for utilizing the satellite for navigation in an elliptical orbit are being worked out," ISRO stated.

The space agency is now exploring alternative mission strategies to utilize the satellite for navigation in its current elliptical orbit. However, the low perigee of NVS-02 poses a significant risk, as it exposes the spacecraft to high atmospheric drag, potentially leading to an early reentry if the orbit cannot be raised.

NVS-02 is based on ISRO's I-2K satellite bus, which has been used for other Indian communications and navigation satellites and operates in geostationary orbit (GEO). The spacecraft had a launch mass of approximately 2,250 kg.

The spacecraft was intended to operate at 111.75° east in GEO to replace the IRNSS-1E spacecraft there. It is the second of five satellites planned for the NavIC program to provide PNT services in India and the surrounding region. The first satellite, NVS-01, was launched in 2023 and operates in GEO.

EUSPA Launches GNSS and Secure SATCOM User Technology Report



EUSPA

The European Union Agency for the Space Programme (EUSPA) has released its first *GNSS and Secure SATCOM User Technology Report*, offering a comprehensive overview of recent developments in GNSS and secure satellite communications (SATCOM). It combines and expands upon previous reports, addressing the satellite industry's ongoing transformation influenced by evolving security concerns, increased digitalization efforts, rapid progress in artificial intelligence (AI) and the emergence of the New Space sector.

The report begins by highlighting recent advancements in GNSS technology, including the adoption of new frequencies and multi-frequency capabilities. As new GNSS frequencies and signals become available for civilian applications, receiver manufacturers have been upgrading their products to accommodate satellites in medium-Earth orbit. The European GNSS program has made significant strides in this area, backed by the recent implementation of the Galileo High Accuracy Service (HAS) and the Open Service Navigation Message Authentication (OSNMA) feature, the report states.

Addressing growing concerns about spoofing and jamming threats, the report highlights solutions such as authentication, resilient receivers and hybridization with multiple sensors. The secure SATCOM section outlines key trends, including improved performance through digitalization, AI, cloud environments and integration with 5G networks. It also highlights the deployment of non-geostationary orbit (NGSO) constellations for reduced latency and the shift from hardware-centric to software-oriented designs in user terminals.

The report concludes by exploring potential and existing synergies between GNSS, secure SATCOM and Earth observation. Examples include relaying Earth observation data through SATCOM, using GNSS to operate mobile NGSO terminals, and combining GNSS and secure SATCOM in emergency management.

The full report can be downloaded at **euspa.europa.eu/tech-report**. Read more about the report on pg 17.

Iridium Considers Small Satellites to Advance PNT Capabilities

Iridium Communications is exploring the potential use of small satellites to demonstrate advanced positioning, navigation and timing (PNT) capabilities.

Iridium CEO Matt Desch discussed this initiative during the Smallsat Symposium in Silicon Valley, where he suggested the company might venture into the smallsat business, even if only for experimental purposes.

Desch said that small satellites could also support the development of a very-high frequency (VHF) radio system aimed at enhancing pilot communications with Aireon, a provider of aircraft surveillance services using hosted payloads on Iridium's satellites.

Iridium operates a constellation of 66 Iridium Next spacecraft in low-Earth orbit (LEO) for L-band connectivity services, along with additional spare satellites. Following an engineering assessment in 2024, the company expects this constellation to remain operational until at least 2035.


Iridium Communications

The Iridium Next satellites, weighing approximately 860 kg, are significantly larger than typical small satellites used for LEO communications, which generally range from a few dozen to a few hundred kilograms. While smaller satellites offer advantages in terms of faster and more cost-effective deployment for specific missions, Iridium's larger satellites are designed for extended operational life, supporting its global, cross-linked network.

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

1. NEW ECO-FRIENDLY CARRYING CASE

FOR EOS POSITIONING SYSTEMS' RECEIVERS

The Skadi Gold, Skadi 300 and Skadi 200 GNSS receivers will now be shipped in a field-rugged carrying case made entirely from recycled materials. The case is designed to meet the demands of professionals who utilize GNSS technology in challenging environments. Its construction incorporates durable, eco-friendly materials that can withstand various field conditions, from remote wilderness areas to urban construction sites.

A key feature is its composition of 100% post-consumer recycled resin, which significantly reduces waste and promotes environmental sustainability, according to the company. It is specifically engineered to be shock-resistant and weatherproof.

The case is provided as a standard inclusion with every purchase of the Skadi Gold, Skadi 300 or Skadi 200 GNSS receivers at no additional cost.

Eos Positioning Systems, eos-gnss.com

2. MULTIBEAM SONAR

DESIGNED FOR BATHYMETRIC SURVEYING

The Gemini 1200id is built on the same robust platform as the Gemini 720is multibeam sonar. The device features a 120° horizontal field of view, operating at both 720 kHz and 1,200 kHz acoustic frequencies.

The Gemini 1200id incorporates advanced noise reduction technology to significantly improve the attenuation of waterborne electrical noise to enhance imaging performance. An integrated speed-of-sound sensor ensures high positional accuracy of displayed targets, while CHIRP processing technology enhances target separation over extended ranges.

Compatibility with Tritech's Genesis software package allows users to control multiple Tritech products from a single interface to streamline operations. The company has also made software development kits available for Windows and Linux operating systems to integrate into various platforms. The sonar's design includes a custom-developed analog front-end solution with fully differential receiver channels, making it ideal for longer-range applications.

Tritech, tritech.co.uk

3. GNSS RECEIVER

WITH ADVANCED TILT COMPENSATION

HiPer XRa is a GNSS receiver for surveying, mapping and construction applications. It can benefit a wide variety of users, including construction professionals, surveyors, geographic information systems (GIS) professionals, archeologists, engineering firms and more. The HiPer XR supports GPS, GLONASS, Galileo, BeiDou, IRNSS, QZSS and SBAS.

The new receiver has advanced Topcon Integrated Leveling Technology (TILT) compensation, featuring a calibration-free and magnetic interference-immune integrated IMU that provides up to 60° of tilt for precision measurements in challenging positions. It has signal integrity protection, anti-jamming and anti-spoofing capabilities. Through the myTopcon NOW! website, users can access online training materials, firmware updates and additional software resources.

Topcon Positioning Systems, topconpositioning.com

4. AIRBORNE LIDAR SYSTEM

IDEAL FOR COASTLINE AND RIVER SURVEYING

CoastalMapper is an airborne bathymetric lidar system for coastline and river surveying. The CoastalMapper can survey coastlines and rivers 250% faster than previous sensor models, according to Leica Geosystems.

It is suitable for various mapping applications, from assessing infrastructure resilience to monitoring river floods and conducting environmental investigations.

It features a high-performance bathymetric lidar module, a Leica TerrainMapper-3 topographic lidar and an imaging sensor, integrated into a compact and lightweight sensor head. This allows the CoastalMapper to capture up to 1 million bathymetric data points and 2 million topographic data points per second while providing high-resolution imagery with a 5-cm ground sampling distance at typical flying heights.

It integrates with Leica Geosystems' airborne mapping workflows and offers cluster processing capabilities, allowing users to analyze large datasets and reduce the time from data collection to final deliverables. These outputs can include classified point clouds, digital terrain and surface models, and various imaging products.

Leica Geosystems, leica-geosystems.com

5. SURVEYING KIT

STREAMLINES BASE STATION AND CHECKPOINT SETUP

WingtraGROUND, a comprehensive survey kit, streamlines base station and checkpoint setup for on-site post-processing kinematic surveys with the WingtraONE Gen II, a vertical takeoff and landing UAV. The kit combines receivers, checkpoints and tools into a single, portable workflow.

The system integrates hardware components with a Wingtra tablet interface, which can help surveyors confirm correct receiver placement and avoid common errors associated with improper base station setup and inaccurate coordinates.

Wingtra receivers, equipped with Emlid Reach RS3 technology, provide accuracy within 2 cm, meeting high standards for aerial data validation. These receivers can also function independently for terrestrial surveys in real-time kinematic mode, including point collection and stakeout for various applications.

Wingtra, wingtra.com

6. GALILEO HAS-ENABLED RECEIVER

OFFERS POSITIONING CAPABILITIES WITH 20 CM ACCURACY

The Geode GNS3H supports Galileo High Accuracy Service (HAS). It offers positioning capabilities with 20 cm accuracy worldwide without requiring additional infrastructure or subscriptions.

It is built to withstand tough conditions, making it ideal for demanding fieldwork. The device offers various accessories, including the Geode Grip, which combines the Geode with a data collection device of choice into a single handheld solution. A backpack strap kit and survey pole are also available to enhance mobility and flexibility in the field. The GNS3H can be used for surveying, agriculture, construction, forestry, mining and archaeology.

Juniper Systems, junipersys.com

7. EXPANDED MAPPING PORTFOLIO

3D MAPPING TECHNOLOGIES AND MORE

Topcon Positioning Systems has become an authorized distributor of Pix4D's photogrammetry software portfolio.

The partnership aims to enhance reality capture solutions across various industries, including surveying, mapping, utilities infrastructure, public safety, forensics, and architecture, engineering and construction.

The agreement streamlines the procurement process for end users by allowing them to access Pix4D's advanced photogrammetry software solutions through Topcon's global distribution network.

Topcon Positioning Systems, topconpositioning.com

1. CLICK BOARD

WITH A UNICORE RTK POSITIONING MODULE

The GNSS real-time kinematic (RTK) 5 Click — a compact add-on board for high-precision positioning and navigation demands — features the UM980, an all-constellation multifrequency RTK positioning module from Unicore, with the advanced NebulasIV SoC for enhanced performance.

It supports Swift Navigation's Skylark precise positioning service, multiple GNSS constellations and RTK positioning for centimeter-level accuracy. The board also features JamShield technology for robust performance in challenging environments, USB connectivity for easy configuration and visual status indicators for module status and GNSS signal reception.

It can be used for a variety of applications, including surveying and mapping, precision agriculture, UAVs, autonomous robots and autonomous driving.

MIKROE, mikroe.com / Unicore, en.unicore.com

2. MULTI-BAND GNSS ANTENNA

CAN OPERATE IN URBAN ENVIRONMENTS

Levity Series' AHP24510 (L1/L2/L-Band) and AHP54510 (L1/L5/L-Band) directional patch antennas are designed to receive signals from GPS, Galileo, GLONASS and BeiDou satellite constellations.

These antennas offer faster and more accurate signal acquisition and lock, specifically in urban environments. The L-Band capability allows compatibility with high-precision GNSS correction services. The multi-band antennas offer integral redundancy to minimize satellite security blind spots and reduce energy consumption due to faster acquisition, requiring less system uptime to save power.

The Levity Series active antennas feature a 45 mm x 45 mm x 10 mm wide-band, dual-stacked patch design with a dual-feed, low noise amplifier, providing 28 dB to 29 dB gain and filtering. They operate with a maximum antenna VSWR of 1-to-1 from 1,207 MHz to 1,603 MHz, and the passive antenna efficiency ranges from 39.93% to 68.51% in the L1 band. These antennas use right-hand circular polarization to mitigate multi-path interference.

The Levity Series includes other multi-band products for high-precision applications, such as the HP24510A and HP54510A stacked-patch passive components, and the TFM.120A surface-mount front-end module, which covers the full multi-band GNSS spectrum including L-band. These antennas are suitable for various applications, including wearables, transportation, robotics, precision agriculture and autonomous vehicles.

Taoglas, taoglas.com

3. HELICAL ANTENNA

MITIGATES LTE INTERFERENCE

The M9PLUS-HCT-A-SMA is an active multi-frequency GNSS antenna designed for high-accuracy applications. It supports L1/L2/L5 GPS, Galileo, Beidou and GLONASS bands, as well as L-band correction services. The antenna utilizes Maxtena's proprietary Helicore technology, which offers advanced pattern control, polarization purity and efficiency in a compact form factor.

It integrates a pre-filter specifically engineered to mitigate LTE interference. This is crucial for maintaining signal integrity in environments with dense mobile communication networks, where LTE signals can overlap with GNSS frequencies. The pre-filter can effectively block out-of-band LTE signals, reducing intermodulation risks and ensuring clear GNSS signal reception.

The M9PLUS-HCT-A-SMA is built with rugged, IP67 automotive-grade components and includes an integrated SMA connector. It also features an O-ring for enhanced environmental sealing. Weighing only 24 grams, the antenna is ground plane-independent, making it versatile for various installations. It is particularly well-suited for GIS and RTK applications where high accuracy and reliability are crucial.

Maxtena, maxtena.com

4. THREE-AXIS FOG

WITH AN 8 KHZ OUTPUT

The MostaTech G321M is a three-axis fiber optic gyroscope (FOG) that offers high-precision navigation and orientation measurement capabilities. This advanced sensor features a data rate of 8 kHz.

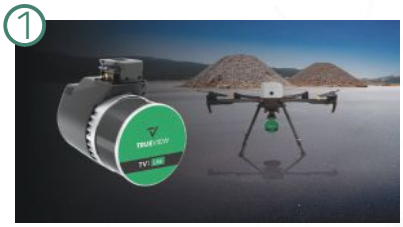
Key features of the G321M include an input range of 400° per second, a bias RMS of 1° per hour and an angular random walk of 0.025 °/√h. Additionally, it has a power consumption of 2 W and an initialization time of 1 second. The G321M is designed with a compact form factor, making it suitable for various applications where size and weight are critical factors.

It is ideal for UAVs, robotics, borehole surveys, image stabilization, gimbal stabilization and underwater vehicles.

MostaTech, mosatech.mt

1. HIGH-PRECISION LIDAR

DESIGNED FOR PRECISION APPLICATIONS



The TV1 Lite and the TV1 UAV systems are designed for various precision applications, such as mapping and data collection.

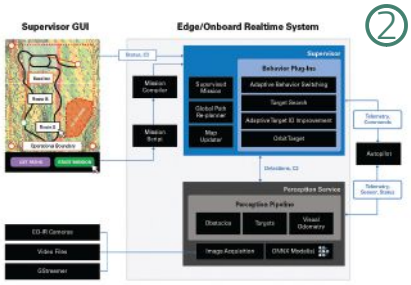
The TV1 Lite features TrueNav technology, a Hesai 32-channel laser scanner and a FLIR 5MP global shutter camera with a 90° field of view. It also includes one year of TV1 Lite Annual Processing with support and maintenance.

