

GPS WORLD

GNSS
POSITIONING
NAVIGATION
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BUYERS
GUIDE

THE INDUSTRY'S MOST TRUSTED TECHNICAL RESOURCE SINCE 1990

STACKED ROVERS

The rise of multi-sensor
stacks for field surveying
and mapping systems



EMPOWERING
FUTURE
GEOSPATIAL
EXPERTS

JUNE 2025 | Vol 36 | No 6
GPSWORLD.COM

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BY GAVIN SCHROCK

We explore how manufacturers are integrating GNSS, inertial measurement units, cameras, lidar and more into compact, field-ready devices, transforming workflows and boosting productivity. Industry experts weigh in on the benefits, trade-offs, and future trends, revealing how these innovations are reshaping the balance between high-precision point collection and mass reality capture. Discover how stacked rovers are redefining what's possible in the field.



Scott Walls, Walls Land-Water

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CHC Navigation's RS10 handheld SLAM 3D laser scanner integrates GNSS RTK, laser scanning and visual SLAM technologies into one platform. This fusion increases the efficiency and accuracy of both indoor and outdoor 3D scanning and surveying tasks. (Credit: CHC Navigation)

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FCC Opens Door to GPS Alternatives, but Risks Undermining its Greatest Strength

BY SEAN GORMAN, CEO AND CO-FOUNDER, ZEPHR.XYZ

On March 27, the Federal Communications Commission (FCC) unanimously approved a Notice of Inquiry (NOI) to explore GPS alternatives, amid escalating threats to security and system resiliency. The move signals growing federal concern about the reliability of space-based navigation and timing infrastructure amid rising global interference and spoofing incidents.

But while the FCC’s broad consideration of alternative technologies is a welcome step forward, its framing also risks weakening one of GPS’s most important defenses: the growing adoption of multi-constellation strategies across the commercial sector.

The FCC’s decision follows the release of the International Air Transport Association’s (IATA) latest

safety report, which documented a 175% increase in GPS interference and a 500% rise in spoofing attacks year-over-year. These incidents pose critical challenges to aviation safety, emergency services, telecommunications and countless other sectors that rely on positioning, navigation, and timing (PNT) services.

Against this backdrop, the FCC’s vote reflects a bipartisan sense of urgency. The NOI invites public comment on a range of technologies that could serve as complements or alternatives to GPS, including low-Earth orbit (LEO) satellites, terrestrial signals and enhanced end-user devices. This broad framing is encouraging and acknowledges the multifaceted nature of PNT resilience. 🌐

Read the full article at gpsworld.com/category/opinions.

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Published monthly



Deeper Dives and More Exclusive Content

As *GPS World* marks its 35th anniversary, we continue to evolve to meet the needs of our valued subscribers and marketing partners. This month, we unveil strategic refinements to our magazine publishing schedule, and our expanding digital content and solutions portfolio plans.



Tod McCloskey

To better align with buying cycles and industry events, *GPS World* is transitioning from a monthly print and digital edition cadence to a six-times-per-year magazine frequency. Remaining 2025 issues are set for September and October. Beginning in 2026, *GPS World* issues will publish in February, March, May, June, September and October.

Each *GPS World* issue will continue to deliver exclusive technical content and market insights.

In tandem with our magazine's evolution, *GPS World* is significantly expanding its digital content and media solutions offerings, including:

- **Expanding GPSWorld.com:** We will feature more exclusive content, delving deeper into today's hottest trends in GNSS' and complementary PNT's top segments: autonomous solutions, defense, mobile, machine control/precision ag, simulators, surveying, mapping and transportation
- **New Custom Media Solutions:** Leading technology suppliers now have an arsenal of platforms and offerings to educate our audiences on trends and advancements
- **Expanding Enews:** Navigate Weekly!, Survey Scene, Autonomous Arena and Defense PNT e-newsletters: We will deliver even beefier segment news to your inbox each week

GPS World's audiences are highly engaged confirmed buyers/specifiers. We promise to continue to evolve our integrated media offerings to meet readers' and marketers' changing preferences — because you are, and always have been, at the center of our information constellation. 🌐

Tod McCloskey | SALES DIRECTOR

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What urgent policy or industry actions are needed to protect and advance resilient PNT services amid spectrum sharing debates and GNSS regulation changes?

“In my article, ‘Is There a Silver Bullet for Resilient PNT?’, I addressed the confusion caused by the numerous and diverse industry initiatives now being offered. Industry is understandably motivated to provide resilient PNT capabilities, but each also wants the government to pick its solution and make policy decisions accordingly. Spectrum sharing decisions that favor a single service provider may harm others in a crowded space, and so are difficult or impractical, as we have seen with the decades of litigation associated with LightSquared/Ligado and the spectrum surrounding the GPS L1 frequency. Not everyone can win that competition, and as I noted at the end of the article, ‘Unless our government accepts responsibility, there will be no PNT silver bullet for domestic critical infrastructure. Experience shows that industry will not solve this problem alone.’”



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“Regulatory authorities must quickly approve and protect RF spectrum allocated for new PNT capabilities, particularly for emerging low-Earth orbit (LEO) constellations. These systems offer clear advantages in signal strength, geometric diversity and resilience against jamming and spoofing. Without timely and well-defined spectrum authorization, along with strong adjacent-band protections, the deployment of GNSS receivers capable of supporting these constellations will be delayed.

On the industry side, LEO PNT developers must urgently finalize signal structures and release Interface Control Documents, enabling GNSS receiver manufacturers to begin implementation, validation and system integration.”



“If I were to point to a single thing that has held the U.S. (and many other countries in the world back, except for China), it is the lack of strong mission-oriented, dedicated leadership. It is time to designate a single entity, office and person responsible for ensuring resilient PNT services to U.S. critical infrastructure, thereby maintaining the safety, security and economic benefits these sectors support. Some wise men once came up with the idea that a government must ‘provide for the common defense’ and ‘support the general welfare.’ Resilient PNT is essential to achieving both.

Engineering System Designers should never fall in love with their solutions. The mission, i.e., the needs of their customers, must always remain their first concern.”

MORE ONLINE

For longer versions of the responses, go to gpsworld.com and click on Opinions



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Next-Gen NAVWAR Simulation with **BroadSim Genesis**

Massive Signal Capacity

BroadSim Genesis supports generation of up to 2000 signals, enabling advanced multi-constellation simulations across MEO, LEO, and alternative PNT sources—all in a single test environment.

Resiliency and NAVWAR Readiness

Designed to meet modern NAVWAR demands, BroadSim Genesis supports multi-antenna and multi-vehicle configurations, M-Code, and robust integrated jamming and spoofing capabilities to test against the most sophisticated signal threats.

Operator-Friendly Design

An intuitive UI, integrated front panel with N-type connectors, extractable drives, and onboard timing card make BroadSim Genesis easy to use, secure, and field-ready.

Debuting June 3-4 at the 2025
Joint Navigation Conference
Booth 101



BROADSIM GENESIS



sales@safranfs.com

Prevent Million-Dollar Mistakes: Why GNSS Simulation Is Essential for Surveyors

A few years ago, a highway project in Minnesota suffered a costly setback. A bridge was misaligned — not by much, just about a meter — but enough to trigger massive delays, structural rework, and skyrocketing costs. The root cause? A GNSS error that went undetected during equipment calibration. What seemed like a minor glitch in positioning data turned into a logistical nightmare, reinforcing one critical truth: in surveying, precision isn't just a requirement — it's the very foundation.

The Hidden Vulnerability in Modern Surveying

GNSS has revolutionized surveying and mapping. From infrastructure to land development and construction, today's professionals rely on pinpoint GNSS accuracy to deliver results. Yet, GNSS signals are surprisingly fragile. They're vulnerable to jamming, spoofing, multipath interference and environmental factors that are often impossible to control in the field. Positioning accuracy can be lost in seconds.

Resilience in the Face of GNSS Interference

Exposing GNSS-based survey equipment to simulated GNSS interferences — whether natural or intentional — before deployment is no longer optional. Fully repeatable, simulation tests allow users to diagnose, fix and validate GNSS receivers under consistent conditions, by generating authentic RF signals from any constellation.

Testing GNSS Receivers in real-world conditions

Survey and mapping professionals need to validate and stress-test GNSS receivers and positioning systems in real world conditions - from urban canyons, construction sites to rural terrain. Few high-tech GNSS simulators are able to model those real-life environments, down to the last detail: dynamic motion, signal blockage, multipath reflections and even customized antenna behavior.

Powering Confidence with Safran's Skydel GNSS Simulation

Safran's Skydel-powered GNSS simulators, such as the GSG-7 and GSG-8 Gen2 enable precise, repeatable testing of GNSS equipment in the lab before deployment. Designed to simulate GNSS threats such as **jamming and spoofing** without extra hardware, both simulators support high signal capacities, all constellations (legacy and LEO) and generate accurate RF signals.



Built for speed and usability, the GSG-7 and GSG-8 Gen2 simulate multi-vehicle, multi-antenna scenarios, and are equipped for HIL testing while providing unmatched realism.

Main features:

- Full constellation support
- LEO and custom constellations
- Sub-millimeter signal precision
- CRPA and OTA testing support
- Complex environment simulation
- Hardware-in-the-Loop (HIL) integration
- Software-defined architecture
- Lab-based testing for real-world scenarios

With Safran's Skydel-powered GNSS simulators, confidence isn't just tested — it's engineered.