TV1 offers customization options, allowing users to choose from 26 MP, 45 MP or 61 MP cameras and various Trajectory Correction Service options.

GeoCue, geocue.com

2. FLIGHT CONTROL SYSTEM

WITH AUTOPILOT FUNCTIONALITY



The Prism Supervisor software combines UAV autopilot flight control systems with AI-based observations processed in real time, aiming to enhance UAV operations.

The system provides a programming framework and software development kit for users to create custom mission scenarios. During flight, Prism Supervisor can adapt its autopilot functionality in real time, generating mission segments and flight plans as needed.

The software features a user-friendly graphic interface for mission planning, real-time visualization and execution. It supports Windows, Linux, macOS, iOS and Android.

Teledyne FLIR, flir.com

3. REMOTE ID RECEIVER

ENHANCES AIRSPACE AWARENESS AND UAV SAFETY

RIDER is designed to enhance situational awareness by providing real-time detection of UAV activity in sensitive areas. It also seeks to provide a clear visibility of surrounding UAV operations to help avoid potential collisions and ensure safer flight experiences.

The device features a built-in industrial chip SIM that provides global coverage through LTE-M and NB-IoT, ensuring connectivity in various environments.

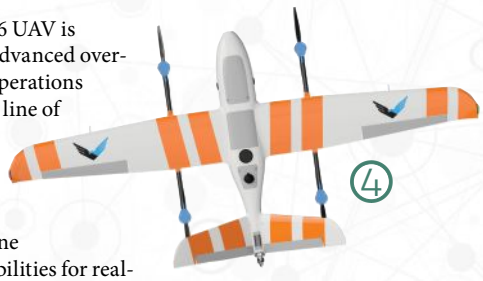
It operates effectively within a temperature range of -20 °C to +60 °C and is rated IP54 for dust and water resistance. The device complies with ASTM F3411-22A and ASD-STAN EN 4709-002 standards, making it suitable for regulatory environments.

The RIDER can detect signals from up to 5 km with its default antennas and up to 10 km when using an optional high-performance antenna. It is equipped with an internal cellular and Bluetooth antenna, along with an integrated GNSS antenna that provides precise positioning and timestamping capabilities. It supports multiple GNSS frequencies and utilizes Bluetooth and Wi-Fi technologies for Remote ID communications.

Dronetag, dronetag.com

4. STREAMLINED BVLOS OPERATIONS

FOR A VARIETY OF APPLICATIONS



The Sentaero 6 UAV is designed for advanced over-the-horizon operations beyond visual line of sight (OTH-BVLOS). It features built-in AI and machine learning capabilities for real-time data processing. The system can be used for surveying, mapping, inspection, asset monitoring and more.

Engineered to streamline operations, the Sentaero 6 offers more accurate and up-to-date intelligence on assets. Its onboard computer can processes data mid-flight.

Future developments will include swarm operations, enabling one human to control multiple UAVs simultaneously; fully remote operations and higher safety standards, such as a parachute for urban missions, according to Censys Technologies.

Censys Technologies, censystech.com

5. SENSOR UPDATE

NOW INCORPORATES THE LATEST WMM

SBG Systems has significantly updated its Ellipse series sensors, incorporating the latest World Magnetic Model (WMM) to enhance accuracy and reliability in navigation applications. This upgrade is available for all Ellipse sensors, including first-generation models.

Designed for unmanned systems such as UAVs, UGVs and marine platforms, the Ellipse series comprises compact, high-precision inertial sensors. These devices feature built-in three-axis magnetometers that measure Earth's magnetic field, crucial for accurate heading and positioning data.

Updated every five years, the WMM is a globally recognized mathematical representation of Earth's magnetic field. The latest version, released in December 2024, ensures precise heading and positioning corrections to account for ongoing geomagnetic changes.

SBG Systems, sbg-systems.com

LAUNCHPAD | DEFENSE

1. NDAA-COMPLIANT UAV

NOW INTEGRATED WITH ARCGIS FLIGHT

Esri now supports the Astro Max UAV in its ArcGIS Flight application. The Astro Max is the first Blue UAS-cleared and NDAA-compliant UAV to integrate with Esri's platform.

The Astro Max, developed by Esri partner Freefly Systems, adheres to the security and performance standards set by the National Defense Authorization Act and the Defense Innovation Unit's Blue UAS initiative. This industrial UAV is designed to enhance the capabilities of government and enterprise users utilizing ArcGIS Flight.

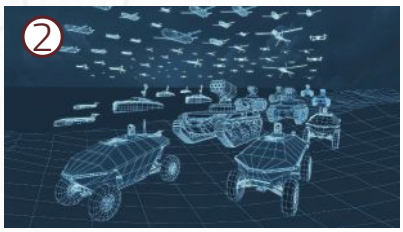
Freefly Systems, freeflysystems.com

2. AUTONOMOUS SWARM CONTROL

CONTROLS VARIOUS AUTONOMOUS PLATFORMS

The Autonomous Multi-Domain Operations Resiliency Platform for Heterogeneous Unmanned Swarms (AMORPHOUS) software features a single-user interface to operate thousands of autonomous assets simultaneously. Designed with an open architecture, this software enables the U.S. and allied militaries to control a mix of uncrewed platforms, payloads and systems.

AMORPHOUS includes an intuitive and distributed command-and-control interface to give operators the flexibility to conduct a wider array of intricate military missions. This collaborative autonomy at scale will provide warfighters with a decisive overmatch capability.



L3Harris is developing prototypes using the AMORPHOUS architecture on contracts for the U.S. Army and the Defense Innovation Unit. AMORPHOUS has demonstrated flexibility and interoperability by controlling multiple, separate assets across multiple vehicle types operating in different domains during government-managed tests.

AMORPHOUS supports decentralized decision-making, which enables individual, uncrewed assets to perform tasks autonomously and make real-time tactical decisions inside the network.

L3Harris, l3harris.com

3. ADVANCED COUNTER-UAV RADAR

MULTI-CONSOLE RADAR CONTROL AND DISPLAY SYSTEM

Cambridge Pixel has developed a radar control and display system for Weibel Scientific's XENTA surveillance radar, which is designed for modern air defense and counter-unmanned aerial systems (C-UAS) applications. The XENTA radar includes 3D target tracking, continuous target illumination and synthetic receiver beamforming. It is available in two configurations: the XENTA-M for short-range air defense and the XENTA-C for C-UAS operations.

The system is designed to work seamlessly with third-party command-and-control systems, enhancing operational efficiency.

Cambridge Pixel's library of radar processing software allows users to develop a tailored radar controller specific to the XENTA radar's requirements. Enhancements were made to existing functionalities, such as improved MIL-STD-2525 overlay graphics and support for dual-redundant operator consoles.

The XENTA radar system can detect small UAVs at distances exceeding 7 km and classify them beyond 5 km. This capability makes it suitable for various applications, including airport security, border control, critical infrastructure protection and event security.

Cambridge Pixel, cambridgepixel.com

LAUNCHPAD | MACHINE CONTROL/AG

1. UAV

FOR AUTONOMOUS SPRAYING

The Pelican 2 agricultural spray UAV has an expanded 300-liter payload capacity and can cover up to 5.3 ha/hr.

It incorporates several technological enhancements designed to meet the demands of agriculture applications. The aircraft features an upgraded four-motor electric propulsion system, a wider 18-m spray swath and advanced lidar and radar systems for fully autonomous day-and-night spraying. These improvements aim to increase efficiency and precision in aerial application while reducing operational costs for farmers.

The Pelican 2's airframe and structural components are constructed from carbon fiber composites, corrosion-resistant metallic components and 3D-printed assemblies.

Pyka, flypyka.com

EUSPA's First Ever GNSS and Secure SATCOM User Technology Report

Good Reading for Policymakers

BY DANA GOWARD
PRESIDENT, RESILIENT NAVIGATION AND TIMING FOUNDATION

In case you missed it, the European Union Agency for the Space Program (EUSPA) recently issued its first ever *User Technology Report* addressing both GNSS and Secure SATCOM. Though they seem to be different and distinct topics, EUSPA does a reasonable job of drawing them together with an "Editor's Special — Synergies from Space" at the end of the document.

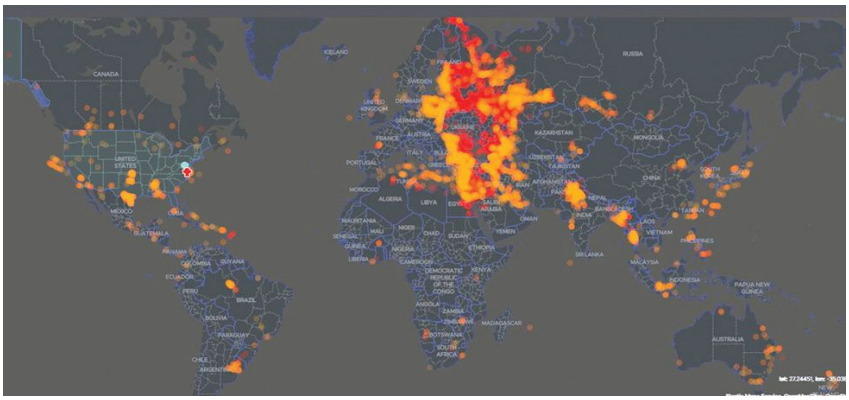
The first half of the report deals with GNSS and is an exploration and celebration of how far we have come with GNSS. While the report is aimed at "users" and is designed to be "technical," it is written to be accessible by most who are generally familiar with the topic.

Also, a careful reading reveals several messages for policymakers.

Protecting Frequencies

The report opens with a celebration of what has now become a multi-constellation, multi-frequency, open positioning, navigation and timing (PNT) system with 110 satellites, two regional augmentation systems (Japan's QZSS and India's NavIC), and Satellite Based Augmentation Systems (SBAS). All of this depends, of course, on clear and uninterrupted signals.

One of the first cautions policy makers should note is a subheading in the section that reads "Frequencies: a scarce resource to be protected." This is the first of many mentions of the need to protect signals and users from accidental and malicious interference.



US DOT and DOD

30 DAYS of GPS Interference in 2024.

From 2016 to 2019, the European Union's STRIKE3 project deployed equipment to monitor L1/E1 signals in 23 countries across the globe. They found more than 450,000 signals that could interfere with GNSS, 59,000 of which were assessed to be intentional jamming or spoofing.

This was well before the current wars in Ukraine and the Middle East and before Russia's malicious ongoing electronic warfare in the Baltic. So, even in the absence of aggressive nation-state actions, which could flare up at any time, STRIKE3 showed that GNSS interference was a significant problem threatening users' reliance on GNSS.

Both the European Union and the United States have undertaken projects in response to widespread jamming and spoofing.

In Europe, EUSPA has begun the EGIPRON project, or European Global Interference PROtection Network. It aims to develop and deploy "…an interference monitoring system covering all European territories and worldwide areas of European interest" working with contractors Qascom and Leonardo.

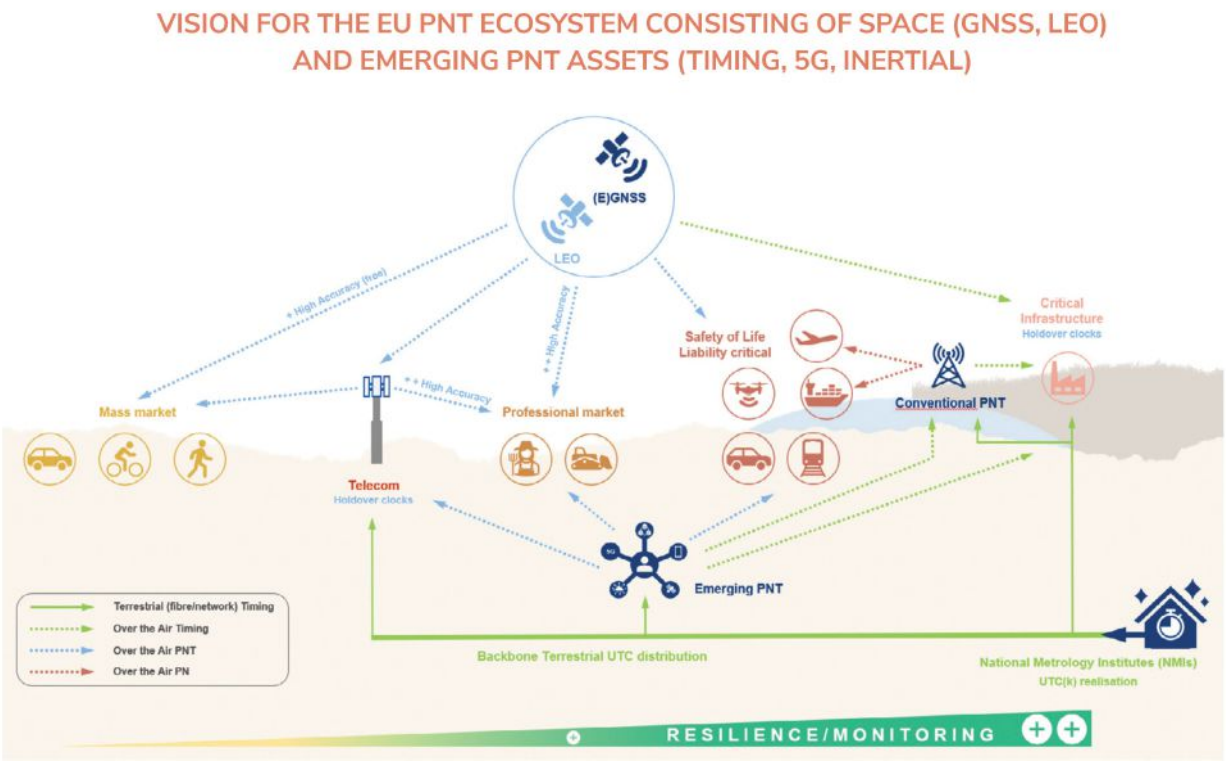
The U.S. Department of Transportation (DOT) announced the "GNSS Situational Awareness Common Operational Picture GovCloud Environment" at the December 2024 National PNT Advisory Board meeting. The government version was described as operational, with a public version to be available in mid-2025.

These detection — and hopefully geolocation — systems will be great tools. Policy makers must remember, though, that better understanding the scope of the problem will not solve it.