Contact us to know more:

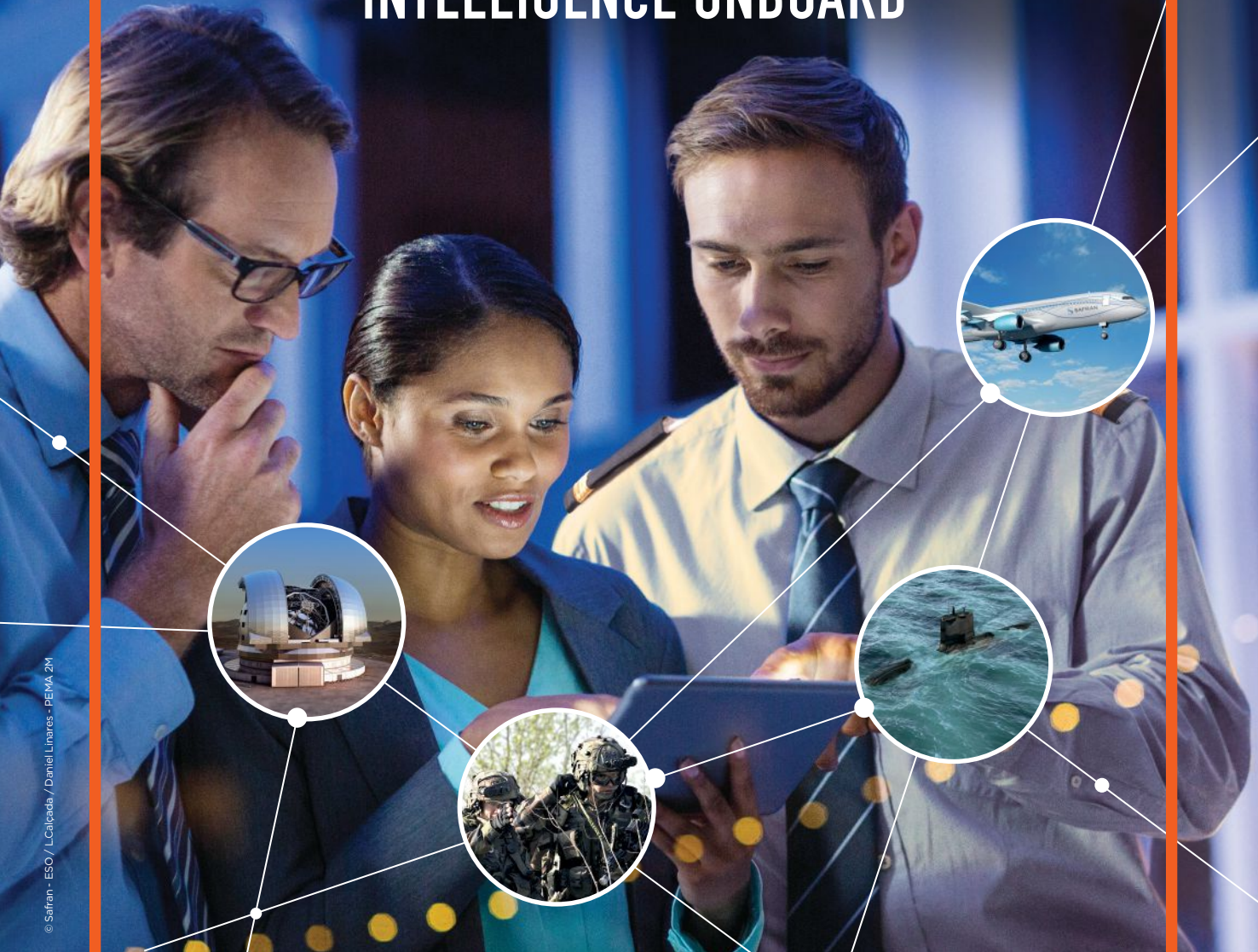
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 **SAFRAN**

SYSTEM OF SYSTEMS

POLICY AND SYSTEM DEVELOPMENTS IN GNSS AND OTHER PNT TECHNOLOGIES



ESA

ESA Selects SpacePNT Receiver for Genesis Mission

SpacePNT has joined the European Space Agency's Genesis mission, a navigation satellite project

that will be the first to carry all four space-based geodetic techniques on board: GNSS, Satellite Laser Ranging (SLR), Very Large Baseline

THE GENESIS SATELLITE design places the solar panels on the sides to optimize power generation.

Interferometry (VLBI) and Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS).

SpacePNT's NaviLEO spaceborne GNSS receiver technology was selected for the mission's critical satellite navigation ranging instrument. Although NaviLEO has flight heritage in low-Earth orbit, it will be adapted for Genesis to operate in medium-Earth orbit at 6,000 km. The system will use a dual-antenna configuration to receive GNSS satellite signals from both zenith- and nadir-looking antennas.

The Genesis mission aims to update the International Terrestrial Reference Frame (ITRF), a global Earth model, targeting an accuracy of 1 mm and long-term stability of 0.1 mm per year. This will provide a precise coordinate system for advanced navigation applications. 🌐

Satellite Safety Alliance Urges Reversal of FCC Ligado Order

A new letter protesting the Federal Communications Commission's (FCC) Ligado Order marked the fifth anniversary of the controversial decision on April 22, 2020.

In the letter, the Satellite Safety Alliance (SSA) and 93 companies and organizations stated the need for the Ligado Order to be overturned by President Trump and Congressional leadership.

"The proposed network is designed to inappropriately use spectrum reserved for satellite communications,

causing significant interference to other services," the SSA stated. Interference with GPS is a major concern of the group.

The letter urges the president and the chairs and ranking members of the House and Senate armed services and commerce committees to work with the FCC on granting petitions for reconsideration that will help prevent the building of Ligado's terrestrial wireless network.

"Ligado's network would threaten a wide range of critical government and

commercial services, including military communications, private satellite communication, GPS, agriculture, aviation, weather forecasting, and more," the SSA stated.

"For over two decades, Ligado and its predecessors have tried and failed to build a terrestrial network that wouldn't harm GPS, national security, and other critical interests," commented the SSA. "The FCC's Ligado Order has faced unprecedented opposition, including from 14 federal agencies and over

SEE SATELLITE, NEXT PAGE. >>

SpaceX Details Starlink's Role in PNT Resilience Amid FCC Inquiry

SpaceX has submitted reply comments to the Federal Communications Commission (FCC) detailing how its Starlink low-Earth orbit (LEO) satellite system currently provides, and could further support, positioning, navigation, and timing (PNT) services. The filing is part of the FCC's ongoing Notice of Inquiry (WT Docket No. 25-110), which seeks to promote resilient and diverse PNT capabilities across the United States in response to vulnerabilities associated with the nation's reliance on GPS, such as the risks of jamming and spoofing.

The FCC's initiative, titled "Promoting the Development of Positioning, Navigation and Timing Technologies and Solutions," aims to explore both space-based and terrestrial alternatives to ensure the continuity of critical PNT functions for national security, public safety and economic stability. The agency is soliciting input from stakeholders on technologies that could complement or serve as alternatives to GPS, with a focus on robustness, geographic coverage and resilience to interference.

In response, SpaceX noted in its comments: "One opportunity stands out as a particularly ripe, low-hanging fruit: facilitating the rapid deployment of next-generation LEO satellite constellations that can deliver PNT as a service alongside high-speed, low-latency broadband and ubiquitous mobile connectivity."

SpaceX also states that it already has been working on a PNT system for its cellular Starlink service, which is currently in public beta and is set to launch through T-Mobile in July.

Starlink Architecture and Features

SpaceX also noted that Starlink terminals already can provide nanosecond-level timing accuracy and meter-level positioning by using time-of-arrival measurements from its satellites. These capabilities allow the network to support precise



STARLINK'S GATEWAY TERMINALS are positioned worldwide, so remote areas without terrestrial infrastructure can access high-speed internet.

timing applications, such as cellular network synchronization, without relying on external GPS sources. Timing signals are derived from the LEO constellation and synchronized through Starlink's broadband infrastructure.

The filing highlights the Starlink system's architecture, which includes thousands of satellites in LEO for global coverage and short signal travel times. SpaceX points to its phased-array user terminals, which use directional antennas to enhance signal integrity and mitigate interference. The company also notes that Starlink employs end-to-end encryption, making its timing and positioning information less susceptible to spoofing or tampering. According to SpaceX, Starlink is already in commercial use by a variety of customers and has been tested by U.S. military and civilian users in environments where traditional GNSS signals are degraded. The company emphasizes these capabilities have been demonstrated under real-world conditions, not just in theory.

A Layered Approach to PNT

Addressing the FCC's interest in a "layered" approach to national PNT resilience, SpaceX positions Starlink as one of several complementary solutions to enhance national PNT resilience. The company argues that using diverse, independently operated systems — both satellite and terrestrial — can provide redundancy and reduce dependence on any single technology or spectrum band. 🌐

SATELLITE

« CONTINUED FROM PREVIOUS PAGE.

90 organizations representing huge swaths of the economy — from aviation and agriculture to science and manufacturing. Rarely does any issue

garner agreement from such a wide and divergent group of constituencies."

Congress found through independent analysis that the Ligado Order poses unacceptable risks of interference to GPS, satellite communications, weather forecasting,

and other services, the SSA explained. "Countless federal staff hours and resources have gone to reviewing, debating, and litigating this issue. It is past time the FCC put the issue to rest by granting the pending petitions for reconsideration." 🌐



Q+A with BAE Systems

Justin Wymore

M-Code Solutions

What is the status of BAE Systems' line of M-code products?

BAE Systems is actively developing and fielding a comprehensive family of M-code GPS receiver solutions. Our company has created security-certified Common GPS Modules (CGMs) that leverage the robust M-code signal across an all-inclusive GPS receiver portfolio. The portfolio scales from the world's smallest and lowest-power M-code GPS for size, weight, and power (SWaP)-challenged applications, to highly robust receivers with integrated anti-jam antenna electronics for exceptionally challenging environments.

The diverse line of M-code receivers include:

- ASR™-M
- DIGAR™-300M
- MPE™-M
- MicroGRAM™-M
- NavFire™-M
- NavGuide™
- NavStrike™-M
- NavStorm™-M
- SABR™-M

Are you actively fielding from this line?

BAE Systems has delivered selective availability anti-spoofing module

products to more than 45 countries and has begun delivering M-code GPS receivers in multiple form factors and levels of capability to the U.S. armed forces and its allies through foreign military sales.

Customers who have integrated these products into their platforms are at a competitive advantage, as the open-architecture capability can be tailored to solve their most pressing battlefield problems at an affordable price with a short timeline.

Explain the misconception about the status of M-code.

Work has been underway for more than two decades to modernize GPS with the more secure, jam-resistant, M-code. However, a recent U.S. Government Accountability Office report suggested technical and manufacturing challenges had delayed the deployment of M-code.

While the scrutiny of the operational efficiencies of M-code products provided by defense technology companies is important and necessary, significant successes and advancements are currently underway.

BAE Systems is not only dedicated to maintaining a supply of cutting-edge GPS solutions today, but also



proactively overcoming the challenges of a rapidly changing defense landscape for the foreseeable future.

Justin Wymore, Business Development Manager, Navigation and Sensor Systems, BAE Systems

BAE SYSTEMS

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BAE SYSTEMS

LAUNCHPAD | MOBILE

1. MOBILE CLOCK GENERATOR

WITH AN INTEGRATED MEMS RESONATOR

SiTime's Symphonic is a mobile clock generator built around the SiT30100, which integrates a MEMS resonator and a temperature sensor in a compact 2.22 mm² chip. Designed for 5G and GNSS chipsets, Symphonic delivers precise, resilient clock signals while supporting efficient power consumption in mobile and IoT devices, including smartphones, tablets, laptops and asset trackers.

The integrated temperature sensor feeds data to compensation algorithms, providing frequency stability as low as ± 0.5 parts per million to enhance GPS accuracy and shorten lock times, which is critical for reliable performance in challenging environments. The device operates across a -30°C to 90°C temperature range and is engineered for dynamic stability and power optimization, helping to mitigate electromagnetic interference. Symphonic features four configurable clock outputs, each capable of delivering 76.8 MHz, 38.4 MHz or 19.2 MHz, suitable for baseband, radio frequency and GNSS applications. The single-chip design eliminates the need for external resonators.

SiTime, sitime.com



2. DUAL-BAND L1/L5 ANTENNA

FOR CRITICAL POSITIONING AND TIMING APPLICATIONS

The TW3885TL is a dual-band GNSS antenna engineered to deliver reliable, interference-free signal reception for critical positioning and timing applications. Supporting both L1 and L5 frequency bands, the antenna is compatible with a wide range of global navigation satellite systems, including GPS, QZSS, Galileo, BeiDou, GLONASS and NavIC, as well as regional satellite-based augmentation systems.

The TW3885TL incorporates advanced filtering technology designed to reduce interference from crowded radio frequency environments. It features a low-noise preamplifier, with a typical noise figure of less than 2.5 dB, and offers high gain, typically around 40 dB. The antenna maintains a low axial ratio, under 2.0 dB, and exhibits tight phase center variation, which contributes to precise timing and superior signal quality. Constructed with a weatherproof enclosure rated to IP69K, the TW3885TL is suitable for permanent outdoor installations and can be mounted through-hole, with optional accessories available to support various mounting configurations.

Calian GNSS, calian.com



LAUNCHPAD | UAV

1. SOFTWARE UPGRADES

ENABLE POSITIONING IN GNSS-DENIED ENVIRONMENTS

eBee VISION application software now includes a suite of updates for UAV navigation in environments where GNSS signals are compromised or unavailable. The latest software enables autonomous position updates with map referencing, allowing for precise navigation even when satellite signals are jammed, spoofed or blocked. This product is suitable for defense personnel, public safety agencies, and industrial teams working in high-stakes environments where GNSS signals are unavailable (densely populated urban areas, near critical infrastructure, or in contested zones with active interference). The update introduces optical flow stabilization for target lock, which uses visual cues to keep the camera centered on a point of interest during zoom-ins or drone movement. The software allows for adaptive behavior after GNSS recovery or visual repositioning. Additional enhancements include real-time mission duration and return-to-home estimates, optimized cruise speed in windy conditions, high-precision landings using lidar-based altitude calibration, a gimbal auto-recovery mechanism to clear obstructions mid-flight, and smart motor speed reduction to prevent overheating during extreme conditions.

AgEagle Aerial Systems, ageagle.com



2. IMU

FOR UNMANNED COMMERCIAL AND DEFENSE APPLICATIONS

The IMU-H100 is a micro-electromechanical systems inertial measurement unit (IMU) designed to improve tactical guidance and navigation for UAVs, short-range missiles, precision-guided munitions, and a range of commercial applications.

The tactical-grade unit features accelerometers and gyroscopes on all three axes. It offers a gyro bias of 1° per hour and an accelerometer bias of 1 mg. The unit measures 5 in³ and weighs 160 g. The IMU-H100 surpasses comparable products in data rate, measurement range, stability and repeatability, even under challenging conditions such as vibration, shock, high acceleration, spinning, temperature changes and acoustic noise.

Inertial Labs, a VIAVI Solutions company, inertiallabs.com



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Reception Pattern
Antenna (CRPA)

Four-element GNSS CRPA
for L1/L2, E1/E5b signals

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20–40 dB null depth

eXtended Filtering
Plus (XF+) for superior
cross-band isolation

COMING JUNE 2025

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calian.com/GNSS



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STACKED ROVERS

A LASER SCANNING PROFILER and three cameras have been incorporated into this GNSS rover system. The CHC RS10 can be used as a standard rover on a pole or mounted on a chest harness (shown). Some users have mounted them on vehicles or inverted rods for maintenance holes, etc.

Surveying and mapping benefits from multi-sensor stacks. Just how many sensors could, or should, be stacked into a single field device? There are several schools of thought...

BY GAVIN SCHROCK, PROFESSIONAL LAND SURVEYOR AND CONTRIBUTOR

Anyone who has had to carry cumbersome legacy surveying instruments over rough terrain can probably confess to daydreaming about having something similar to Mr. Spock's "Tricorder," a small device that captures everything about your surroundings. Such sci-fi devices provide a glimpse of the "reality capture" wave of the present day.

Multi-sensor stacks have become the norm and are essential for many geospatial applications. Consider vehicular autonomy. For safety-of-life considerations, no single positioning technique could suffice. Each sensor type has strengths and weaknesses. Lidar exhibits good performance under certain conditions, as does radar, GNSS and inertial measurement unit (IMU) systems. That is why a typical autonomy stack will include one or more sensor types. More data of different types is better, especially if they can share a standard, highly precise spatial reference.

Platforms, Positioning and Progress

As surveying and mapping practitioners, we are bombarded with news and ads for a seemingly endless parade of the latest reality capture devices: handheld simultaneous localization and mapping (SLAM) scanners, drone payloads, mobile mapping systems, backpacks and more.

Many are using OEM sensors from a relatively small subset of manufacturers; this trend is similar to the wave of third-party GNSS rovers a decade ago.

While the individual sensors deliver astounding data, integration into field capture devices often shortchanges one crucial element: positioning. There is a tendency to keep cost, size and power consumption low by including positioning components (e.g., GNSS and IMU) initially developed for mass-market applications such as vehicle autonomy. Not every handheld SLAM system can afford to add survey-grade capabilities, such as those delivered by dedicated surveying rovers. Users need to have realistic expectations.

A surveyor might wince when they hear a marketing message from yet another SLAM device manufacturer claiming, "centimeter precision, anywhere!" Even with top-tier survey rovers, skill and experience temper such expectations. But what if the platform of a highly capable, survey-grade rover is packed with multiple data capture sensors? This idea is not new, and the evolution of rover-based solutions in many ways has enabled the development of the current wave of reality capture systems.

Positional Integrity Through Motion

It is a prospect that might seem counterintuitive: deriving a precise position while moving the instrument.

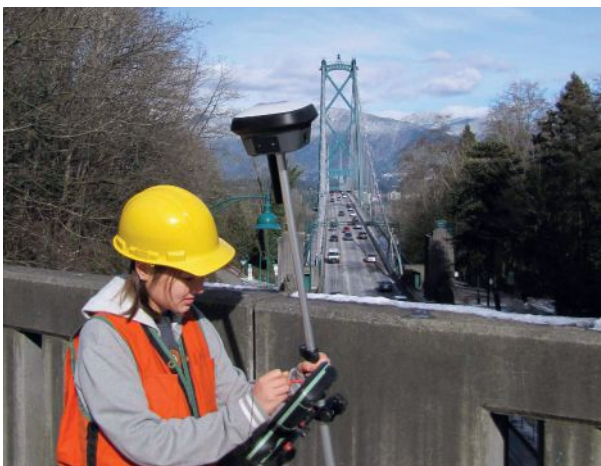


Providing tilt compensation for a GNSS survey rover (on a pole/rod), freeing the user from the tyranny of the bubble, was one goal. Still, it was also the first crucial step in enabling further sensor integrations.

Integrity through motion is one of the foundational elements of GPS/GNSS: The trajectories of the navigation satellites can be predicted with high confidence. For example, frequently updated ultra-rapid orbit products used in many GNSS solutions rival the precise orbit products we used to wait days for. Similar principles apply to modern tilt compensation solutions. The movement of the rover's head provides a highly predictable reference trajectory for the orientation of the tilt sensors.

Tilt compensation in rovers first appeared more than a decade ago. These were, at the time, unfortunately, magnetic-oriented systems. While a noteworthy achievement, the inconsistencies inherent in magnetic reference and cumbersome calibration routines soured many users on the idea of tilt compensation.

This changed with the introduction of the Leica GS18 T GNSS rover. This was one of the first "stacked rovers," spawning a chain reaction of similar feature integration across the industry. The development process was part of a 10-year drive to enhance field efficiency, but it was not the singular goal. Dynamic precise positioning was the first step to enabling the integration of additional features. After a year or so of end users getting over the skepticism of tilt compensation, you'll now find it as a standard feature on nearly all new GNSS rovers.



Gavin Schrock

THE LEICA GS18 T began the wave of multi-sensors stacks for GNSS rovers with the introduction of no-calibration tilt compensation in 2017. This was soon followed by the GS18 I, adding a camera for offset points, stakeout, and point cloud creation. Since then, such features are common across the industry.

Adding Sensors

GNSS in sky-view-challenged environments was the impetus for the first multi-sensor integrations. Namely, how to get the shot under the adjacent canopy or roof overhang. While manufacturers and integrators had been offering various ranging lasers as peripherals for GNSS rovers since the late 1990s, the Achilles heel was the orientation, limited to magnetic references. Despite this handicap, such offset point solutions were popular for specific applications.

Once dynamic precise positioning was achievable in a rover head, cameras were the next logical step in stacking sensors. Leica Geosystems soon followed up its GS18 T with the GS18 I, which added camera-based offset point capabilities. Rather than some early photogrammetric offset point solutions where you took individual static photos, with the GS18 I, you capture a series of precisely spatially registered images while in motion. In the companion Leica Captivate software, you can quickly identify the offset points. The same images can be processed in the software as a 3D point cloud, which many users do.

Again, we started to see camera-based offset point (and stakeout) solutions in nearly every brand of GNSS rover. What's next? We're starting to see lidar added to some rovers. But at what point should a field user reach for a dedicated reality capture device, rather than trying to do everything with an enhanced GNSS rover? There's a lot to consider, so we asked some integrators for insights.

Eric Gakstatter, principal and owner of Discovery Management Group, has been promoting multi-sensors at conferences for decades. His firm also has developed and consulted on such designs in conjunction with various manufacturers.