Better laws and regulations to empower enforcement, along with improved enforcement capability, will both be needed if even a dent is to be made in the problem. Getting these in place will be significant legislative and budgetary challenges. Even then, the problem of accidental and malicious GNSS interference will not be solved. Authorities will just be able to manage it a bit better.

Toughen Receivers

A great majority of the GNSS portion of the document is appropriately devoted to receivers. They are, after all, the only part of the GNSS system over which



European Union

users have any discretion and control.

Receiver design, signal processing, antennas and PNT processing are all discussed. The most attention is paid to describing the characteristics and appropriate uses of five different families of GNSS receivers:

- Mass Market Entry-Level
- Mass Market Premium
- Professional Non-Regulated
- Professional Regulated
- Special Applications

Using the right kind of GNSS receiver for a given application is essential for safety and effectiveness.

The question for policymakers, though, is not whether the right technology exists to mitigate risks — it does. Rather, the issue is whether that technology is being used appropriately.

Most GNSS users are uninformed about GNSS issues and tend to purchase equipment based upon price rather than resilience. Policymakers must consider how to motivate users, especially in critical applications, to purchase and use more expensive equipment. Government leaders have many levers of influence at their disposal, from education to regulation and requirements. As of yet, however, we have seen few in use.

Alternative & Complementary PNT

The booklet devotes a page to "Complementary PNT Technologies" with the subhead "Complementary PNT technologies are redefining navigation solutions." Saying "one size does not fit all" — which can also be said for GNSS — includes a graphic from the most recent European Radionavigation Plan of a conceptual, system of systems PNT architecture.

Perhaps more significantly, other pages have mentions of the desirability of "diversifying" PNT sources and "hybridizing" PNT sources.

Safety-Critical Applications

Overall, the GNSS section of the *User Technical Report* is an excellent general overview and reference document.

Its description of SBAS, however, might give a misimpression to the uninformed reader.

The title on page 12 reads "SBAS enhance GNSS performance and enable safety critical operations."

SBAS improves GNSS accuracy with corrections and ionospheric models and helps with integrity. However, it does little to prevent service disruptions due to interference.

The title for SBAS conflict on page 12, with a comment on page 17, discusses "GNSS Vulnerabilities and Mitigation Measures." The very last note on the page and in the tiniest type reads, "For critical applications, implement alternative (non-GNSS) technologies as a backup to ensure continuous PNT information."

This latter statement is very much in keeping with the most current, 2023 version of the European Radionavigation Plan, which says:

"Thus, for critical applications or critical infrastructure protection, it is broadly accepted that GNSS, even in a multi-constellation and multi-frequency environment, should not be the unique source of PNT information. For those applications, an alternative PNT solution (back-up but also

complementary) should be developed and maintained, not necessarily based on radio frequency technologies."

To a certain extent, this has been echoed in the United States as well.

In 2020, a Presidential Executive Order warned against over-reliance on GPS/GNSS, saying the government "must ensure critical infrastructure can withstand disruption or manipulation of PNT services."

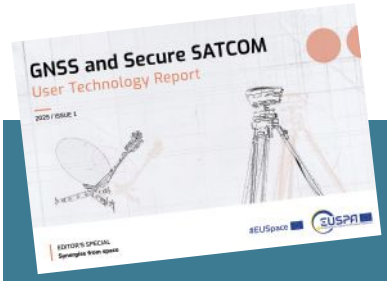
Following this, in its January 2021 report on a PNT demonstration project, the DOT said:

"Promoting critical infrastructure owner/operator use of those technologies that show strong performance, operational diversity, operational readiness, and cost-effectiveness is worthwhile. Based on this demonstration, those technologies are LF and UHF terrestrial and L-band satellite broadcasts for PNT functions with supporting fiber optic time services to transmitters/control segments."

Additionally, a 2023 presentation to an international group by the Office of the Assistant Secretary of the Air Force was titled "Alt. PNT — the Pathway to Resilience."

GNSS are great systems, but we cannot let our understandable enthusiasm for what are truly miracles of technology unintentionally mislead others. Policymakers must be constantly on the lookout for such missteps and help us all maintain a broader, user-focused perspective.

DANA A. GOWARD is president of the Resilient Navigation and Timing Foundation and a retired Coast Guard Captain. He also served in the federal Senior Executive Service as the maritime navigation authority for the United States. He has decades of experience with navigation policy and leading government policy and programs.



A note on reading the report: We highly recommend a read-through of the report and keeping it as a reference document. It is formatted as a 116-page landscape booklet and the online version is very difficult to read without magnification. There is an option for a full-screen view, but even then, more magnification is needed, which prevents viewing both pages of the open e-booklet. On top of that, the controls are balky. We strongly recommend downloading it as a PDF for a much easier and more pleasant reading experience. It is available here: **euspa.europa.eu/tech-report**

HARVESTING EFFICIENCIES

From Brazil to Japan, GNSS Steers Ag Machines

BY MATTEO LUCCIO EDITOR-IN-CHIEF

An early 1900s Italian folk song tells of a farmer walking into his fields at dawn to spread wheat seeds with his hand from a small bag.[1] Farming has changed quite a bit since then. After remaining essentially unchanged for about 12 millennia, in the past century, it has been transformed by such innovations as tractors, electrification, chemical fertilizers and pesticides. In the 1990s, precision agriculture (PA) emerged. (This magazine produced a few supplements on the subject around 1999. If you still have any of them, please let me know.)

PA reduces inputs of water, fertilizer, seeds, pesticides and fuel and increases harvests by mapping variations in soil characteristics and plant health and then using those maps to adjust the inputs using variable rate technology on sprayers. It also ensures that no part of a field is sprayed twice or missed and greatly reduces overlap in seeding and tilling. Double spraying is costly


Chris Clifford, Agri Automation

CHRIS AND CAM CLIFFORD, owners of Agri Automation, which distributes agricultural robots.

and wasteful; missing a row when spraying pesticide can cause pests to concentrate there and then spread, nullifying a whole spraying operation.

The data for the maps are gathered from sensors on tractors and other farm machinery in the fields, as well as by aerial platforms — nowadays, mostly UAVs. GNSS receivers are essential in guiding the farm machinery. The required accuracy depends on the crop but is typically at the centimeter to decimeter level.

Increasingly, farm machinery also incorporates a variety of other sensors, both to compensate for GNSS outages and to minimize the risk of collisions, such as when a cow crosses the path of a tractor. To maintain navigation during GNSS outages, inertial navigation is used. For obstacle avoidance lidar, radar and stereo vision cameras are used to measure the distance to the object. (Both challenges — navigation in GNSS-denied areas and obstacle avoidance — and their solutions are very similar to those encountered with autonomous vehicles on roads.)

In-cab displays enable growers to monitor their progress in real time. They often also download the data and maps to a laptop to better identify missed spots or areas with special issues and to plan their next task.

Manufacturers of PA equipment compete in a global market. Some challenges are the same everywhere, while some are specific — such as strong ionospheric scintillations in Brazil or antiquated agricultural practices in Japan's Furano region. For this year's cover story on PA, I discussed these challenges and the latest generation of farming hardware, software and services with

- **KIRSTIN SCHAUBLE,** director of systems engineering, **ANELLO Photonics**
- **JOEY KOEBELEN,** founder and CEO, **Deep Sand Technology**
- **CHAD HUEDEPOHL,** PA portfolio manager, autonomy and positioning division, **Hexagon**
- **KEN MACLEOD,** director of product management and **GORDON ECHLIN,** director of business development, **Calian GNSS.**

This article contains a few excerpts from those interviews. For the full transcripts, go to **www.gpsworld.com**. I also received case studies from **AgLeader Technology, ComNav Technology** and **Harxon Corporation**.

ANELLO PHOTONICS makes silicon photonics optical gyroscopes, which enable accurate dead reckoning without GNSS and are targeted mostly at the autonomy market. (Anello means ring in Italian, which reflects the nature of the company's technology and the Italian-American background of its CEO, Mario Paniccia.) Because ANELLO specializes in high precision in situations with obstructed GNSS signals, orchard cultivation is one of the agricultural practices in which it specializes. "Orchards have high-value crops, such as almonds or walnuts, and you're driving your tractor between very narrow rows with trees completely covering the sky above you," Schauble said. "Our job is to replace that GNSS input with our inertial navigation system (INS) input."

DEEP SAND TECHNOLOGY — in partnership with GEODNET, the largest real-time kinematic (RTK) network in the world — sells affordable RTK corrections to farmers. It also maintains and troubleshoots the system, compensated by the network's cryptocurrency. "We handle the blockchain and use it for maintenance," said Koebelen. "We have someone that checks every day and makes sure that the

[1] "Di buon mattino il contadino va nei suoi campi a seminare il grano. Ha un sacchettino e ci tuffa la mano."

bases are up. We do the support on it. Instead of charging for that, we take the tokens; that's just our part of the program, and they get free RTK." Koebelen, who is also a peanut farmer, adds: "You can trust anything that we sell because it has been tested and used by a farmer and is supported by a farmer."

HEXAGON, a very large company, makes a wide range of sensors that capture and display data about physical reality. Its latest contributions to PA include the TerraStar-C PRO and the TerraStar-X Corn Belt corrections services, which incorporate improvements in ionospheric resiliency. "Especially in the Brazil market, some growers were often experiencing hours of downtime due to ionospheric scintillation," said Huedepohl. "With the ionospheric enhancements that we've added, that downtime now is down to just a few minutes here and there." He also cites safety enhancements for the autonomy market, such as dual antenna solutions and geofencing.

CALIAN GNSS is a global supplier of technical solutions, services and products to the space communications, defense, wired and terrestrial wireless, manufacturing, GNSS, agricultural technology and nuclear industries. The company's recent entries in the PA market include GNSS antennas with lower elevation gain and extended filtering. "Our GNSS agriculture antennas support centimeter level precision, have best in class lower elevation angle gain enabling L-Band correction reception (at northern and southern latitudes), and have eXtended Filtering (XF), which creates very deep attenuation of nearby out of band radio frequency signals," said Echlin. "Having a digital signal from the antenna to the smart ag controller simplifies and reduces the cost of the installation," said MacLeod.

AG LEADER, founded in 1992 and focused exclusively on precision farming technology, offers a complete line of systems that integrate with existing farm machinery. In February, it introduced the RightPath passive implement steering solution to alleviate the problem of trailed implements drifting off the guidance line by up to 10 inches or more, even when farmers utilize auto steer and on flat ground. RightPath keeps implements centered on the guidance line, ensuring precise input placement and increasing operational efficiency throughout the growing season while minimizing crop damage, yield loss and operator challenges, Ag Leader said. To utilize RightPath, both the vehicle and the implement require Ag Leader's GPS 7500, but only the vehicle needs to be equipped with TerraStar-C, TerraStar-X, or RTK. RightPath will be available in late fall 2025 through a single purchase unlock and without any recurring subscription fee.

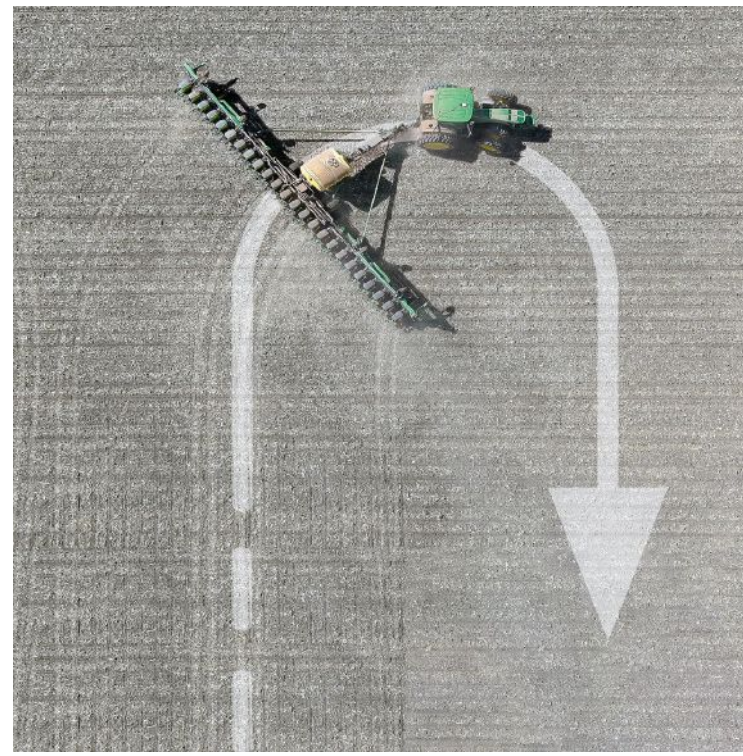
COMNAV TECHNOLOGY is an original equipment manufacturer (OEM) that develops and manufactures GNSS OEM boards, receivers and solutions for high-precision positioning applications worldwide. Japan's Furano region is renowned for its vast farmland and abundant agricultural resources. Still, it is challenged

A Very Short History of Precision Agriculture

BY CHAD HUEDEPOHL, HEXAGON

- The term precision agriculture emerged when yield monitoring was first invented and brought to market.
- GPS receivers were added to map the sources of the yields, which began to make it possible to manage farmland and zones based on productivity.
- This very quickly evolved into also mapping soil sampling results and directly tying that type of information to point-specific yield information from a field.
- After several years, variable rate application of fertilizer emerged.
- In the mid 2000s, auto-swath technology came on the market, making it possible to turn on and off the different implement sections on application equipment — primarily, sprayers and spreaders.
- In the mid 2000s, autosteering systems started to become standard on newer equipment and soon became a key product in the aftermarket. This gave farmers better efficiency and helped provide them more hours of productivity per day. It also allowed them to pay better attention to the equipment and the application that they were set up to do.
- The combination of swath control and auto guidance greatly accelerated the development of precision agriculture, eventually leading to the monitoring and control of planter equipment.
- More recently, the trend toward autonomy began, with greater focus on live sensors, including camera imagery.

by traditional manual driving methods that provide insufficient accuracy, low efficiency, and operator fatigue during prolonged tasks. To address these issues, ComNav introduced the AG502 autosteer system, which integrates satellite reception, positioning, navigation and autonomous driving. It is compatible with a variety of mainstream tractors on the market and is suitable for a wide range of agricultural tasks such as ridging, seeding, spraying and harvesting, ComNav said. In the Furano project, the AG502 demonstrated its versatility through its successful deployment on a transplanting machine.