"There's a difference between lidar SLAM devices and rovers," said Gakstatter. "With one, you are looking for a point cloud, but with the other, you are more interested in discrete points of interest; you're very deliberate in measuring specific features." Gakstatter had recently given me an overview of the Eos Positioning Systems Skadi GNSS rover, a receiver from the makers of the Arrow GNSS systems. The Skadi has a built-in antenna and full tilt compensation. It also can snap into a companion smart handle that has a "virtual pole" feature, and a ranging sensor with a visible laser pointer for offset points and stakeout. You also can capture offset points in continuous mode, using the pointer to (sort of) "trace" features.

His firm also has developed, in partnership with another manufacturer, an angle encoding peripheral that mounts on the pole. When used in conjunction with a rangefinder-style laser, the GNSS rover can perform traverses in much



the same manner as a surveyor's total station.

"I think you'll find that some folks are just going to go after the low-end sort of basic RTK receiver and some simple integration," Gakstatter said. "But, you'll always have the manufacturers that are sinking a lot of time and money into research and development (R&D), the pioneering stuff. But it is very expensive and for a relatively small market."

When new solutions are developed and integrated by those willing to invest in R&D, users gripe about high prices for the gear. Still, the payoff is a major increase in productivity and safety. Sure, such features might show up in lower-priced rovers, but with varying degrees of performance.

Rover Lidar

Lidar can be quite powerful for creating 3D point clouds and models. However, doing a formal scanning campaign with a large-format laser scanner is not always justified. And even if a site is scanned, surveyors might still need to shoot key features with a total station and/or GNSS rover. This practical reality is why limited scanning capabilities (and imaging) were integrated into some total stations. For example, the Trimble SX12 total station and the Leica Nova MS60 multistation. As such instruments provide, by default, highly precise spatial references, any of the selective scans are automatically registered.

It was inevitable that GNSS rover manufacturers would eventually seek to add lidar scanners. An example is the CHC Navigation RS10. It can operate as a rover or as a SLAM scanner. According to Logan Zhou, mobile mapping business director at CHCNAV, when the RS10 was released in 2024, it brought a substantial boost to their mobile 3D sales.

"Compared to a traditional SLAM solution, we have integrated a high-performance receiver and antenna," Zhou said. "So, the users can acquire the results with geographic coordinates directly." He added that there



Eric Gakstatter

THE EOS POSITIONING SYSTEMS Skadi rover fits on a pole, or this handle, with automated height-above-ground and features measurement sensors.

are three cameras integrated into the RS10 — for image capture and point cloud colorization.

Matt Sibole, PLS, owner of iGage Mid-Atlantic, part of the iGage surveying equipment sales and support network, has several RS10s in his rental inventory. He finds the unit very capable as a reality capture system. Sibole also related that his customers are very pleased with other CHC rovers that have camera-based offset and stakeout capabilities.

One consideration of adding a high-precision SLAM scanner to a rover is weight. When using one for standard rover point capture for extended periods, the added weight can become a burden. Sibole prefers a different topo survey workflow. "I'll go through with my CHC i89 rover and pick specific points I need, as a check," he said. "I'll shoot center and rims of manholes, shoot some property corners, etc. Then, I put that away and grab the RS10 to collect the lidar, usually on a chest harness."

Cameras Abound

"I think photogrammetry could overtake lidar, for many applications, as the sensor fusion gets better, the algorithms get better, and the actual physical hardware gets better," said Jesse Huff, surveyor and general manager of Tersus GNSS in North America. "Even in the literary world, you know, a picture is worth a thousand words. There's a lot more information to be gleaned from the images, and the stuff that we're doing with point clouds. The feature recognition revolution is just getting started," he said.

"The point cloud that we're getting out, I won't say it's as clean as some lidar data," Huff said. "There's a little bit of noise in that, but it rivals lidar data for most of what folks are doing, save for structural mechanical work."

One characteristic of legacy close-range photogrammetry, which had been a source of lingering doubts about its utility, was the legacy cumbersome processing workflows. Huff explained the offset point selection and creation of the point clouds from the Tersus Trek is performed on the data controller. The same Tersus field software also can run on an Android tablet or phone.

"When you talk about sensor stacks, it's not just sensors, it's technology stacks," Huff said. "It's not just taking advantage of the tech that's in the receiver, it's also taking advantage of the tech that has evolved in terms of mobile computing devices, artificial intelligence (AI), the cloud, and more."

GNSS Quality

Developers are following two roads: bringing precise positioning to the sensor-stacked device, or sensor stack a precise positioning device. This paradigm was of prime consideration for Looq AI, when it was developing its



A GNSS+IMU+CAMERA INTEGRATION: The Tersus Trek is being used on a survey for a school expansion project.

flagship handheld, camera-based reality capture system.

“From a technological foundation, we knew that for triangulating thousands of image features, which are represented by points in the real world, multiple optics were required,” said Dominique Meyer, co-founder and CEO of Looq AI. “We create a triangulation algorithm for the camera system that would provide robustness that is much greater than many of the photogrammetric single camera solutions out there, and at the same time, exceed the point cloud density of many lidar point clouds. A precise spatial and temporal component is crucial to apply to the observations.

“This is why Looq AI decided to make post-processed kinematic (PPK) an integral part of our workflow,” Meyer said. “Because our computer vision algorithms always run after the capture, in the cloud, we knew we could afford to run PPK, automatically, first.”

Key as well was the choice of the GNSS and IMU components of the Looq AI handheld. “What we cared about is multiple bands, especially the newer bands like L5,” said Meyer. As noted, there are GNSS boards for many different applications. While some of the lower-cost solutions are “multi-constellation,” they may only support a limited number of signals per constellation. Looq AI chose a high-quality GNSS solution from Septentrio.

Duality

Surveying is, in many ways, reality capture, but it is handled in a different, more selective and focused manner. Features observed must often meet very tight precision and integrity expectations: property marks, control for engineering and construction, monitoring, and more. Reality capture is about mass data capture. While there are advantages for certain applications in the proximal richness of mass data capture, there always may be the need for discrete points.

“When we designed the GS18 T, we recognized a challenge in bridging the gap between single-point measurement and reality capture,” Richter said. “Our goal was to improve the efficiency of discrete point collection while maintaining survey-level quality.” With

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tilt achieved, the later addition of camera-based offset point capabilities to the GS18 I was simply to improve efficiency even further.

“One of the main concepts behind the GS18 I is that everything you capture through photogrammetry is immediately aligned with the same reference frame or coordinate system as your normal GNSS points,” said Richter. “This additional feature does not put any extra burden on your hardware, and if you work in the conventional way, it performs just as well as any other method.” While you can produce point clouds from the images, that was not the primary goal, but a nice feature for certain situations. This brought up another consideration: Is the capture of potential excess data a wise move?

“You can use mobile scanners, or sensors on your rovers, and generate point clouds of everything,” said Richter. “Capturing massive amounts of data is easy from a hardware perspective. But then you have to process and use all of this data. Right now, the software side of the industry is playing catch-up. There just isn’t enough automation yet, though AI will certainly help with that moving forward.” It is a common complaint in the geospatial sector that there are substantial backlogs in the office processing of reality capture data.

I hear misgivings among surveyors about the “scan everything” approach. They often can meet the needs of clients with conventional topo, mapping right there in the field, and that reduces the office component, compared to a scanning workflow. So, is there a compelling need (for now) to add mass data capture sensors to survey rovers? Perhaps not. As prices for reality capture devices, SLAM scanners, drones, etc., drop over time, they become part of a firm’s standard kit, along with a rover and total station. Simply pick the right tool for the job.

What If?

Manufacturers can be averse to revealing what they’re working on next, but watching lateral developments in the world of geospatial sensors, certain moves might seem inevitable. We’ve seen how disruptive the addition of various types of Time-of-Flight (ToF) sensors to consumer tablets and phones has been. For specific (very short-range) applications, the point cloud quality from some phone sensors can match, or even best, that of some lidar systems. There also are examples of highly refined ToF sensor implementations in reality capture devices, such as the Leica BLK2GO PULSE.

There has even been a wave of devices where you can attach your ToF-enabled phone to the handle where there also is an RTK-capable GNSS antenna/receiver. These have become popular, for instance, for capturing utilities



FOR ITS HANDHELD, camera-based 3D mapping system, Looq AI opted for a high-precision GNSS board from Septentrio to integrate with an IMU for their automated PPK and AI-processed workflow.

in an open trench before they are buried. One misgiving is that there is a tendency to go cheap on the GNSS hardware. You only get to measure those pipes once — why not get the best quality (and precisely positioning) data?

So, why not put the ToF sensors on a high-performance rover? Someone is bound to do it; it is just a matter of time. The same applies to other types of solid-state lidar. There are some types of what folks call solid-state lidar that still have moving parts on the MEMS. Now we are seeing true solid-state lidar (no moving parts), for example, that have been integrated into mobile mapping and road inspection systems by XenomatiX. There are still some miniaturization and power budget issues ahead, but we likely will see solid-state lidar on rovers at some point, which would overcome the weight handicap of SLAM lidar heads attached to rovers.

Some folks dismiss the prospect of a multi-sensor GNSS rover as being akin to a multi-tool, such as a Leatherman or Swiss-style military knife. Super handy when you need it, but the individual tools might not ever match the utility of a dedicated tool. I’m among those who, to some degree, disagree with that analogy. Unless it is a case of some hastily assembled systems (with the lowest-cost components possible), for many systems, the added-on features can boost productivity and deliver precise data, provided that careful and appropriate practices are employed.

There’s a lot for users to consider: do they invest in multiple dedicated instruments, can they afford the best of each? But on the other hand, is the stacking of multiple sensors on a GNSS rover really warranted, or even practical? Can combination systems perform well enough for most of your needs? Do you consider fit-for-purpose solutions? The good news is that the progression of innovation in hardware and software is continuous. Plenty of intriguing options are already out there, with more to come. 🌐

Crafting a GNSS Curriculum for the Future Geospatial Workforce

BY LAURA C. LOYOLA, GUOPING HUANG, ISAIAH MACK AND YI QI, CORRESPONDING AUTHOR

The Spatial Sciences Institute (SSI), part of the Dornsife College of Letters, Arts and Sciences at the University of Southern California (USC), is a national leader in geospatial research and education. Founded on July 1, 2010, SSI has been educating students and professionals with both the theoretical foundation and hands-on technical training to advance spatial thinking and geospatial technologies.

Graduates solve complex problems across diverse industries and domains such as environmental sustainability, geodesign, public health, human security and geospatial intelligence. Education and training with GNSS are integral to SSI's mission.

Addressing the Generation Gap

Despite its fundamental importance, the GNSS workforce is facing a growing generational gap as many experienced professionals near retirement, and fewer young individuals enter the field. This decline in incoming talent poses a critical challenge for industries that rely on high-precision positioning, from infrastructure development and environmental monitoring to national security and disaster response.

Part of the challenge stems from a lack of early exposure and awareness among younger generations about the relevance and applications of GNSS technology. Many students encounter the topic only indirectly, if at all, in traditional STEM or Geography curricula.

To preempt this generic approach, SSI has invested in high-accuracy GNSS receivers, RTK-enabled UAVs and immersive virtual/augmented reality visualization equipment to provide students the capability to translate the theoretical lessons in geodesy, spatial

data acquisition, data analysis and integration into technical skills that result in actionable information.

Additionally, SSI has developed a range of experiential learning opportunities in GNSS to bridge the gap between classroom instruction and real-world GIS applications. While completing their coursework, students often solve the same real-world challenges as many industry professionals.

Engagement Through Experimental Learning

One such example is the undergraduate course SSCI 220L: Spatial Data Collection Using Drones, taught by Yi Qi, Ph.D., an associate professor with expertise in remote sensing and geospatial artificial intelligence. "When young students are introduced to imagery and geospatial technologies, one of the first questions they often ask is how the positions of real-world features are measured — and how accurate those measurements need to be for applications like building construction or urban tree mapping" Qi explained. "This presents a great opportunity to introduce students to more advanced industry practices such as real-time kinematic (RTK) correction."

Qi added, "We use the RTK-enabled DJI Mavic 3M drone for field data collections, which is often a highlight of the class." One memorable field activity took place at the historic Los Angeles Memorial Coliseum, where students participated in drone flights alongside faculty. Before takeoff, they helped establish communication between the drone's RTK system and the California Real-Time Network (CRTN), learning how to configure the system for centimeter-level accuracy. Later, they processed the imagery into high-resolution 2D orthophotos and 3D models. "This

class benefits undergraduates by providing early exposure to GNSS," Qi said. "This foundation is important for students to imagine their pathways in the geospatial industry and choose other advanced courses"

At the graduate level, as part of the SSCI 587: Spatial Data Acquisition course, students are required to participate in a week-long intensive-learning field experience at the USC Wrigley Institute for the Environment and Sustainability campus on Catalina Island. Laura Loyola, Ph.D., assistant professor in SSI with specialties in ecological physiology and field data collection, has led this course for many years and acknowledges that, "Catalina offers the ideal location for rugged terrain data collection, practice with online or offline mapping, and incorporates spatial data collection utilizing the RTK-enabled UAV and high-accuracy GNSS receivers, with spatial analysis and visualization methods."

While on Catalina Island, students meet with industry partners, such as Isaiah Mack, the owner of Eclipse Mapping and GIS, and an alumnus of USC, who bring professional experiences and the latest technology from industry. "The question now facing industry is whether the added investment in both hardware and training of personnel on high-accuracy GNSS receivers for spatial data collection is viable and needed for everyday uses, especially with RTK and satellite-based augmentation systems (SBAS) available," Mack said. "The answer is overwhelmingly yes, with many mapping and GIS professionals utilizing centimeter-level RTK accuracy, so I feel it is important to share with students the growing market for these careers."

Students quickly learn that without a viable connection, such as Wi-Fi or Starlink in remote areas, RTK capabilities in the UAV are limited. This requires the ability to incorporate high-accuracy ground control points into their collection workflows for georeferencing the drone imagery. As students work through the image processing and integration workflow, they gain firsthand experience in how GPS accuracy influences final image quality. Loyola noted, “In remote environments where WiFi connectivity is limited or non-existent, smartphone positional accuracy is decreased even more from the standard 30 cm to 50 cm, forcing students to work offline and with external GNSS receivers.”

Lastly, in certain field scenarios where students are unable to physically reach the survey target, they have learned to apply alternative methods to ensure accurate data collection. One effective technique involves using a laser rangefinder to measure the distance to the remote object. By combining this distance measurement with GNSS-derived position and bearing data, students can use in-app tools to calculate the location of otherwise inaccessible features. These experiences not only demonstrate their problem-solving abilities in challenging environments but also reflect a practical understanding of integrating complementary technologies to achieve high-precision geospatial results.

GNSS also has been integrated into the geodesign programs at SSI. Guoping Huang, Ph.D., is an associate professor with specialties in landscape planning and geodesign. “High-accuracy GNSS has become increasingly important in the architecture, engineering and construction sector due to the growing adoption of geospatial workflows,” he said. “These workflows span the entire project lifecycle — from spatially-enabled design tools that help create context-aware and environmentally responsive plans, to precision construction, where GNSS-integrated



Laura Loyola

USC SSI GIST graduate students collect field data with the Eos Arrow 100 submeter GNSS receiver during the field excursion week of the Spatial Data Acquisition course in the fall of 2022.

technologies such as sensor networks are used to monitor construction activities in real time.”

This integration ensures that construction adheres closely to the original design intent, minimizes costly deviations, and helps avoid damage to critical infrastructure. As a result, high-accuracy GNSS supports not only greater efficiency and accuracy but also enhances safety and sustainability in complex construction environments.

Empowering the Next Generation

By integrating GNSS into education programs and engaging students through practical fieldwork, faculty in the spatial sciences spark interest and develop the next generation of geospatial professionals. These efforts are essential to sustain the workforce and fuel innovation in a field increasingly critical to smart cities, climate science, autonomous systems and beyond. The experiential learning has inspired young generations to enter the geospatial workforce and make immediate, transformative impacts on existing practices.

Student Evelyn Vega commented, “The concepts and hands-on experience from course SSCI 220L helped me understand and appreciate GPS technology.” Recent graduate

Yimiao Wang, who now works with the County of Riverside, California, has directly applied the GNSS data collection and processing techniques learned in course SSCI 587 to her work in roadway deterioration detection with RTK-enabled drone imagery. Her ability to leverage high-accuracy GNSS not only enhanced the quality and efficiency of her team’s outputs but also led to her career development success. These examples illustrate how GNSS education can empower students to drive innovation and advancement in the public sector and beyond. 🌐

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GUOPING HUANG, D.DES, is a landscape planning scholar, practitioner and geospatial innovator.

ISIAH MACK has been in the geospatial industry for more than 18 years. After earning a degree in Environmental Science from the University of Oregon and a master’s degree in Coastal Geomorphology and GIS from the University of Southern California, Mack spent 15 years working for Trimble GPS dealers in California. In 2017, he launched his own business selling and representing bring-your-own-device GNSS technology.

YIQI, PH.D., is an associate professor of Spatial Sciences with the Spatial Sciences Institute at the University of Southern California.

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41 Instrumentation Integrated with GPS

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(including Software)
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#

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GPS Networking



Mil-spec splitters

GPS Networking is a leading provider of GPS infrastructure products and solutions. The company specializes in designing, manufacturing and distributing GPS splitters and GPS re-radiating kits, which are used to distribute GPS signals to multiple receivers and extend coverage in areas with poor signal strength. Moreover, GPS Networking offers a comprehensive range of products that operate across the L-band, including amplifiers, filters, combiners and attenuators. GPS Networking's products provide reliable and accurate GPS signals, ensuring that customers have access to them wherever and whenever necessary.

GPS Networking's products are used in a wide range of applications — including surveying, mapping, military and defense, aviation, transportation and telecommunications. For example, the company's GPS splitters are used to distribute GPS signals to multiple receivers in surveying applications, and its GPS re-radiating kits are used to extend GPS coverage in areas with poor signal strength in military and defense applications.

The company's GPS splitters are designed to distribute signals from a single receiver to multiple other devices

while managing the signal strength to ensure the effective distribution of the GPS signal. GPS re-radiating kits extend coverage in areas with poor signal strength, such as inside buildings or underground, by amplifying and re-transmitting the GPS signal. These systems can be tricky to design, but GPS Networking can help users design custom signal distribution systems that meet their exact needs.

GPS Networking is known for its excellent customer service and support. The company has a team of experienced engineers and technicians who are available to provide technical assistance and support to customers around the world. The company has a global network of distributors and partners and has established itself as a trusted provider of GPS products and solutions.

GPS Networking was founded in 1991 and is headquartered in Pueblo West, Colorado. The company's commitment to innovation, customer service, and technical excellence has helped it maintain its position as a leader in the GPS industry. With its comprehensive range of products and solutions, GPS Networking is poised to continue providing its customers with the best GPS infrastructure products possible.



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Hexagon | NovAtel is a global leader, offering comprehensive solutions for assured autonomy and precise positioning across various environments—land, sea, and air. NovAtel's advanced technologies are vital for industries such as precision agriculture, defense, transportation, marine, and surveying.



Images: NovAtel

At the heart of NovAtel's innovations are its GNSS technologies. These include high-precision receivers, antennas, inertial navigation systems (INS) and global and regional correction services. They also specialize in anti-jamming and anti-spoofing technologies, as well as software for receiver management and post-processing.

HIGH-PRECISION GNSS RECEIVERS AND ANTENNAS

NovAtel's OEM7 receiver family is designed to deliver reliable and precise GNSS-based positioning. The receivers work seamlessly with antennas, INS and correction services to ensure high-precision results for diverse applications.

NovAtel receivers are built for resilience, incorporating solutions like SPAN GNSS+INS technology and the GNSS Resilience and Integrity Technology (GRIT) firmware suite. SPAN technology integrates GNSS with INS for

continuous 3D positioning, velocity and attitude data, while GRIT defends against interference, jamming and spoofing through advanced firmware and algorithms.

Choosing the right antenna is crucial for optimizing system performance. NovAtel's GNSS antenna range includes compact, lightweight options for aviation and robust models for agriculture and machine control.

GLOBAL AND REGIONAL CORRECTION SERVICES

NovAtel's global TerraStar precise point positioning (PPP) services are supported by more than 100 GNSS reference stations worldwide, ensuring top-quality global corrections. Additionally, the regional HxGN



SmartNet+ network RTK services provide unparalleled coverage. SmartNet+ includes RTK ASSIST, which maintains operations for up to 20 minutes during cellular outages, ensuring peace of mind.

ANTI-JAMMING AND ANTI-SPOOFING TECHNOLOGY

NovAtel's anti-jamming and anti-spoofing technologies ensure continuous positioning by detecting and characterizing interference and spoofing threats. The GNSS Anti-Jam Technology (GAJT) portfolio offers protection for platforms operating in contested environments, from drones to tanks.