Ag Leader

TO MAXIMIZE an operator's turning accuracy and efficiency, Ag Leader introduced TurnPath, hands-free steering for automatic, repeatable end-of-row turns.

HARXON CORPORATION makes GNSS positioning antenna solutions. The company has been collaborating with Brazilian agricultural navigation solutions and systems developer Agres to integrate Harxon's Smart Antenna into the Agres Autopilot System. This secure and robust agricultural navigation solution has been widely adopted by Brazilian agribusinesses to provide automatic steering on straight or curved parallel lines to assist with such field operations as preparing the soil, planting seeds, cultivating the plantation and harvesting the crops. These systems are suitable for various brands and tractor/vehicle models such as Kuhn, John Deere, Valtra, Massey Ferguson, New Holland, LS, Landini, Jacto and others.

Challenges

The key technical challenges faced by PA systems include minimizing multipath and RF interference and monitoring the positions of implements relative to the tractor. "Agriculture requires positional accuracy, so mounting an antenna on a farm machine is not a trivial matter," said MacLeod. "On metallic machinery, radio frequency surface currents and reflections (multipath) will degrade the antenna radiation pattern, and RF noise coming from other electronics on the machine can interfere with GNSS." Additionally, because most GNSS applications now are full band, "the challenge is designing antennas that are small and full band, and which also reduce local multipath on the machine."

Regarding the position of the implements, MacLeod said: "Many agricultural applications use the moving base technique to estimate a precise heading which can be used to monitor pass to pass overlap. Calian GNSS have smart antennas that support the moving base application."

Accuracy and Reliability

Nearly all PA practices require RTK, which gives repeatable accuracy of 1 cm to 2 cm. "I have this conversation daily with farmers," Koebelen said. "All crops or farm practices benefit from RTK, even if you're just doing hay work — whether you're planting or harvesting. We can't control the weather, commodity prices, or fuel prices but we can reduce input costs. So even if you're just tilling, GEODNET RTK will pay for itself and is better than using traditional autosteer, because you're eliminating all overlap."

Additionally, farmers need reliable repeatability, even from one season to the next, to be able to return to the same spot to harvest what they planted. "Peanut farmers may plant with RTX or SF3, but satellite-based corrections, even higher precision ones, didn't provide them enough repeatability to come back to harvest," said Koebelen. "So, they still had to adjust their lines or hand-drive them. If the spacing between passes are off by even two to three inches, you're going to lose peanuts. That's why peanut farmers — as well as growers of potatoes, cucumbers, and other crops — need RTK."

Once they enter a GNSS-denied area, such as an orchard, farm machines will need a dead reckoning

ComNav Technology

THE AG502 AUTOSTEER SYSTEM being tested and calibrated on a transplanter in Japan's Furano region, which is renowned for its vast farmland.

capability that can keep them within a 20 cm to 30 cm error, said Schauble. "This is typically posed as a cross-track error. Errors in the direction of the distance traveled are slightly less important, because you can tell based on visuals when you exit a row."

Growers think of reliability, accuracy and repeatability in terms of whether they can count on a system to do what they are asking it to do, Huedepohl explained. "They think about all those things. They do not necessarily focus on one thing versus another."

Retrofitting

While many agricultural systems are proprietary, there is also a lot of mixing-and-matching and retrofitting going on. More than 90% of new tractors come with factory-installed guidance, but some growers want to retrofit new receivers on their machines, either because they did not have them or to upgrade. On some machines, it is possible to feed better positioning data — for example, integrating GNSS and inertial navigation — into the port that previously took in only GNSS data, using a standard NMEA format.

"It's a simple plug-and-play to exchange someone's GNSS receiver with our INS solution. Obviously, they need to do some testing to optimize placement, installation and stuff like that," said Schauble. "Many companies are retrofitting existing tractors with an autonomy stack. They take commercial off-the-shelf (COTS) systems, such as ours, or a lidar or a camera, and retrofit a tractor. That's their business model."

Additional Sensors

Among the additional sensors often used are wheel odometers. "Without the wheel speed, you're relying heavily on accelerometers," said Schauble. "Growers cannot afford to pay $100,000 for a reference-grade system. The navigation systems for these applications use MEMS accelerometers, as we do. So, wheel speed aiding is extremely important to maintain that distance traveled."

Integrating GNSS and inertial measurement units (IMUs) has long been standard. Increasingly, this integration is done inside an antenna, called a smart antenna. Calian, among others, does that. "We also have smart antennas that employ the L1-L5 observation pair rather than L1-L2, since the L5 signal is stronger and performs better under cover," said MacLeod. "L5 uses an enhanced signal architecture with 10x faster chipping rate (10.23 MHz) offering more precise standard localization and improved multipath mitigation for reflections exceeding 29.3 m."

Corrections

Corrections have also been key to the evolution of PA. A reference base station can provide 1-inch accuracy for up to 21 miles, degrading beyond that distance. It needs a WiFi network to communicate, so farmers often place the base station near their home and connect it to their home network. "We haven't found an internet connection that isn't quick enough to handle that," said Koebelen. "From there, you can use your hotspot with a SIM card on your phone, and it's like texting, so it will

not drop like with voice calls. We haven't run across rural areas where cell coverage is the limiting factor."

RTK adoption is growing among farmers. "In the past, many people did not want to use RTK, because it was not very affordable nor easy," Koebelen said. "However, now that we have these networks [such as GEODNET], you're going to see a lot more people rely on the precision of RTK and you're going to see many new products come out. Right now, even John Deere, Trimble and other major brands that are more expensive are trying to make the tier below RTK more affordable or easier to get — for example, RTX, SF3, the satellite-based corrections." GEODNET's network is growing rapidly, he said, "because our price for RTK is lower than Trimble's or John Deere's basic entries, which use free satellite signals that drift throughout the day."

Huedepohl agrees that RTK has improved while prices have dropped significantly. "Earlier in my career," he said, "RTK positioning was very expensive and satellite-based augmentation systems (SBAS) were not as stable. Also, RTK systems and such used a single constellation for the longest time. We started adding in GLONASS and then positioning network (Ntrip) corrections, which gave us a lot more robustness."

Precise point positioning (PPP) has also improved. It used to have convergence times of up to 45 minutes. "Then, you would drive underneath one tree on the edge of a field, and you had to start all over," Huedepohl recalls. "That did not sit well with farmers, so PPP corrections struggled to take off. Because of those early experiences, it took a long time for the market to start to accept the newer PPP models that we've seen in the past seven or eight years. Now there are farmers who enjoy the reliability of those PPP corrections." The convergence time for one of Hexagon's PPP services, TerraStar-C PRO, is often less than five minutes, according to Huedepohl. "We have a fast startup time. So, if the tractor was shut down, already converged and you turn it back on, most people are going to be reconverged in just a minute or two."

Harxon

HARXON enables autonomous agricultural applications with GNSS antennas, smart antennas and wireless data radios.

Division of Labor

The division of labor between manufacturers of PA equipment depends, in part, on whether a system is a retrofit or built from scratch. "If you are, let's say, John Deere, and you own the entire autonomy stack within this tractor, then you can take our INS solution, add cameras, maybe add a lidar, and you can have your own fusion of those sensors," said Schauble. "We have our own sensor fusion with IMUs and GPS. The tractor's autonomy stack can do the sensor fusion with our output and other visual sensors, such as cameras and lidars."

"Dealerships want their tractors to be known as having the highest tech," said Schauble. "For a dealership to offer our state of the art, autonomy-enabling technology would be a huge benefit to them."

Another differentiator is whether a factory-installed system is an OEM or branded. "We've been providing NovAtel branded receivers to AGCO for many years, through their channel, both factory-installed and aftermarket. Some of the others, such as CNH, are white labeled, so it would just say 'Case-IH' or 'New Holland' and have no Hexagon markings."

Whether OEM or aftermarket, most manufacturers have some type of proprietary integration. "There are products that are just NEMA; they are typically at the lower end and priced much lower," said Huedepohl. "The higher performing flagship products out of everybody's portfolio are usually doing a more customized integration."

Echlin has a similar perspective: "We provide products to OEMs who designed our products into their machinery. There are also system integrators and aftermarket system providers that use our smart antennas."

According to Harxon, one reason for the success of its smart antenna in the agriculture market, especially for autonomy users, has been its ease of integration and high performance. "GNSS positioning is just one part of an autonomous system, and the autonomous integrators don't necessarily have resources or expertise to develop an OEM component portfolio. Therefore, it's a timesaving and cost-effective choice to directly integrate a smart antenna into an autonomous system."

Julian Luna and Sarah Wondra

LUCCIO using a Garmin Forerunner 745 and a DeLorme PN-40 on a hike. (Garmin bought DeLorme in 2016.)

GNSS for the Other 99.9%

News from the World of Consumer Applications

BY MATTEO LUCCIO, JESSE KHALIL AND BRIAN RICHESSON

GPS World is a business-to-business magazine, and most of our readers are engineers, surveyors and other professionals specializing in geospatial technologies. In general, we do not cover consumer applications. Nevertheless, it is important to remember that, while GPS was designed and built, and is managed, by the U.S. military (from 1973 to 2020 by the U.S. Air Force, since then by the U.S. Space Force), more than 99.9% of its users are not members of the U.S. military, nor surveyors, but consumers. They benefit from GPS — and the three other GNSS, namely Russia's GLONASS, China's BeiDou and Europe's Galileo — in many ways and are unaware of most of them, such as the fact that GNSS receivers provide essential timing for radio and television broadcasts, cellphone communications and financial transactions.

The vast majority of consumers access GNSS via their smartphones. We are all familiar with the myriad smartphone applications that rely on GNSS for positioning and navigation — from Google Maps and Apple Maps to Waze and social media platforms such as Instagram. Additionally, weather apps, such as the Apple Weather app, and parking apps utilize GNSS to enhance user experience and functionality. Nearly all smartphones

today use at least three of the GNSS constellations — GPS, GLONASS and Galileo — and some use all four. (The use of BeiDou in the United States is a controversial topic that we will explore soon.)

For most people, smartphones have replaced such previously separate electronic devices as calculators, digital cameras and car navigators. (A freestanding GNSS-based car navigation device is still useful, however, when you travel in areas with spotty or nonexistent cell phone coverage, because it relies on maps stored on the device, so it does not require an Internet connection. That is why I still carry a nearly 20-year-old Garmin nüvi in my car.)

For a few years, there were even handheld televisions. (My 1989 Casio TV-400 LCD Pocket Color handheld VHF-UHF TV has a 4 cm x 3 cm LCD screen. It is analog, however, so it stopped working when U.S. television broadcasts switched to digital in 2009.) Now, many people watch news, shows and movies on their phones.

Nevertheless, there are still many freestanding GNSS-based devices. For example:

- **Handheld receivers for hikers and boaters** that display your position and heading on topographic maps or nautical charts, as well as such information as elevation, speed, distance to your destination, number of GNSS satellites in view, tides, and sunset and sunrise times.
- **Cyclometers** that show bicyclists their speed, pace and position on a map.
- **Fitness trackers and smartwatches** that track your exercise, sleep, heart rate and biometric data.
- **Tracking devices** that monitor the movements of people, such as children and Alzheimer's patients, and help recover stolen vehicles and boats.

Additionally, many digital cameras have GNSS receivers that insert the location of each photo into their metadata.

Since I began working in this industry 25 years ago, I have always detested the term "GPS tracker" because it

Matteo Luccio

A NEARLY 20-YEAR-OLD GARMIN NÜVI still provides the author navigation in areas without cellphone reception.

reinforces the already widely held misperception that a GPS receiver somehow "tracks" its user. As most readers of this magazine know, GPS receivers only display and/or store location data for the user, without sharing it with anyone else, let alone broadcasting it. Tracking something requires coupling a GPS receiver with a way to transmit the location data — typically, using a cellphone connection. Plus, nowadays, the word GPS should in most cases be replaced with GNSS. Therefore, I am always careful to say or write "GNSS-based devices."

What follows highlights three very different GNSS applications in consumer devices:

- Handheld receivers and smartwatches by Garmin for outdoor recreation and fitness.
- GNSS-based tracking of vulnerable people.
- A smartphone application from Google to monitor jamming and spoofing.

— **Matteo Luccio,** EDITOR-IN-CHIEF

Handheld GNSS Receivers

Garmin, founded in 1989, is the 800-pound gorilla in the *consumer* GNSS market. The company's annual revenue of more than $5 billion is comparable to the nearly $4 billion annual revenue of Trimble, founded in 1978, which is the 800-pound gorilla in *industrial* GNSS markets.

Garmin sells a vast array of handheld receivers, smartwatches and other devices for outdoor recreation and fitness, as well as GNSS receivers for general aviation and marine navigation.

In remote areas with scant or no cellphone reception, Garmin's GNSS receivers offer users substantially more reliable satellite reception and greater positioning accuracy than smartphones. That is for two reasons. First, because a Garmin receiver can host a larger GNSS antenna than a smartphone, which contains several antennas. Second, because it is mostly dedicated to the positioning and navigation mission — unlike the many missions crammed into a smartphone.

Garmin's multi-constellation and multi-band GNSS handheld receivers come with preloaded topographical maps optimized for outdoor

activities, with terrain contours, summits, coastlines and more.

Garmin's latest line of handheld GNSS navigators — the Montana 710i and Montana 760i — feature built-in inReach technology, which allows users to stay in touch when venturing beyond cell service using reliable satellite communication. Users can utilize two-way text messaging and location tracking via the global Iridium satellite network. In the event of an emergency, users can send an interactive SOS message to Garmin Response, an international emergency assistance coordination center that is staffed 24/7/365.

These devices are ideal for a variety of outdoor activities, including hiking, mountain biking, off-road riding and more. They are also compatible with multiple mounting options to adapt for use on ATVs, boats, cars, motorcycles, RVs and other vehicles.

Garmin Smartwatches

Garmin smartwatches have established themselves as leaders in the fitness and outdoor adventure market. Whether running, cycling, swimming or golfing, Garmin smartwatches provide users with many activity-specific features and metrics.

These watches feature advanced heart rate monitors and pulse oximeters for health monitoring. The company's latest line of smartwatches come with a Body Battery feature that continuously analyzes combinations of the user's heart rate, heart rate variability and movement data. The goal of this analysis is to identify meaningful physiological states and to describe the impact they have on the body's energy levels. At a high level, this means documenting whether users are awake or asleep and when they are physically active, as well as tracking stress levels during periods of inactivity, according to Garmin.