RECEIVER MANAGEMENT AND POST-PROCESSING SOFTWARE

For receiver management, the NovAtel Application Suite offers a comprehensive tool for monitoring receiver status, GNSS satellite tracking and interference detection. NovAtel's Waypoint



software is a trusted post-processing tool, leveraging GNSS and INS data to deliver accurate post-mission trajectories and mapping.



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Images: Safran Electronics and Defense

The SRO-5680 oscillator

is a high-performance GPS/GNSS-disciplined rubidium oscillator. This atomic clock is ruggedized for harsh environment (shocks, vibrations, humidity, etc.) and is particularly suited for defense application (SATCOM, RF comms, ELINT, ...) It also offers ultra-low noise and exceptional stability in a compact, rugged form factor.



GEONYX - Inertial Navigation System

Geonyx is designed for the most demanding artillery systems, such as howitzers (towed, tracked, truck-mounted), multiple rocket launchers, mortars, and light guns.



SecureSync - Timing Synchronization Platform

SecureSync harnesses Safran's leading PNT technology into one flexible, modular platform designed to synchronize critical defense and commercial infrastructure that requires extreme reliability and security.



WR-Z16 - Sub-nanosecond Timing

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8230AJ - Anti-Jam Antenna

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Trimble Applanix

Trimble Applanix stands as a global leader in advanced positioning and orientation solutions, serving the marine, land and air sectors with cutting-edge technology. In the marine sector, Applanix provides precise positioning and motion compensation for hydrographic survey applications. The POS MV product line, including SurfMaster, WaveMaster and OceanMaster, ensures highly accurate seafloor mapping. The top-tier Elite system and POSpac MMS post-processing software further enhance data quality. Notably, PP-RTX technology offers real-time corrections, eliminating the need for base stations, thus streamlining operations and improving efficiency.

For land applications, Applanix offers the POS LV system, which integrates GNSS, inertial, and wheel sensor data for reliable positioning. This integration is crucial for mobile mapping and vehicle-based surveying, especially in complex urban environments where precision is paramount. The POS LVX 120 and 125 systems provide advanced capabilities for high-performance mapping and autonomy applications, while Applanix POSpac MMS software plays a vital role in refining data accuracy to ensure that the collected data meets the highest standards of precision and reliability.

In the air domain, Applanix's POS AV product line, including the 310, 510, and 610 models, provides precise georeferencing for manned airborne mapping and remote sensing. The

Applanix POS AVX 210 is a GNSS inertial solution designed to reduce the cost and improve the efficiency of mapping with small- and medium-format cameras. TrimbleAPX RTX boardsets are compact GNSS inertial solutions designed for UAVs, offering flexibility and adaptability in various aerial missions. Trimble's RTX technology provides real-time GNSS corrections, enhancing the accuracy and reliability of data collected during flight. Furthermore, POSpac MMS software is instrumental in improving data accuracy for aerial missions, ensuring that the information gathered is both precise and actionable. The Trimble PX-1 RTX for urban air mobility provides the accurate, continuous orientation and position information required for landing and takeoff in confined areas

Trimble Applanix's comprehensive suite of products and technologies significantly enhances the efficiency and accuracy of data collection across various platforms. By supporting surveying, mapping and navigation with state-of-the-art solutions, Trimble Applanix remains a key player in precision technology, continually advancing the capabilities of professionals in the field. Through innovation and dedication to quality, Applanix empowers users to achieve unparalleled results in their respective domains.



Images: Trimble Applanix



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Synergy Systems

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PO Box 262250
Ste 106
San Diego CA 92131
858-566-0666
oeminfo@synergy-gps.com
synergy-gps.com

Syntony GNSS

5 Chemin De Chevreuille
Toulouse 31300
France
33-0-5-81-319-919
contact@syntony.fr
syntony-gnss.com

T

Taoglas

Unit 5 Kilcannon Business Centre
Old Dublin Rd
Enniscorthy Y21 XW56
Ireland
35-38-7056-6387
dconnolly@taoglas.com
taoglas.com

Branch Location:

8525 Camino Santa Fe
Ste A&B
San Diego CA 92121
858-450-0888
nasales@taoglas.com
taoglas.com

TDK Trusted Positioning

1000 Vetrans Place NW
Ste 405
Calgary AB T3B 2B9
Canada
403-992-8379
phil.gabriel@tdk.com
trustedpositioning.tdk.com

TeleOrbit GmbH

Sandrartr 6
Nürnberg Bavaria 90419
Germany
49-911-300-339-80
sales@teleorbit.eu
teleorbit.eu

Teletype GPS

44 School St
Boston MA 02108
617-542-6220
contact@teletype.com
teletype.com

Telit

Cannon Place
78 Cannon St
London EC4N 6AF
United Kingdom
northamerica@telit.com
telit.com

Branch Location:

8th Floor
Shinyoung Securities Bldg
6 Gukjegeumyung-Ro8-Gil
Seoul Yeongdeungpo-Gu 150-884
South Korea
82-2-368-4600
apac@telit.com

Telogis Fleet Mgmt Software

85 Enterprise
Ste 450
Aliso Viejo CA 92656
866-835-6447
team@telogis.com
telogis.com

TerraGo

45610 Woodland Rd
Ste 350
Sterling VA 20166
866-453-1609
info@terragotech.com
terragotech.com

Tersus GNSS

666 Zhangheng Rd
Level 2
Shanghai Pudong District 201203
China
8621-5080-3061
sales@tersus-gnss.com
tersus-gnss.com

Branch Location:

809 San Antonio Rd
Ste 10
Palo Alto CA 94303
415-800-3664
sales@tersus-gnss.com
tersus-gnss.com

Thales

75-77 Ave Marcel Dassault
Campus Thales Bordeaux
Merignac 33700
France
avionics@fr.thalesgroup.com
thalesgroup.com

Time & Frequency Solutions

25 Eastways
Witham Essex CM8 3AL
United Kingdom
44-13-7651-4114
enquiries@timefreq.com
timefreq.com

TimeTools

2 Silverend Business Park
Brettell Ln
Brierley Hill West Midlands
DY5 3LG
United Kingdom
44-19-0289-7400
sales@timetoolsltd.com
timetoolsltd.com

TMYTEK

3F No 3 Yuandong Rd
Banqiao District
New Taipei City 220
Taiwan
08-22-69168
cici.tang@tmytek.com
tmytek.com

TomTom

150 Baker Ave Ext
Concord MA 01742
978-287-9555
info@tomtom.com
tomtom.com

Topcon Positioning Systems

7400 National Dr
Livermore CA 94550
925-245-8300
channelmarketing@topcon.com
topconpositioning.com

TowCentric

16511 Eaglewood Shadows Dr
Sugar Land TX 77498
832-877-4162
aanzehra42@gmail.com
towcentric.com/

Track Your Truck

21754 S Center Ave
New Lenox IL 60451
888-434-3848
trackyourtruck.com

Trimble

10368 Westmoor Dr
Westminster CO 80021
720-887-6100
sales_info@trimble.com
trimble.com

Branch Location:

85 Leek Crescent
Richmond Hill ON L3X1M9
Canada
applanix.com

Trimble OEM GNSS

10368 Westmoor Dr
Westminster CO 80021
sales-intech@trimble.com
oemgnss.trimble.com

Tronics Microsystems

400 Rte de Souveyron
Crolles 38920
France
334-769-72960
vincent.gaff@tronicsgroup.com
tronicsgroup.com

Tualcom

Mustafa Kemal Mahallesi 2119
Cadde No 11
Cankaya Ankara 06530
Turkiye
90-312-485-22-85
tualcom.com

U

u-blox AG

Zuercherstrasse 68
8800 Thalwil
Switzerland
41-44-722-7444
info@u-blox.com
u-blox.com

UHU Technologies

1201 Executive Dr W
Richardson TX 75081
972-905-0437
info@uhutechnologies.com
uhutechnologies.com

Unicore Communications

F3 No 7 Fengxian E Rd
Haidian Yongfeng
Beijing 100094
China
86-10-6993-9828
info@unicorecomm.com
unicore.com

See our ad on page 39

Union Leasing

425 N Martingale Rd
Schaumburg IL 60173
847-240-1500
info@unionleasing.com
unionleasing.com



UrsaNav

85 Rangeway Rd
110 Bldg 3 Ste 110
North Billerica MA 01862
781-538-5299
stephen.bartlett@ursanav.com
ursanav.com

Branch Location:

44160 Scholar Plaza
Ste 380
Leesburg VA 20176
703-623-5212
cshue@ursanav.com
ursanav.com

US Radar

121 Amboy Rd
PO Box 319
Matawan NJ 07747
732-566-2035
info@usradar.com
usradar.com

USGlobalsat

14740 Yorba Ct
Chino CA 91710
909-597-8525
sales@usglobalsat.com
usglobalsat.com

UTC Aerospace Systems

14300 Judicial Rd
Burnsville MN 55306
952-892-4000
communications@utas.utc.com
utcaerospacesystems.com

VectorNav Technologies

10501 Markison Rd
Dallas TX 75238
512-772-3615
sales@vectornav.com
vectornav.com

Wang Electro-Opto Corp

805 Franklin Ct SE
Ste B
Marietta GA 30067
770-955-9311
products@weo.com
weo.com

Wingtra

Giesshübelstrasse 40
Zurich 8045
Switzerland
hello@wingtra.com
wingtra.com

WORK Microwave GmbH

Rudolf-Diesel-Ring 2
Holzkirchen 83607
Germany
49-802-4640-8222
xidus@
work-microwave.com
gnss-simulator.com

Branch Location:

2220 Northmont Pkwy
Ste 250
Duluth GA 30096
770-241-2645
waylon.sun@work-microwave.
com
work-microwave.com

Xsens

Pantheon 6A
Enschede 7521 PR
Netherlands
31-88-97367-00
info@xsens.com
xsens.com

Branch Location:

101 N Pacific Coast Hwy
Ste 306
El Segundo CA 90245
310-481-1800
info@xsens.com
xsens.com

Y

Yellowscan

525 Ave St Sauveur Du Pin
St. Clement De Riviere 34980
France
33-4-11-93-14-00
yellowscan.com

Z

ZMicro

9820 Summers Ridge Rd
San Diego CA 92121
858-831-7000
techsupport@zmicro.com
zmicro.com



Smart Positioning For Future Geoinformation



UM980/UM981S/UB9A0 Series
Full-constellation Multi-frequency
Module/Board

- ▶ 1408 channels
- ▶ Support full-constellation multi-frequency, on-chip RTK positioning solution
- ▶ Instant RTK initialization technology
- ▶ Support interference detection and provide 60dB narrowband interference mitigation
- ▶ UM981S: RTK+IMU, support tilt compensation
- ▶ Support E6 HAS, L6 MADOCA-PPP and B2b-PPP services
- ▶ Support 50Hz satellite observation rate and RTK data update frequency



UNICORE COMMUNICATIONS, INC.

| E: Info@unicorecomm.com
| W: https://www.unicore.com



2025 BUYERS GUIDE

PRODUCTS + SERVICES DIRECTORY

ACCESSORIES

Allis Communications Co
ComNav
Epson America
EVE Energy
First RF Corp
GigOptix
Gladiator Technologies
GPS Networking
iCONN Systems
Instock Wireless Components
ISA Telematics GmbH
Jiashan Jinchang Electronics
Karel Electronics
L3Harris Corp
Leica Geosystems AG
Micro Engineering Tech
National Instruments
NavCom, A John Deere Co
Nexteq Navigation
Omnetics Connector Corp
Optical Zonu Corp
Ranger SST
Rockwell Collins
Skyworks Solutions
Tersus GNSS
ZMicro

Cable Assemblies

AeroAntenna Technology
Allis Communications Co
Brandywine Communications
C-Nav
GPSTrackit.com
Hirschmann Car Communication
Janus Remote Communications
Larsen Antennas/Pulse Electronics
Leica Geosystems AG
Linx Technologies
Mobile Mark
NavCom, A John Deere Co
NavSync
Omnetics Connector Corp
Panorama Antennas
PCTEL
Rojone Pty
USGlobalsat

Communications

Datalinks/Modems

Janus Remote Communications
John Deere AMS
Leica Geosystems AG
NavCom, A John Deere Co
NavSync
Optical Zonu Corp
QinetiQ
Rojone Pty
Satel Oy
Satel Survey USA
Skyworks Solutions
u-blox AG

Connectors

Allis Communications Co
ComNav
GPSTrackit.com
Hirschmann Car Communication
ikeGPS
Janus Remote Communications
Larsen Antennas/Pulse Electronics
Linx Technologies
NavSync
Omnetics Connector Corp
Panorama Antennas

Rojone Pty
USGlobalsat

Power Supplies/Converters

C-Nav
GPSTrackit.com
ikeGPS
Leica Geosystems AG
NavCom, A John Deere Co
NavSync
Skyworks Solutions
USGlobalsat

ANTENNAS

Advanced Navigation
Allis Communications Co
Allystar Technology (Shenzhen)
Antcom Corp
Antenova
Arbiter Systems
Borealis Precision
Calian GNSS (Formerly Tallysman Wireless)
Carlson Software
Chelton
ComNav
Foxcom
GPS Source
GPSAntennas.com
Gutec AB
Hemisphere GNSS
JAVAD GNSS
KCS BV
Leica Geosystems AG
Maruwa America Corp
Maxtena
Meinberg Funkuhren GmbH & Co
KG
Microlab
Multicom
NavCom, A John Deere Co

NovAtel
Optical Zonu Corp
Parsec Technologies
Quectel
RFOptic
Rockwell Collins
Rohde & Schwarz GmbH & Co
KG
Skyworks Solutions
Synergy Systems
Taoglas
TeleOrbit GmbH
Trimble OEM GNSS
UHU Technologies
Wang Electro-Opto Corp

NovAtel
Optical Zonu Corp
Parsec Technologies
Quectel
RFOptic
Rockwell Collins
Rohde & Schwarz GmbH & Co
KG
Skyworks Solutions
Synergy Systems
Taoglas
TeleOrbit GmbH
Trimble OEM GNSS
UHU Technologies
Wang Electro-Opto Corp

NovAtel
Optical Zonu Corp
Parsec Technologies
Quectel
RFOptic
Rockwell Collins
Rohde & Schwarz GmbH & Co
KG
Skyworks Solutions
Synergy Systems
Taoglas
TeleOrbit GmbH
Trimble OEM GNSS
UHU Technologies
Wang Electro-Opto Corp

Antijam/Interference

Suppression Units

AeroAntenna Technology
Allis Communications Co
Antcom Corp
BAE Systems
Calian GNSS (Formerly Tallysman Wireless)
CAST Navigation
GlobalTop Technology
GPSAntennas.com
Harxon Corp
L3 Interstate Electronics
Micro-Ant
NavCom, A John Deere Co
NovAtel
NVS Technologies AG

QinetiQ
Reelektronika BV
TeleOrbit GmbH
Thales
Tualcom
Wang Electro-Opto Corp

GPS, External

AeroAntenna Technology
Allis Communications Co
Altus Positioning Systems
Antcom Corp
Arbiter Systems
Calian GNSS (Formerly Tallysman Wireless)
Carlson Software
Chemring Technology Solutions
ComNav
DataGrid
FEI-Zyfer
ftech Corp
Garmin International
Globalsat Technology Corp
GlobalTop Technology
GPSAntennas.com
GPSTrackit.com
Harxon Corp
Hemisphere GNSS
Hirschmann Car Communication
ikeGPS
Inventek Systems
Janus Remote Communications
KCS BV
Laird Technologies
Larsen Antennas/Pulse Electronics
Leica Geosystems AG
Linx Technologies
Micro-Ant
Microlab
Mobile Mark
Motorola
Multicom
NavCom, A John Deere Co
Novariant

NovAtel
NVS Technologies AG
Panorama Antennas
Parsec Technologies
PCTEL
Reelektronika BV
Rojone Pty
Sokkia Corp
Spectratime
Surrey Satellite Technology
Synergy Systems
TeleOrbit GmbH
Time & Frequency Solutions
TomTom
u-blox AG
USGlobalsat
Wang Electro-Opto Corp

NovAtel
NVS Technologies AG
Panorama Antennas
Parsec Technologies
PCTEL
Reelektronika BV
Rojone Pty
Sokkia Corp
Spectratime
Surrey Satellite Technology
Synergy Systems
TeleOrbit GmbH
Time & Frequency Solutions
TomTom
u-blox AG
USGlobalsat
Wang Electro-Opto Corp

NovAtel
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PCTEL
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Rojone Pty
Sokkia Corp
Spectratime
Surrey Satellite Technology
Synergy Systems
TeleOrbit GmbH
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Wang Electro-Opto Corp

NovAtel
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Rojone Pty
Sokkia Corp
Spectratime
Surrey Satellite Technology
Synergy Systems
TeleOrbit GmbH
Time & Frequency Solutions
TomTom
u-blox AG
USGlobalsat
Wang Electro-Opto Corp

GPS, Integrated

AeroAntenna Technology
Allis Communications Co
Altus Positioning Systems
BAE Systems
Brandywine Communications
Calian GNSS (Formerly Tallysman Wireless)
Carlson Software
ComNav
DataGrid
FEI-Zyfer
ftech Corp

Garmin International
GlobalTop Technology
Harxon Corp
Hemisphere GNSS
Hirschmann Car Communication
ikeGPS
Infospectrum
Inventek Systems
Janus Remote Communications
KCS BV
Laird Technologies
Larsen Antennas/Pulse Electronics
Leica Geosystems AG
Linx Technologies
Micro Modular Technologies
Micro-Ant
Mobile Mark
NavCom, A John Deere Co
Novariant
NovAtel
Panorama Antennas
Parsec Technologies
PCTEL
Rojone Pty
Sokkia Corp
Spectratime
TeleOrbit GmbH
Time & Frequency Solutions
Trimble OEM GNSS
u-blox AG
USGlobalsat
Wang Electro-Opto Corp

GPS/Communications

AeroAntenna Technology
Allis Communications Co
Altus Positioning Systems
Antcom Corp
Blue Sky Network
Brandywine Communications
Calian GNSS (Formerly Tallysman Wireless)
Carlson Software
ComNav
CSR plc
FEI-Zyfer
Garmin International
GPSTrackit.com
Hirschmann Car Communication
Inventek Systems
Janus Remote Communications
Japan Radio Co
John Deere AMS
KCS BV
Laird Technologies
Larsen Antennas/Pulse Electronics
Leica Geosystems AG
Linx Technologies
Micro-Ant
Mobile Mark
NavCom, A John Deere Co
Panorama Antennas
PCTEL
RFOptic
Rojone Pty
Skyworks Solutions
Spectratime
TomTom
u-blox AG
Wang Electro-Opto Corp

COMPLEMENTARY PNT

Inertial Labs, a VIavi Solutions
Co
Iridium
LKD Aerospace



CONNECTED CAR

Averna
GPSAntennas.com
Infospectrum
KVH Industries
STMicroelectronics
Swift Navigation
Taoglas
Xsens

Components (including Software)

Infospectrum
Xsens

Integrated Systems

Averna
GPSAntennas.com
Infospectrum

DIFFERENTIAL GPS

ComNav Technology
Emlid

Eos Positioning Systems

Geneq
Geodetics
Geomatics USA
Geometer International
Geostar Navigation
Hemisphere GNSS
Inertial Sense
KCS BV
Sapcorda Services GmbH
Satel Oy
SingularXYZ Intelligent Technology
Swift Navigation
Tersus GNSS

DGPS-Capable Radiobeacon Receivers

Garmin International
Geneq
Hemisphere GNSS
KCS BV
NVS Technologies AG
Satel Oy
Sokkia Corp

Ephemeris Information

Baseband Technologies
Geodetics
i-cubed
Rx Networks

Real-Time DGPS Correction Services

AXIO-NET GmbH
C-Nav
Geodetics
Hemisphere GNSS
KCS BV
NVS Technologies AG
OmniSTAR
Rx Networks
Swift Navigation

Real-Time DGPS Receivers

Altus Positioning Systems
Blue Sky Network
C-Nav
Communication & Navigation
DataGrid

Eos Positioning Systems

Esterline CMC Electronics
Geneq
Geodetics
Geomatics USA

Geometer International
Geostar Navigation
Hemisphere GNSS
Inertial Sense
KCS BV
Motorola
Novariant
NVS Technologies AG
Satel Oy
Sokkia Corp
Swift Navigation

Reference Stations

AXIO-NET GmbH
Broadcom Corp
Communication & Navigation
DataGrid
Geneq
Geodetics
KCS BV
Novariant
NVS Technologies AG
Rx Networks
SingularXYZ Intelligent Technology
Swift Navigation