Garmin smartwatches also feature additional sensors to improve location data. They include an altimeter sensor that helps track elevation changes and an accelerometer that detects movement. The latter is used for such tasks as step counting, sleep tracking and other activity measurements.

Garmin watches use multi-constellation (GPS, GLONASS, BeiDou and Galileo) GNSS receivers that enable accurate distance, pace and route mapping during outdoor activities, even in challenging environments.

— **Jesse Khalil,** ASSOCIATE EDITOR

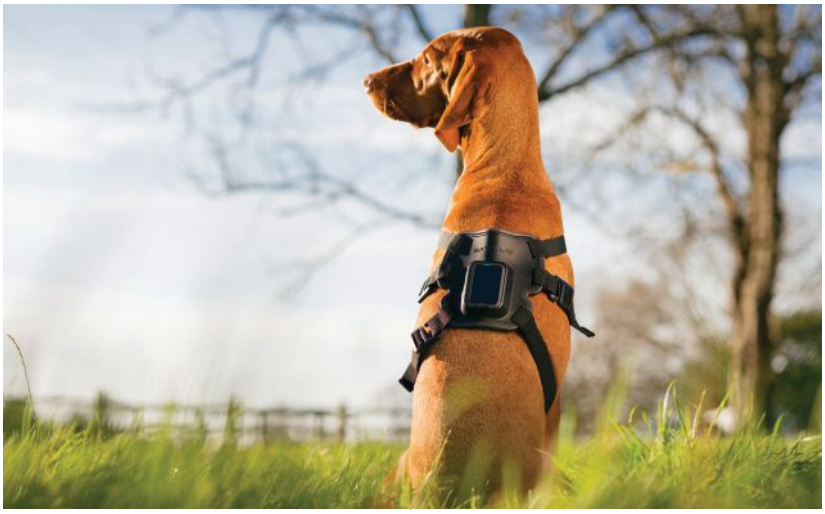
Tracking Family Members and Pets

GNSS technology enables consumers to track those most important to them – their family, friends and even their pets.

Companies such as u-blox offer devices that can be worn by the elderly and children to enable their caregivers or parents to track them. The devices help locate individuals through ›GNSS receivers (using all four GNSS constellations); Bluetooth, Wi-Fi and low power wide-area cellular communications; and cloud connectivity.

Families can monitor the movements of their children as they travel to and from school by bus by tracking those buses as they drive along their routes. Families can better time their kids' departure to the bus stop in the morning and know when the bus has returned in the afternoon — all by viewing a live tracking function, provided by the school district, on their computer or smartphone.

Some of the newest tracking technology was on display at this year's Consumer Electronics Show (CES) in Las Vegas in January. SATELLAI, a provider of AI-integrated pet solutions, showcased its SATELLAI Tracker and SATELLAI Collar. "The SATELLAI Tracker and the SATELLAI Collar use satellite and AI technologies to



SATELLAI

THE SATELLAI COLLAR features a lightweight tracker attached to a padded harness designed to avoid snags, discomfort or mobility restrictions.

accurately relay their positions and status at all times," said Mark Mao, founder and CEO of SATELLAI.

The lightweight tracker attaches to a padded harness that won't snag, cause discomfort or hinder a pet's mobility, according to the company. It features the Qualcomm MDM9205S modem, the 3GPP Rel17 5G IoT-NTN satellite communications system and the Aware platform, allowing it to use both cellular and satellite communication for continuous tracking even in remote areas without terrestrial cellular coverage. Working with the Skylo communications network ensures that the tracker works with more than 680 global networks across more than 180 countries. The SATELLAI Collar leverages a dual antenna and a multi-constellation GNSS receiver to deliver precise tracking, even in areas with low connectivity, the company adds.

Tractive, a global provider of pet GNSS and health tracking, also unveiled its latest dog tracker at CES in Las Vegas. Companies are also offering new ways to keep pets within areas chosen by their owners. According to Tractive, most virtual fences use a collar-mounted GNSS-based tracker in combination with an app or software. Users can create their preferred fence boundaries and receive notifications when pets cross them. Utilizing Mapbox's advanced mapping platform, the SATELLAI Collar also allows users to manage these virtual boundaries, supporting overlapping and nested fences. The collar supports virtual fencing for areas up to 100,000 acres. Virtual fences are also commonly used with cattle.

— **Brian Richesson,** SENIOR EDITOR-IN-CHIEF

Google Tools for Detecting Jamming & Spoofing

The sharp increase in the past few years of instances of GNSS jamming and spoofing, much discussed in these pages especially with regards to civil aviation, also affects smartphones, smartwatches and other consumer devices. Google — which makes the Pixel phones as well as Android, the most used operating system, which is used by three quarters of the world's smartphones — has been developing a tool to help detect these attacks.

It is based on the fact that the carrier-to-noise ratio (C/No) of the signal as well as the automatic gain control (AGC) of the GNSS radio in the phone can be good indicators of interference. "The AGC tends to dip when spoofing or jamming is observed," said Mohammed Khider, Ph.D., manager and senior staff software engineer at Google. However, he pointed out, for jamming events the C/N0 value drops while for spoofing it increases.

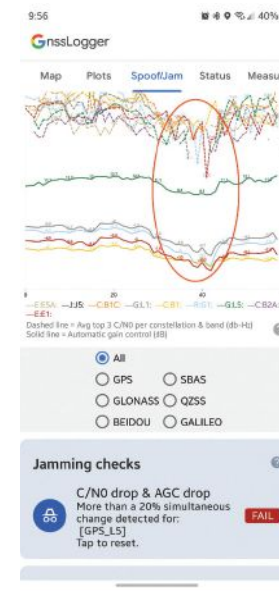
Making use of this effect, desktop tools that log data and analyze the AGC and C/No have long made it possible to detect interference. Now, Android users can do the same thing on their phones in real time, using the spoof/jam tab in Google's GnssLogger app. It creates a graphic of AGC and C/No for each GNSS constellation and band. Moreover, the app cross checks the GNSS signals with other independent sources of information to flag potential jamming and interference. Below the real-time plot of AGC and C/N0 are a series of additional automated jamming and spoofing checks.

This is an experimental feature, and the algorithms behind it will be further improved as research progresses, Khider pointed out. Moreover, it will not catch all jamming or spoofing. However, it will make it much easier to examine data related to these GNSS interference events in real time.

Google launched its GnssLogger app in 2020, and it has been a leading tool for the GNSS community to better understand positioning and navigation on smartphones. "It helped establish a de-facto CSV (.txt) standard for raw measurements and other data for Android devices that has been used in many other tools, including Google's own Gnss Analysis app," said Khider.

Last fall, in addition to the new spoof/jam screen discussed above, Google also launched GnssLogger for Wear OS, a new companion app for Android smartwatches that offers several of the key features found in the phone app, and a new measurements screen, which enables users to view GNSS raw measurements in real time.

— **Matteo Luccio,** EDITOR-IN-CHIEF



Google

AGC AND C/N0 both drop when a phone is held next to a Wi-Fi router (red oval)

GPS WORLD
GNSS POSITIONING NAVIGATION TIMING

2025 SIMULATOR BUYERS GUIDE

In our 14th annual Simulator Buyers Guide, we feature simulator tools, devices and software from seven prominent companies that aid GNSS receiver manufacturers in product design.

SPIRENT FEDERAL SYSTEMS

DELIVERING PROVEN PERFORMANCE & EXPERT SUPPORT

Spirent simulators set the standard with a flexible, customizable software-defined radio (SDR) architecture designed to meet the most demanding requirements while having the ability to evolve with program needs.

PNT X: ALL-IN-ONE PNT SIMULATION. Launched in 2024, PNT X supports rapidly evolving NAVWAR threat vectors, improves simulation correlation to the real world, increases test coverage and saves time and resources.

Real-Time 3D Visualization with Dynamic Terrain Modeling. Embedded terrain modeling creates a realistic 3D environment that automatically applies multipath, diffraction and obscuration effects to dynamic GNSS, jamming and spoofing signals.

I/Q Spatial Awareness. Bring your own signals into the simulation environment via I/Q data, and PNT X applies all the effects of relative motion — a new benchmark for realism.

Advanced Jamming & Spoofing. New jamming waveforms and complex signal control more closely represent a real-life NAVWAR environment. Embedded spoofing supports high-power spoofers and dedicated channels for generating repeater noise.

Wavefront CRPA Testing. Test CRPA electronics with thousands of independent GNSS, jamming and spoofing signals. A precise wavefront generated by our unique phase alignment techniques and high jamming-to-signal (J/S) power ratio ensure accurate results no matter how extreme the test case.

SPIRENT FEDERAL SYSTEMS

Spirent PNT X for defense, NAVWAR & space

PNT X 3D dynamic terrain modeling

GSS6450 record & playback system

Over-the-Air CRPA Testing. Spirent Federal offers a patented zoned chamber approach enabling hours-longer test times with thousands of jamming and spoofing signals, along with terrain modeling.

Military Signals. Simulate true M-code using approved MNSA-encrypted signals. AES, SDS, Y-Code and RMP are also supported.

Alternative PNT. PNT X enables advanced PNT with embedded test capabilities for integrated inertial systems, sensor fusion, ALTNAV, low-Earth orbit (LEO) orbital modeling and S-band frequency signals. Spirent offers the only certified simulator for Xona Space Systems' PULSAR LEO PNT signals.

FIELD TESTING. Synchronize Spirent simulators with live-sky signals for in-field resilience testing. The lightweight GSS6450 RF record & playback system brings the rich detail of real-world GNSS or complementary PNT signal environments into the lab for repeatable testing.

COMMERCIAL APPLICATIONS. The GSS7000 multi-constellation simulator is a precise, flexible and easy-to-use solution that can grow with your requirements.

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SYNTONY GNSS

ADVANCED GNSS SIMULATION FOR SATELLITE FAL & CRPA TESTINGS

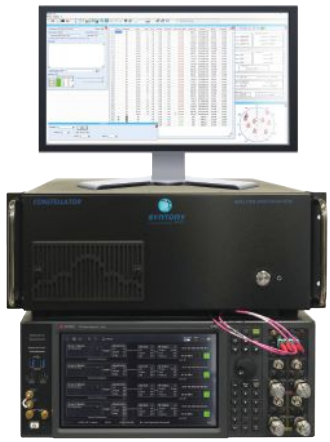
Constellator FAL display

Comprehensive Computational Performance and Highest Fidelity

Constellator is a high-end real-time multi-frequency multi-constellation GNSS simulator designed for high-performance signal generation. It can generate over 1,200 signals simultaneously and exceed 2,000 signals in MixInBand mode, making it one of the most capable simulators available. This level of performance supports detailed and rigorous testing of GNSS receivers in demanding scenarios, from civilian applications to critical resilience assessments. Constellator supports all available constellations and signals, including the emerging LEO PNT, together with all kind of jamming/spoofing scenarios (including multiple, moving sources), realistic environment simulation (urban, radio occultation, launcher, etc.) and the ability to be synchronized to the external GNSS constellations.

CRPA Simulation with Keysight's VXG-C

Thanks to a strategic partnership with Keysight Technology, a dedicated CRPA version of Constellator has been designed using Keysight's VXG-C 4 channels version, offering unrivalled signal purity, frequency coverage and phase synchronization. Together, the SDR Constellator product and the powerful 4ch VXG-C bring an important technological advancement to CRPA testing, thanks to the 2.5 GHz instantaneous bandwidth of the VXG-C and its extended frequency band support (up to 40 GHz). All L-band and S-band GNSS signals are emitted by the same RF channel, bringing a quasi-perfect timing synchronization between frequencies. 7 channels capacity, 11 channels or beyond can be constituted by chaining VXG-C's, with one of the highest performances on the market in terms of phase synchronization.



Constellator VXG-C setup

Adapted for Final Assembly Lines (FAL)

Constellator is recognized as one of the market leaders for use in FAL environments, as more than 1,000 satellites that are currently in space have been tested by it. Its real-time processing and automation compatibility support efficient testing and validation of GNSS receivers, helping manufacturers meet quality standards while minimizing post-production issues.

Multi-Constellation and Future-Ready Signal Support

Constellator supports all the GNSS constellations and frequencies, as well as major Augmentation Systems, supporting natively L, S and C band. It also includes upcoming constellations, including the diverse LEO PNT constellations, ensuring adaptability for future navigation technologies.

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IFEN

NCS NOVA & NOVA+ GNSS SIMULATOR

NCS NOVA+ GNSS simulator

NCS NOVA & NCS NOVA+. The NCS NOVA/NOVA+ GNSS simulators are both available serving standard and professional GNSS RF simulation solutions.

Multi-Frequency and Multi-Constellation. The NCS NOVA/NOVA+ GNSS RF simulators support all major GNSS signals, including GPS L1/L2/L5, Galileo E1/E5/E6, BeiDou B1/B2/B3, GLONASS L1/L2, NavIC L1/L5/S, QZSS L1/L2/L5 and SBAS L1.

Flexible SDR Platform with Scalable Multi-RF, Signal Bands and Channels. With the proven NOVA+ signal generator platform, a fully scalable GNSS signal generator is available, supporting 160+ signal channels, up to 4 RF-outputs and up to 8 RF-bands simultaneously. This scalable solution is fully suited to cover all signal generation needs for advanced professional applications requiring multi-RF outputs for multi-antenna (e.g. space applications) or multi-user (spoofing). The NOVA+ takes advantage of the latest generation of signal generation technology.

New NCS Release. The new release v2.11 of the NCS simulator is providing key enhancements beyond the previous version, detailed further below.

Quasi-Pilot (QP) Signals. The new QP signals are part of the coming Galileo second generation, offering outstanding short time to first fix (TTFF) optimized for IoT applications, while also enabling meta-signals processing for high-accuracy applications under severe signal conditions.

High Accuracy Service (HAS). A key enhancement of the NCS GNSS constellation simulator is the support of the Galileo E6 HAS according to HAS SIS ICD 1.0. Activities are ongoing to support the coming Service Level 2 of HAS, offering improved performance for PPP-IAR, but also ionosphere corrections for PPP-RTK. Sophisticated satellite and ionosphere error modelling is part of this capability extension.

Navigation Message Authentication. Another key enhancement of the NCS GNSS constellation simulator is the support of the updated Galileo E1B Open Service Navigation Message Authentication (OSNMA) according to OSNMA SIS ICD 1.1 from October 2023.

Range Authentication. The advanced "range authentication" capability of Galileo second generation is fully supported by the simulator, further protecting the Galileo signals from spoofing threats.

Mixed Satellite Generation Simulation. The NCS simulator is fully supporting mixed generation constellations for GPS (IIR/IIF/III), Galileo (1G/2G) and BeiDou (-2/-3), now also supporting BeiDou IGSO orbits. This enables test setups using these real-life mixed satellite generation constellations.

About IFEN

IFEN is a leading provider of GNSS navigation products and services. IFEN's technology portfolio includes GNSS RF-signal simulators, GNSS R&D software receivers, GNSS T&M test receiver, simulation and data processing tools. IFEN's satellite navigation expertise is offered to customers for services including GNSS system studies, research and development of navigation and integrity algorithms, design and development of GNSS software and hardware up to engineering of turnkey facilities and systems.

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SAFRAN FEDERAL SYSTEMS

ADVANCED SIMULATION FOR GNSS, NAVWAR & ENCRYPTED CODES

BroadSim Solo/Duo	BroadSim	Next Generation BroadSim	BroadSim Anechoic	BroadSim Wavefront
Multi-GNSS simulations at your desk	Advanced NAVWAR simulations, M-code and Y-code	Coming Soon!	Multi-GNSS simulations for chambers	Phase-aligned NAVWAR simulations for CRPA

BROADSIM

Powered by the Skydel Simulation Engine, BroadSim brings users superior NAVWAR performance with the benefits of software-defined architecture. Users can choose from several turn-key models or inquire about a custom solution.

Applications

M-code — Available Now, Shipping Today

With **MNSA M-code**, fully test the performance and the security features of Military GPS User Equipment in a repeatable environment. Security-approved by SMC Production Corps, BroadSim offers a flexible implementation of the Modernized NavStar Security Algorithm, providing total control over scenario settings with the real encryption used on the M-code signal. Change any aspect of a scenario, such as time, date, location, constellation, downlink data, signal configuration and visible satellites.

MGUE's Increment 2 M-code SDS is now available to authorized users.

CRPA Testing

BroadSim delivers powerful capability for Controlled Reception Pattern Antenna testing, whether the method is over-the-air or direct inject.

BroadSim Anechoic tests an entire CRPA system as-is. Designed to streamline the chamber setup and reduce hardware redundancy, it auto-calibrates power loss and time-delay and maps the antennas to the chamber's unique setup.

BroadSim Wavefront tests the CRPA's antenna electronics and resilience, prioritizing users' ability to customize dynamic NAVWAR scenarios. It is scalable and phase coherent with continuous phase synchronization, compensating for temperature changes throughout the simulation. Jamming and spoofing are integrated, making it the complete NAVWAR solution.

NAVWAR

NAVWAR is at the core of BroadSim's DNA, leveraging Safran's software-defined architecture to deliver an intuitive solution that meets the ever-changing requirements of the warfighter.

Advanced Jamming. Add dynamic emitters to a scenario, generate unlimited jamming signals and simulate high-dynamic profiles while BroadSim accounts for propagation loss. Take simulation realism to the next level with BroadSim's real-time terrain modeling capabilities.

Advanced Spoofing. Simulate multiple spoofers, repeaters or meaconers simultaneously. Each spoofer generates all-in-view GNSS signals and has an independent trajectory and antenna pattern. Signal dynamics between each spoofer and UUT are accounted for automatically.

More Features

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SAFRAN ELECTRONICS & DEFENSE

EXPERT GNSS SIMULATOR SOLUTIONS FOR NAVIGATION & TIMING

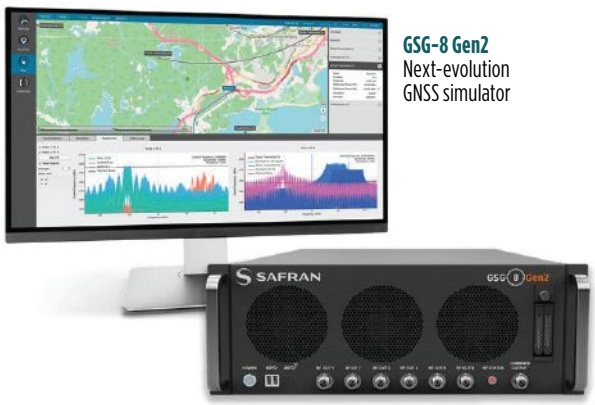
Safran's GNSS simulators offer a range of features, tools and outputs for testing mission-critical navigation and timing operations.

GSG-8 Gen2 is an evolution of the popular GSG-8 GPS/GNSS Simulator — an expert-level PNT test solution offered through Safran's family of Skydel-based simulators.

The GSG-8 Gen2 is ideal for development, NavWar testing and integration projects that require very high performance and an increased number of constellations and satellites in view, and multi vehicle / multi antenna scenarios.

The GPU-powered GSG-8 Gen2 simulator delivers the highest standard of GNSS signal testing in an easy-to-use, turnkey form factor. With 6 front-facing RF outputs and a combined one, the GSG-8 Gen2 GNSS simulator covers the entire GNSS bandwidth and features high-end performance with a 1000 Hz simulation iteration rate, high dynamics, real-time synchronization and simulation of all-in-view satellite signals — including LEO constellations.

Powered by the Skydel Simulation Engine, the GSG-8 Gen2 produces real-time GNSS signals via software-defined radios and replicates true RF signals from any constellation or satellite at any frequency. With a 1,000 Hz simulation update rate, GSG-8 Gen2 simulates multiple



GSG-8 Gen2
Next-evolution GNSS simulator

antennas/vehicles, high-speed dynamics, multipath, atmospheric interferences and sophisticated jamming and spoofing — without extra hardware. Furthermore, Skydel features an intuitive interface, user-friendly automation, a full API, plug-ins and adaptable signals. The custom signal function enables users to test diverse signals, including navigation from LEO satellite constellations.

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LABSAT

TEST ANYWHERE WITH LABSAT

LabSat GNSS simulators deliver multi-constellation and multi-frequency capabilities, ensuring reliable, repeatable and consistent testing. With a one-touch Record & Replay feature, LabSat provides an efficient and cost-effective way to test and develop GNSS receivers.

LABSAT

LabSat 4 and SatGen. Advanced testing with precise customization.

LabSat 4 – Advanced Testing with Precise Customization

LabSat 4 features three individually configurable RF channels, offering selectable quantization up to 12-bit I&Q and bandwidth up to 60 MHz. This flexibility allows precise control over recordings and file sizes.

Additional features include external data integration with CAN, CAN-FD, RS232 and digital event capture, along with saveable custom record settings and multi-system synchronization for dual-antenna testing. A user-friendly web interface ensures easy configuration and operation.

Efficient file management is delivered via high-speed data transfer to and from the 7.6TB internal storage via Gigabit Ethernet and USB 3.

LabSat 4 is packed with new features yet maintains the familiar LabSat benefits of being compact, easily portable and highly cost-efficient.

SatGen Simulation Software

SatGen GNSS Simulation Software provides LabSat users with the flexibility to create custom scenarios to simulate a test anywhere in the world, with position, route, speed, date and time all defined by the user.

Supporting all signals in the upper and lower L-band, including GPS L1C and BeiDou third-generation signals, this powerful software generates a GNSS RF I&Q or IF scenario, which can be seamlessly transferred to the LabSat for replay.

SatGen offers efficient route drawing for road, pedestrian and rail navigation using Google Maps, Bing Maps or OpenStreetMap. The user interface features intuitive navigation and controls, making it easy to create scenarios, view almanac data and edit visible satellites. Additionally, scenarios can be queued and run consecutively for streamlined and efficient testing.

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ROHDE & SCHWARZ

GNSS SIMULATORS FROM THE T&M EXPERT

Rohde & Schwarz offers the complete range of GNSS simulators for development, verification and production testing, including correct simulation of satellite orbits, signal propagation characteristics, receive antenna characteristics and the receiver environment. They are ideal for all GNSS receiver testing from aerospace and defense applications to wireless device testing and automotive applications such as high-precision GNSS.

R&S SMCV100B Entry Level and Production Testing GNSS Simulator

The **R&S SMCV100B** vector signal generator is a multi-standard platform for production lines and has GNSS receiver test capabilities such as positioning capability and TTFF. Pre-defined multi-satellite GNSS waveforms are available for all GNSS constellations. The I/Q sequences can be used for functional tests with fixed satellite positions. Its flexibility and multi-standard capability allows the same instrument to be deployed for other tasks on a production line.

R&S SMBV100B Mid-Range GNSS Simulator

Typical GNSS receiver tests conducted by the **R&S SMBV100B** include the determination of the receiver's time to first fix, acquisition and tracking sensitivity, re-acquisition time. In addition, it is often required to test the receiver's performance under special conditions such as interference or multipath environments or under the influence of atmospheric effects and dynamic stress. The instrument can simulate signals from multiple GNSS constellations and frequency bands in parallel, including the error corrections used in high-precision GNSS. Using its integrated simulation software, even complex GNSS scenarios can be configured in an easy, user-friendly and efficient way. This includes realistic modeling of GNSS orbits, signal propagation effects and system errors as well as realistic modeling of the user environment.

R&S SMW200A High-End GNSS Simulator

In addition to all features of the mid-range solution, the **R&S SMW200A** can generate GNSS signals and any desired coexisting or interfering signal simultaneously. To address adaptive antenna array testing applications (such as CRPA), multiple SMW200As can be coupled and operated as a single setup. This allows to test CRPA DUTS with four or more antenna elements. Thanks to the scalable approach, the system can always be extended by additional instruments in case a higher number of RF ports increases is required.

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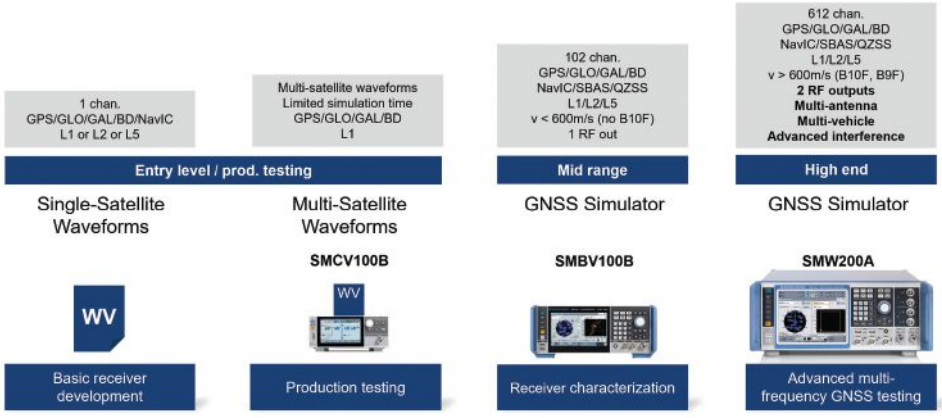
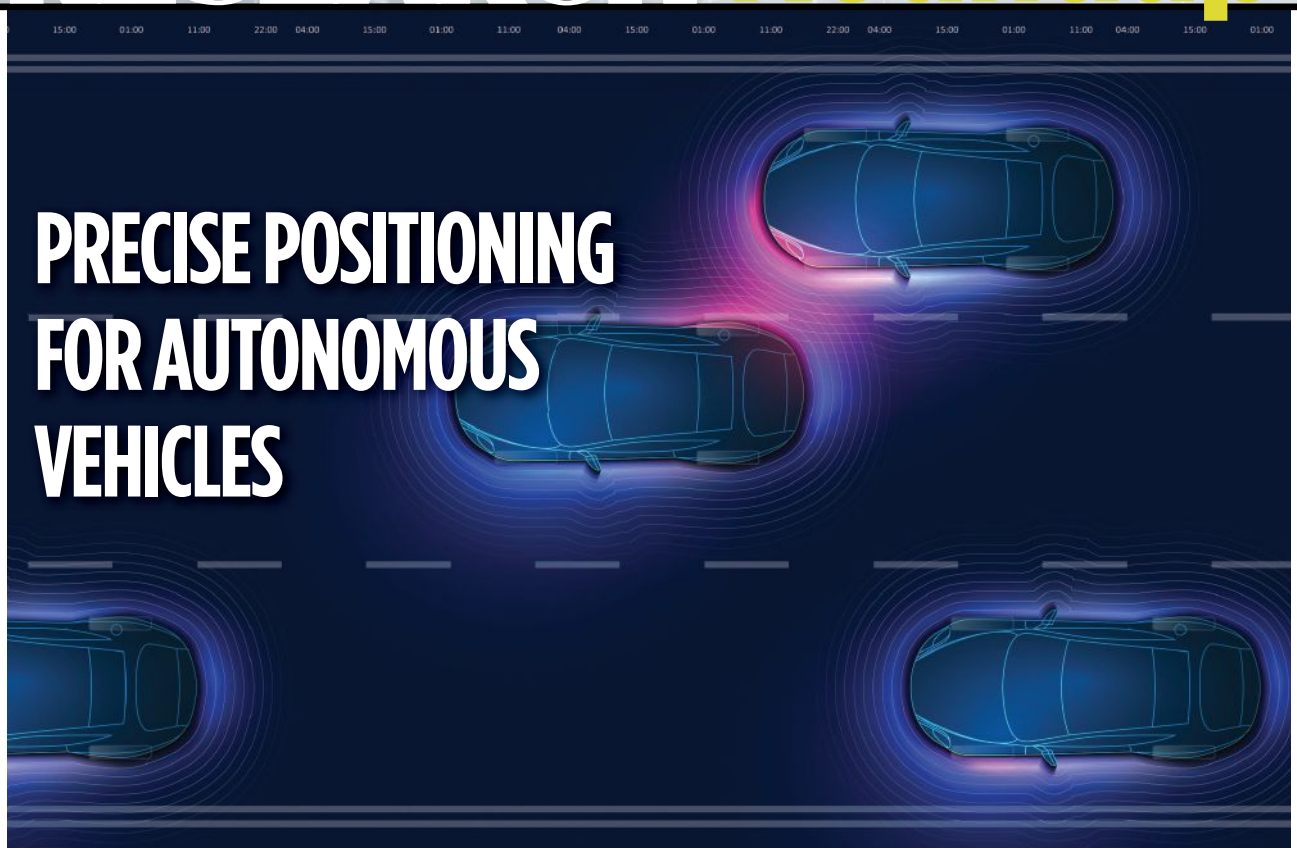


ROHDE & SCHWARZ

PRECISE POSITIONING FOR AUTONOMOUS VEHICLES



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GNSS researchers presented hundreds of papers at the 2024 Institute of Navigation (ION) GNSS+ conference, which took place Sept. 16-20 in Baltimore. The following papers focus on high-accuracy positioning for autonomous vehicles in various environments. The papers are available at **ion.org/publications/browse.cfm**.

HIGH-ACCURACY AND RESILIENT GNSS RECEIVER FOR AUTONOMOUS VEHICLES

The G3STAR GNSS receiver, a key component of the GAMMS Horizon 2020 project, is designed to improve high-definition navigation map production for autonomous vehicles. This Galileo-based receiver leverages the constellation's Open Service features, including the High Accuracy Service (HAS) and Navigation Message Authentication (OSNMA). The research team shared that G3STAR's ability to obtain and decode HAS messages from Galileo E6-B signals, as well as to process OSNMA bits from live Galileo E1-B I/NAV messages, demonstrates its advanced capabilities in providing secure and precise navigation data.

Preliminary tests highlight G3STAR's proficiency in utilizing Galileo's new services. However, the research team shared that further evaluation is necessary to fully assess its impact within the GAMMS project. Plans include validating the HAS data's effect on navigation accuracy, conducting field tests to evaluate OSNMA availability in various environments and assessing the influence of the Chip Scale Atomic Clock on receiver performance. Additionally, comparing the G3STAR's performance to commercial off-the-shelf receivers will be crucial in determining its overall contribution to the GAMMS navigation system and HD map generation. These evaluations will be carried out during upcoming test campaigns, providing valuable insights into G3STAR's potential to advance autonomous vehicle navigation.

Filipe Carvalho, Ricardo Prata, Bruno Cardeira, Carlota Cardoso, Rui Nunes and António Fernández; "High-Accuracy and Resilient GNSS Receiver for an Autonomous Vehicle."

GNSS/INS POSITIONING SOFTWARE LIBRARY

The autonomous vehicle industry has seen significant interest and investment throughout the past 15 years, with numerous practical applications emerging in the market. However, the technology for functionally safe GNSS/INS localization in

autonomous vehicles is still not fully established. This gap is particularly crucial in safety-critical applications, where positioning algorithms must be robust against potential faults, especially in challenging environments. This paper highlights Hexagon's Safety-Critical Positioning Solution, which addresses this need by providing both precision and safety for autonomous land vehicles.

The Positioning System is a safety-first software library that integrates GNSS signals, state space corrections from the TerraStar-X Enterprise service, inertial measurement units (IMUs) and additional vehicle sensors. This system employs an extension of Receiver Autonomous Integrity Monitoring techniques, originally developed for the aviation industry. It computes multiple navigation solutions using a solution separation technique, including an "all-in-view" solution and several subset solutions that exclude various fault hypotheses. These solutions are used to calculate Protection Levels (PLs), which provide an estimated upper bound on positioning errors, accounting for systematic biases and measurement faults. The PLs can be compared against alert limits to determine whether the navigation solution is sufficiently accurate for autonomous decision-making.

Eduardo Infante, Rudi Gaum and Laura Norman; "Demonstration of a Functionally Safe GNSS/INS Positioning Software Library for Autonomous Land Vehicles."

UNMANNED GROUND VEHICLES IN OFF-ROAD ENVIRONMENTS

This paper explores the emerging potential of radar for localization in GNSS-denied scenarios, particularly in challenging off-road environments where lidar-based systems struggle. The research focuses on two distinct settings: a dense forest and an underground mine. To address the localization challenges in these environments, the team developed a pipeline that combines an adaptive extended Kalman filter (EKF) for unstructured forested regions with a factor graph approach that fuses EKF estimates and point-to-plane radar iterative closest point (ICP) measurements for structured underground environments. The results demonstrate significant improvements in localization accuracy compared to existing methods, with the adaptive EKF proving particularly effective in forested areas.

The study provides valuable insights into the integration of radar and IMU data for vehicle localization in GPS-denied scenarios. While the adaptive EKF outperformed conventional EKF in structured outdoor settings, the standard EKF showed better performance in the highly dynamic conditions of the underground mine. The factor graph approach exhibited improved tracking performance, especially in reducing lateral drift along straight trajectory segments. The research also highlights the importance of selecting high-quality ICP registrations for radar-based SLAM. These findings pave the way for future research directions, including refining adaptive EKF for varied environments, exploring radar-based navigation on feature-sparse roads and enhancing the factor graph framework to incorporate additional sensor modalities.

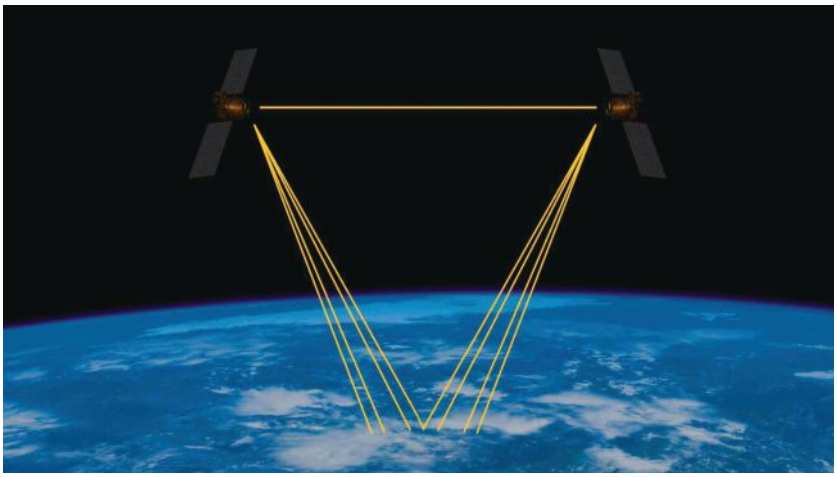
Petar Mitrev and Mohamed Atia, "Radar-Inertial Localization for Unmanned Ground Vehicles in GNSS-Denied Off-Road Environments."

CLOCK DRIFT MONITORING-BASED GNSS SPOOFING DETECTION

GNSS plays a vital role in autonomous systems, providing essential positioning, velocity and timing (PVT) information for platforms such as autonomous vehicles, UAVs and ships. However, GNSS vulnerability to spoofing attacks poses significant security risks, potentially disrupting decision-making processes in these systems. To address this issue, researchers have developed a novel approach called Clock Drift Monitoring (CDM) for detecting GNSS spoofing in autonomous vehicles. Unlike previous methods that focused on directly detecting Doppler bias from measurements, CDM indirectly monitors the adverse impact of Doppler bias on the PVT solution, overcoming challenges associated with bias extraction from raw measurements.

The CDM technique exploits user clock drift derived from Doppler positioning as a detection metric. Under normal conditions with authentic GNSS signals, the clock drift remains stable, reflecting the user's frequency source stability. However, spoofing conditions introduce counterfeit signals with consistent Doppler bias across all measurements, resulting in abnormal clock drift variations. A Generalized Likelihood Ratio Test-based detector identifies these variations, offering a practical and flexible method for GNSS spoofing detection. Field tests have validated the CDM technique's effectiveness in real-world scenarios, demonstrating its robustness as a solution for autonomous vehicles to counter emerging cyber threats. This method's ease of implementation, broader applicability and inherent robustness make it a promising approach for safeguarding autonomous systems against counterfeit GNSS signals.

Ziheng Zhou, Hong Li, Yimin Deng and Mingquan Lu Tsinghua; "Clock Drift Monitoring Based GNSS Spoofing Detection Method for Autonomous Vehicles."


ESA

ESA to Develop Optical Technology for Navigation

The European Space Agency (ESA) has signed a contract with a consortium of European companies to conduct a definition study (Phase A/B1) and associated critical technology predevelopment to drive the development of optical positioning, navigation and timing (PNT) technology.

This initiative marks the initial phase toward a potential in-orbit demonstrator for optical time synchronization and ranging, which is scheduled for proposal at the ESA Council at the Ministerial Level in November. According to ESA, the primary objective is to validate inter-satellite optical links for future implementation in operational satellite navigation systems.

Optical technology presents promising advancements in navigation accuracy and robustness. While optical links, which use laser beams for data transmission, are already established in satellite communications, their application in navigation requires further technological development and in-orbit validation.

The consortium, led by German OHB System, comprises 33 companies from various ESA member states. Following the initial study, the next phase would involve developing and testing the technology in orbit to validate novel system concepts and explore new architectures. The results will assess the readiness of optical technology and inform decision-makers about its potential incorporation into future operational systems.

Laser-based technology offers the potential for enhanced system resilience and robustness, potentially reducing dependence on space atomic clocks and ground segments. Optical links also provide natural immunity to jamming and spoofing attempts.

The high data transfer rates of inter-satellite optical links could enable new, more robust architectures, supporting a multi-layer system approach to navigation. This aligns with the vision of ESA's low-Earth orbit (LEO)-PNT program.

Additionally, optical systems can significantly improve the performance of current navigation systems. Experts anticipate achieving millimeter-level spatial accuracy and picosecond-level timing, which could ultimately lead to enhanced services benefiting billions of users worldwide.


ESA / S. Corvaja

From left, OHB System CEO Chiara Pedersoli, OHB System Director of Navigation Kristian Pauly and ESA Director of Navigation Javier Benedicto sign a contract for a concept definition study and technology predevelopment of optical technology for navigation.

SPACE & EARTH

Advanced Navigation to Aid in Gilmour Space Rocket Launches


Gilmour Space

Advanced Navigation has secured grant funding from the Australian Space Agency through the Moon to Mars Initiative Grant. This funding will expedite the development of a space-grade high-shock inertial navigation system (INS) engineered to endure extreme conditions during rocket launches.

The INS will support Gilmour Space Technologies, an Australian launch services company, in the development and launch of Eris Rockets and Elara Satellite platforms to LEO. This collaboration aims to enhance Australia's sovereign aerospace capabilities and contribute to the growing space industry.

The onboard INS consists of many high-end sensors, including accelerometers and gyroscopes, sensitive enough to detect the smallest change in noise and vibration. To ensure accurate and reliable performance, these delicate components must be shielded from the extreme forces experienced during launch. One solution is the integration of a high-shock enclosure — a protective barrier encircling the INS housing. This enclosure acts as a cushion between the system and the surrounding structure, absorbing and redistributing intense g-forces from engine ignitions and launch vibrations. By dampening these shocks, the enclosure prevents disruptive forces from reaching the sensors, preserving their precision in the harshest conditions.

SURVEYING

SparkFun Unveils Surveying Receiver

SparkFun Electronics has released the SparkPNT RTK Facet mosaic L-Band, a high-precision geolocation and surveying receiver. It features Septentrio's multi-band mosaic-X5 and offers centimeter-grade measurements with 6 mm RTK fixes available in less than one minute, according to SparkFun.

The receiver can connect to phones or tablets via Bluetooth, allowing NMEA output compatibility with most GIS software. It uses u-blox's PointPerfect service for corrections, broadcast from a geosynchronous Inmarsat satellite.

The RTK Facet mosaic L-band features an ESP32 WROOM connected to a mosaic-X5 GNSS multi-band receiver, along with peripheral hardware. It includes a surveyor-grade L1/L2/L5-band antenna designed to receive GNSS signals and PointPerfect correction.

The device operates in various modes, including GNSS positioning, GNSS positioning with RTK L-Band, GNSS positioning with RTK, GNSS base station and GNSS base station NTRIP server. In rover mode, it can achieve 6 mm to 60 mm horizontal positional accuracy.

As an open-source hardware product, users can access and modify the electrical and mechanical design files. The kit includes the enclosed device, thread adapter, charger, data cables and carrying case.

DEFENSE

NATO Selects SandboxAQ for 2025 Defense Innovation Accelerator Program

NATO has selected SandboxAQ as one of approximately 70 companies to participate in the 2025 Defense Innovation Accelerator for the North Atlantic (DIANA) cohort. The selection process involved more than 2,600 submissions from 32 NATO countries. DIANA, established by NATO in 2023, aims to address complex societal challenges by bringing together innovative companies developing dual-use technologies for both commercial and defense applications.

SandboxAQ will join the cohort's Sensing & Surveillance group, focusing on the development of its AQNav magnetic navigation system. AQNav is designed to provide a secure navigation alternative that does not rely on GNSS, making it resilient against jamming and spoofing. The system utilizes SandboxAQ's proprietary Large Quantitative Models, quantum sensors and Earth's crustal magnetic field to offer an all-weather, day and night, terrain-agnostic navigation solution for military and commercial applications.

The AQNav system has undergone extensive testing, including more than 200 hours of flight tests with the U.S. Air Force, involving more than 40 sorties across various geographies and aircraft types. In July 2024, AQNav demonstrated its capability to serve as a primary navigation source and showed potential for scalability across similar aircraft types without individual calibration.

As part of the DIANA program, SandboxAQ will receive resources, insights and developmental support to advance AQNav's capabilities. The company will also have opportunities to test the system in specialized environments.

Zephr.xyz to Enhance GNSS Resilience for US Military Operations

The Air Force Research Laboratory (AFRL) selected Zephr.xyz — a company specializing in augmented positioning, navigation and timing technologies — to receive a $1.74 million Small Business Innovation Research Direct-to-Phase II contract. Under the contract, Zephr.xyz aims to develop a system for real-time detection of GPS/GNSS jamming and spoofing in contested environments while also geolocating the sources of these attacks.

The company's "networked GNSS" technology, which converts standard mobile phones into a high-fidelity GNSS receiver network, will undergo extensive testing in Ukraine and various U.S. military exercises. Following these trials, the system is set to be integrated with the Department of Defense's Tactical Assault Kit and the Department of Homeland Security's Team Awareness Kit.

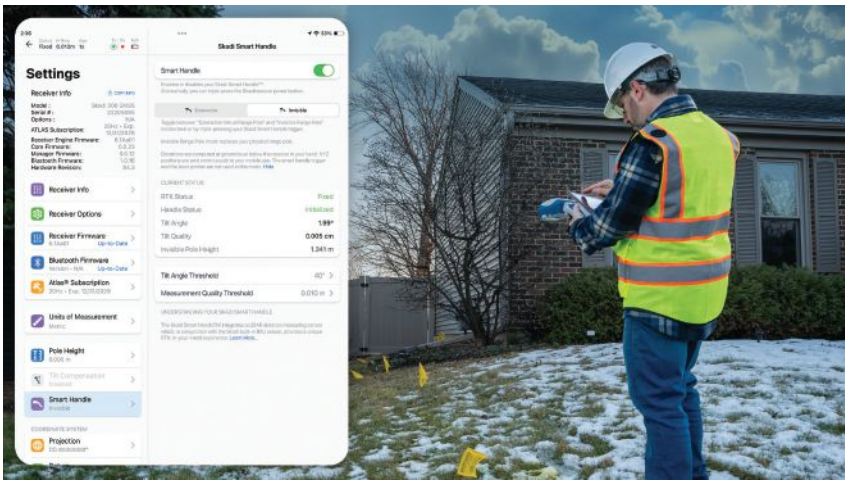
Spc. Markus Rauchenberger / U.S. Army

Zephr.xyz has conducted field research in conflict zones in Ukraine and Israel, revealing limitations in current GNSS interference detection and localization techniques. The company's solution aims to address these challenges by using distributed mobile devices to create a decentralized sensor network. This network collects raw GNSS measurements to identify electronic attack indicators, which are processed in real time for detection and classification.

The technology also aims to enhance positioning accuracy by integrating GNSS measurements from multiple devices with position, velocity, attitude and timing data. Zephr.xyz plans to make its detection and classification capabilities available as a software development kit, enabling mobile applications to alert users and improve positioning accuracy in electronic warfare scenarios.

MAPPING

Eos Positioning Systems Redesigns Eos Tools Pro App



Eos Positioning Systems

Eos Positioning Systems has launched a redesigned Eos Tools Pro app for iOS. The updated app features a modern user interface and user experience to enhance usability, functionality and efficiency for professionals using Eos GNSS technology.

The redesigned app includes a reorganized settings menu to improve the organization of all configuration options, offering a centralized space for users to manage their GNSS preferences and optimize workflows. The new interface has been revamped to take advantage of Split View mode on iPadOS to view all pertinent information when using Eos Tools Pro in conjunction with a data-collection app. This is especially useful for Skadi Tilt Compensation and Skadi Smart Handle users.

TIMING

Xairos Advances US Defense with Quantum Timing Technology

SpaceWERX, the innovation arm of the U.S. Space Force, has selected Xairos Systems for a $1.9 million Direct-to-Phase II contract to develop a fusion PNT system. This project aims to integrate quantum and optical synchronization of clock ensembles to address critical challenges faced by the Department of the Air Force.

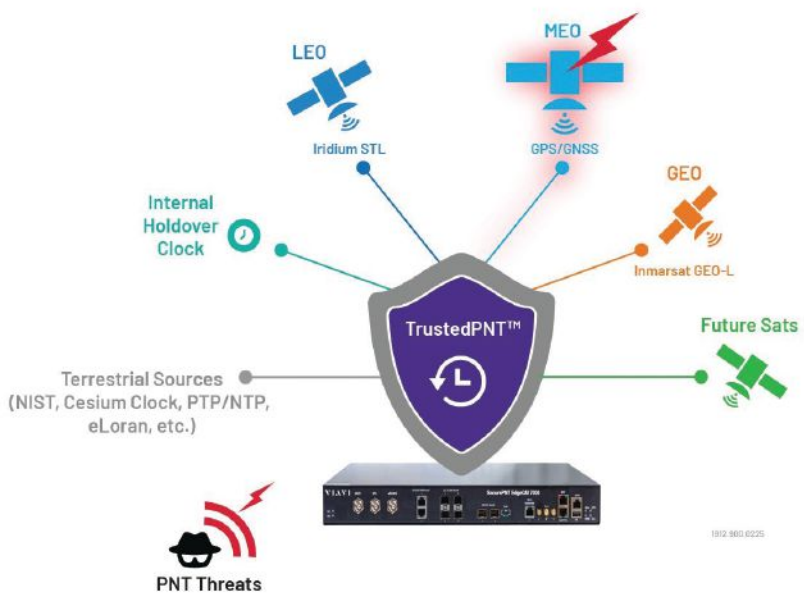
Xairos Systems is collaborating with Luminous Cyber Corporation and Eritek on this initiative. The team has recently completed a Preliminary Design Review. The AFRL shared that the collaboration is part of a broader effort by the AFRL and SpaceWERX to streamline the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) processes.

AFRL and SpaceWERX seek to streamline the SBIR and STTR processes through faster proposal-to-award timelines, changing the pool of potential applicants by expanding opportunities to small businesses and eliminating bureaucratic overhead by continually implementing process improvement changes in contract execution, according to AFRL.

VIAVI Launches Grandmaster Clock

VIAVI Solutions has introduced its new grandmaster clock, the EdgeGM 7000, as part of its SecurePNT portfolio. The device offers Precision Time Protocol (PTP) capabilities up to 25G and multi-orbit SecureTime for PNT services used in critical infrastructure operations.

Critical networks worldwide, including 5G/6G telecommunications, artificial intelligence data centers, defense and various other sectors, depend on GNSS signals for data synchronization. These signals are vulnerable to jamming, spoofing and satellite attacks, prompting governments to mandate improved network resilience.



VIAVI Solutions

SecurePNT EdgeGM 7000 powered with SecureTime GEO/LEO Service

The EdgeGM 7000 combines signals from various satellite constellations across geosynchronous Earth orbit, medium-Earth orbit and low-Earth Orbit. It is designed as a compact, rack-mountable unit with scalable software options. The device can be upgraded from 1/10G to 25G PTP through licensing, and GNSS backup can be activated remotely.

According to VIAVI, the EdgeGM 7000 surpasses Level 4 PNT resiliency as specified in the IEEE P1252 standard. It includes PTP profiles for multiple industries such as telecommunications, enterprise and power.

TIMING

Microchip Technology Unveils Low-Noise Chip-Scale Atomic Clock

Microchip Technology has introduced its second-generation low-noise chip-scale atomic clock (LN-CSAC), model SA65-LN. It features a lower profile height and operates in a wider temperature range, providing low-phase noise and atomic clock stability in challenging environments.

Microchip Technology

Chip-scale atomic clocks (CSACs) offer precise and stable timing in situations where traditional atomic clocks are impractical due to size or power constraints or where satellite-based references may be unreliable.

The SA65-LN, featuring Microchip's evacuated miniature crystal oscillator technology, offers significant advancements in oscillator design. It features a profile height of less than half an inch, power consumption under 295 mW and an operating temperature range from -40°C to +80°C. These enhanced specifications make the SA65-LN an ideal choice for aerospace and defense applications. It is well-suited for use in mobile radar systems, dismounted radios, IED jamming equipment, autonomous sensor networks and unmanned vehicles, where size, power efficiency and temperature resilience are crucial factors.

The LN-CSAC combines a crystal oscillator and an atomic clock in a single device, with a low-phase noise of 10 Hz < −120 dBc/Hz, an Allan deviation stability of < $1E^{-11}$ at 1-second averaging time and an initial accuracy of ±0.5 ppb. The LN-CSAC also demonstrates frequency stability with a < 0.9 ppb/mo drift and maximum temperature-induced errors of < ±0.3 ppb. These features contribute to high-quality signal integrity and atomic-level accuracy.

Adtran Releases Clock Upgrade for Precision Timing Applications

Adtran has launched its Enhanced Short-Term Unit (ESTU) precision timing module for its OSA 3300 series optical cesium clocks.

The module is designed to meet the demands of industries requiring ultra-stable short-term timing. According to the company, the module can achieve performance levels comparable to the passive hydrogen maser, which is no longer available in the Western market.

The ESTU module improves short-term frequency stability, measured through Allan Deviation, a key metric for timing accuracy. This improvement is particularly valuable for sectors such as metrology, space exploration and defense, where precise synchronization is crucial for data collection, satellite communication and measurement operations. Designed to optimize short-term frequency stability, the ESTU module is a versatile addition to Adtran's Oscilloquartz synchronization technologies. It supports both 5 MHz and 10 MHz output frequencies, making it suitable for a wide range of high-precision applications, including those that previously relied on passive hydrogen masers.

Adtran

ADVERTISER INDEX: COMPANIES FEATURED IN THIS ISSUE

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SEEN & HEARD

AMAZON SUED FOR ALLEGED PRIVACY VIOLATIONS

Amazon is facing a lawsuit in Washington state, marking the first dispute under the state's My Health My Data Act. The lawsuit accuses Amazon of violating privacy laws by collecting location data from millions of Americans without their consent through its software development kits used in various mobile applications. The collected data allegedly included information that could indicate a consumer's attempt to acquire health services, violating the My Health My Data Act, which requires explicit consent for collecting and selling health-related data.

EUROPE'S FIRST LUNAR LANDER UNDERWAY

The European Space Agency (ESA) has partnered with Thales Alenia Space to develop Argonaut, Europe's first lunar lander. This spacecraft will provide autonomous access to the Moon, supporting international exploration efforts. Starting in the early 2030s, Argonaut will conduct regular lunar missions, delivering infrastructure, scientific instruments, rovers and essential resources for astronauts. Designed to withstand harsh lunar conditions for up to five years, Argonaut will play a crucial role in sustainable lunar exploration, according to ESA.

LEICA GEOSYSTEMS, SCI-ARC EQUIP FUTURE ARCHITECTS

Leica Geosystems and the Southern California Institute of Architecture (SCI-Arc) have partnered to equip future architects with advanced technology skills. Leica is donating more than $200,000 in equipment, including lidar scanners, and offering expert guidance and scholarships to students. SCI-Arc students are applying this technology to create digital archives of Los Angeles structures and visualize rewilded wilderness.

GNSS SPOOFING DISRUPTS WILDLIFE TRACKING

In a recent study published by *Nature Communications*, researchers share that GNSS spoofing in conflict zones is disrupting wildlife tracking efforts, particularly affecting black-tailed godwits migrating through Eastern Europe. Researchers tagged 15 godwits in Finland in May 2024. Eight of these birds displayed spoofed geolocations during their migrations. The most significant spoofing occurred near Simferopol airport in Crimea, where birds were falsely located while flying over Ukraine or Romania. This spoofing added substantial errors to migration tracks, in one case creating a false 7,200-km round trip.

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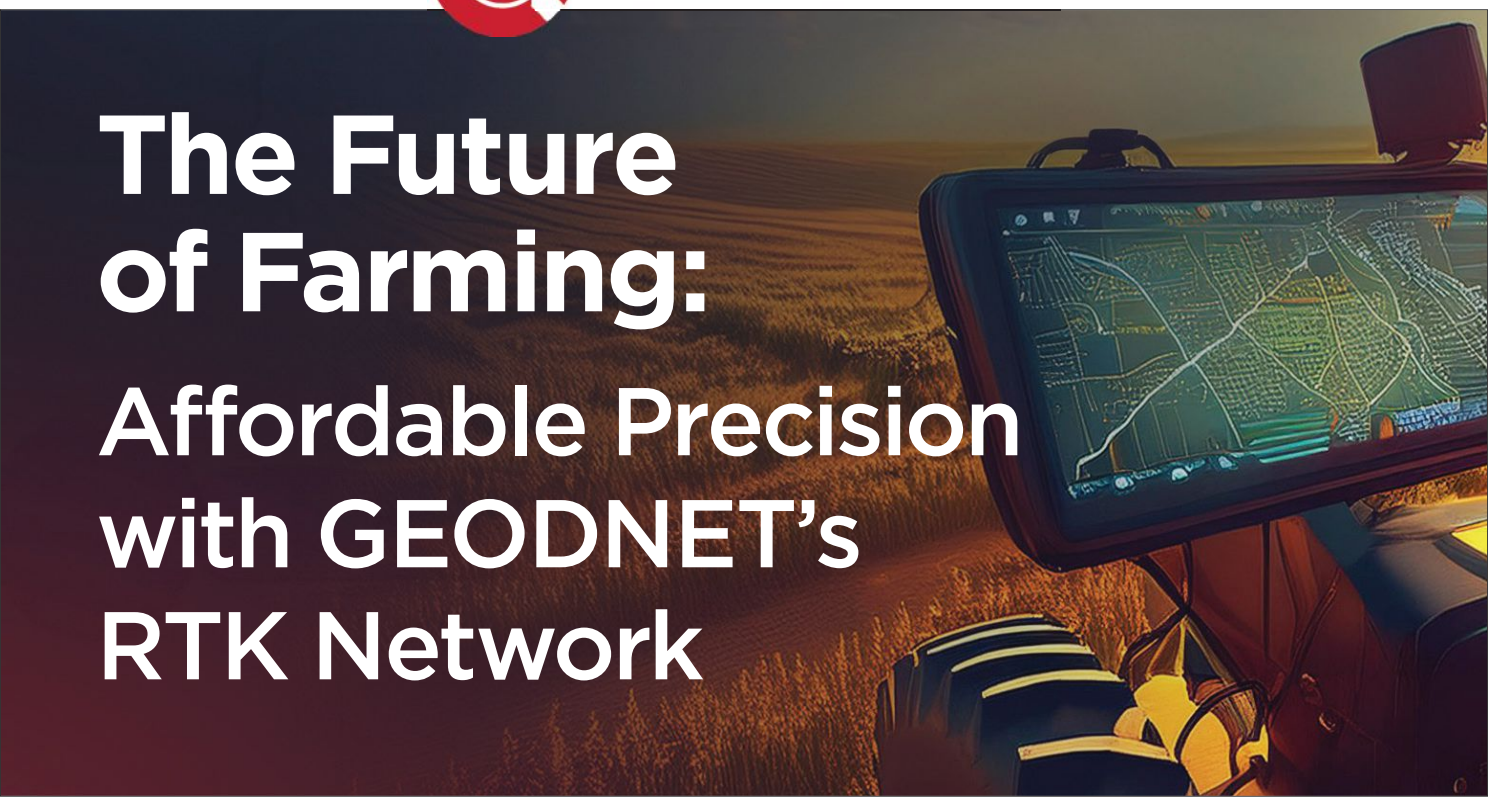

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