DIGITAL COMPASSES

Advanced Navigation
Globalsat Technology Corp
GlobalTop Technology
Honeywell
PNI Sensor Corp
Silicom
STMicroelectronics
ZMicro

ELECTRONIC CHARTS/ MAPS

Geocortex by VertiGIS
Silicom
TomTom

GENERAL SERVICES AND PRODUCTS

Chronos Technology
GEICO
Geocortex by VertiGIS
OHB Austria GmbH

Insurance

GEICO

GEOPHYSICAL

Emlid
Fredericks Co

INSTRUMENTATION INTEGRATED WITH GPS

AutonomouStuff
DT Research
ELPROMA
Geodetics
Geomatics USA
GPS Source
Inertial Labs, a VIAVI Solutions Co
Juniper Systems
Laser Technology
Meitrack Group
Microlab
NextNav
Phase One
Remote GeoSystems
RIEGL Laser Measurement Systems GmbH
Seven Solutions

Spectratime
Spectrum Instruments
Stanford Research Systems
Telit
UTC Aerospace Systems

Automated Machine Control

Applanix
AutonomouStuff
Communication & Navigation
Geodetics

Bar-Code Scanner

Juniper Systems
Ricoh Americas Corp

Camera

Applanix
AutonomouStuff
DT Research
ftech Corp
Juniper Systems
NavSys Corp
Phase One
Remote GeoSystems
Ricoh Americas Corp

Datalogger

Applanix
AutonomouStuff
Communication & Navigation
ELPROMA
ftech Corp
Geomatics USA
Juniper Systems
NavSys Corp
Remote GeoSystems

Infrared/Multispectral Sensors

Applanix
AutonomouStuff
ELPROMA
Remote GeoSystems

Integrity Monitoring

Applanix
Broadcom Corp
ELPROMA
Geodetics
Remote GeoSystems
Thales

Ionospheric Calibrators

Geodetics

Laser Rangefinders

Applanix
AutonomouStuff
Laser Technology
Phase One
Remote GeoSystems
RIEGL Laser Measurement Systems GmbH

PC/Laptop/Handheld Computer

4P Mobile Data Processing
Applanix
DT Research
ELPROMA
Geodetics
Juniper Systems
Maxim Integrated Products
Remote GeoSystems

Sonar

Applanix
AutonomouStuff

Time and Frequency Stability

ELPROMA
GPS Source
Seven Solutions
Spectratime
Spectrum Instruments

Videography (including Time/Position Captioning)

Applanix
Phase One
Remote GeoSystems

Wireless Communications

Applanix
AutonomouStuff
Beijer Electronics
Broadcom Corp
Calian GNSS (Formerly Tallysman Wireless)
ELPROMA
FEI-Zyfer
Geodetics
Juniper Systems
Maxim Integrated Products
Microlab
NavSync
NextNav
Qualcomm
Remote GeoSystems
Ricoh Americas Corp
Satel Survey USA
Spectratime
Spectrum Instruments
Telit

INTEGRATED NAVIGATION EQUIPMENT

Allystar Technology (Shenzhen)
Bynav Technology Co
EMCORE Corp
General Dynamics Mission Systems
Inertial Labs, a VIAVI Solutions Co
Inertial Sense
KVH Industries
LKD Aerospace
Oxford Technical Solutions (OxTS)
Parker LORD
Physical Logic
PolyExplore
SBG Systems
Sensoror
Septentrio
Shaanxi Ericco Inertial System
Spirent Communications
Tronics Microsystems
UrsaNav
UTC Aerospace Systems
VectorNav Technologies
Xsens

Dead Reckoning

Applanix
CSR plc
Honeywell
Inertial Labs, a VIAVI Solutions Co
Inertial Sense
NavSys Corp
Parker LORD
Septentrio
Xsens



Inertial

Applanix

CAST Navigation

EMCORE Corp
General Dynamics Mission Systems
Honeywell
Inertial Labs, a VIAVI Solutions Co
Inertial Sense
LKD Aerospace
NavSys Corp
Oxford Technical Solutions (OxTS)
Parker LORD
Physical Logic
PNI Sensor Corp
Reelektronika BV
SBG Systems
Sensoror
Septentrio
Sparton
Tronics Microsystems
UTC Aerospace Systems
VectorNav Technologies
Xsens

Loran-C/eLoran

Reelektronika BV
UrsaNav

Radiobeacon

Locata

MAPPING

Azimap
Carlson Software
Eos Positioning Systems
ESSP SAS
Inertial Labs, a VIAVI Solutions Co
L3Harris Corp
Laser Technology
Nearmap US
Oxford Technical Solutions (OxTS)
Phase One
Phoenix LiDAR Systems
PolyExplore
Propeller Aero
RIEGL Laser Measurement Systems GmbH
Spectra Geospatial
Trimble

Data Conversion

Azimap
i-cubed

Digital Mapbases

Azimap
deCarta
i-cubed

Geographic Information Systems (GIS)

Azimap
Carlson Software
i-cubed
L3Harris Corp
Laser Technology
Spectra Geospatial
TeleType GPS
Trimble

Imagery

Azimap
Carlson Software
deCarta

i-cubed
Nearmap US
Trimble

Interfaces

Azimap
i-cubed

Market Analyses/Reports

Azimap

Systems

Azimap
Oxford Technical Solutions (OxTS)

RIEGL Laser Measurement Systems GmbH

Travel Information Databases

iTRAK Corp
TeleType GPS

PHOTOGRAMMETRY/GPS INTEGRATED SYSTEMS

Inertial Labs, a VIAVI Solutions Co
Lidar USA
Nearmap US
Propeller Aero
Ricoh Americas Corp
SoftNav Systems
Trimble
US Radar

PUBLICATIONS, GUIDES, VIDEOS, TRAINING SOFTWARE, INSTITUTES

Artech House Publishers
Institute of Navigation (ION)

RECEIVER COMPONENTS

Greenray Industries
iCONN Systems
Instock Wireless Components
Microchip Technology
Parsec Technologies
Rakon Limited
RFOptic
Telit

Unicore Communications

Bandpass Filters

Maxim Integrated Products

Chips/ICs

Maxim Integrated Products
Microchip Technology
Parsec Technologies
Qualcomm
SigNav Pty

Unicore Communications

Interfaces

Beijer Electronics
Maxim Integrated Products

Modules

Inventek Systems
Maxim Integrated Products
Micro Modular Technologies
Microchip Technology
Parsec Technologies
SigNav Pty
Telit

Unicore Communications

Quartz Crystals

Greenray Industries
Maxim Integrated Products
Microchip Technology
Rakon Limited
Time & Frequency Solutions

RF Amplifiers/ Preamplifiers

Maxim Integrated Products
Microchip Technology
Parsec Technologies
RFOptic

Rubidium Oscillators

Microchip Technology

RECEIVER PERFORMANCE ANALYSIS

Averna

RECEIVERS

Advanced Tracking Technologies
Analog Devices
Antenna
Arbiter Systems
Baseband Technologies
Borealis Precision
Bynav Technology Co
CHC Navigation (CHCNAV)
ComNav Technology
DT Research
Effigis Geo Solutions
eSurvey GNSS
etherWhere
F4 Tech
Foxcom
Furuno USA
Geneq
General Dynamics Mission Systems
GEOsat GmbH
Geostar Navigation
Greenray Industries
Gutec AB
IFEN GmbH
IP-Solutions Satellite Applications, Japan
Jackson Labs Technologies
JAVAD GNSS
Juniper Systems
Kolmostar
Multicom
NovAtel
oneNav
Oscilloquartz
PP-Solution
Precise Time and Frequency
Quectel
Rakon Limited
RIEGL Laser Measurement Systems GmbH
Rokubun SL
Satlab Geosolutions
Septentrio
Seven Solutions
SingularXYZ Intelligent Technology
Suzhou Foif Co
Synergy Systems
Syntony GNSS
TeleOrbit GmbH
Topcon Positioning Systems
Trimble OEM GNSS
Unicore Communications
UrsaNav

Attitude/Direction Finding

Baseband Technologies
Borealis Precision
etherWhere
Gutec AB

NovAtel

Septentrio
Syntony GNSS
TeleOrbit GmbH
Trimble OEM GNSS

Unicore Communications

UrsaNav

Automatic Vehicle Location

Advanced Tracking Technologies
Baseband Technologies
etherWhere
GPS Insight
iTRAK Corp
Septentrio
Topcon Positioning Systems
Trimble OEM GNSS

Unicore Communications

Aviation

Analog Devices
BAE Systems
Baseband Technologies
Esterline CMC Electronics
etherWhere
General Dynamics Mission Systems
Jackson Labs Technologies
Multicom
NovAtel
Septentrio
Syntony GNSS
Topcon Positioning Systems
Trimble OEM GNSS
UrsaNav

Computer GPS Cards/ Modules

Antenna
Baseband Technologies
etherWhere
Jackson Labs Technologies
Oscilloquartz
Septentrio
Syntony GNSS

Unicore Communications

Digital Signal Processor Integrated Chips (DSP-IC)

Baseband Technologies
TeleOrbit GmbH

Geodetic/Geophysical

CHC Navigation (CHCNAV)
eSurvey GNSS
Gutec AB
Septentrio
TeleOrbit GmbH
Topcon Positioning Systems
Unicore Communications

GIS

CHC Navigation (CHCNAV)
Effigis Geo Solutions
eSurvey GNSS
F4 Tech
Geneq
GEOsat GmbH
NovAtel
Oscilloquartz
Septentrio
Suzhou Foif Co



Topcon Positioning Systems
Unicore Communications

Handheld

Analog Devices
Baseband Technologies
CHC Navigation (CHCNAV)
DT Research
Effigis Geo Solutions
eSurvey GNSS
etherWhere
F4 Tech
Geneq
GEOsat GmbH
Greenray Industries
Gutec AB
L3 Interstate Electronics
Suzhou Foif Co
Syntony GNSS
Topcon Positioning Systems
Unicore Communications
UrsaNav

Land Vehicle Navigation/ Route Guidance

BAE Systems
Baseband Technologies
eSurvey GNSS
General Dynamics Mission Systems
L3 Interstate Electronics
NovAtel
Septentrio
Syntony GNSS
TeleOrbit GmbH
TeleType GPS
Topcon Positioning Systems
Trimble OEM GNSS
Unicore Communications

Marine

Analog Devices
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 Physical Logic
RIEGL Laser Measurement Systems GmbH
 Sensoror

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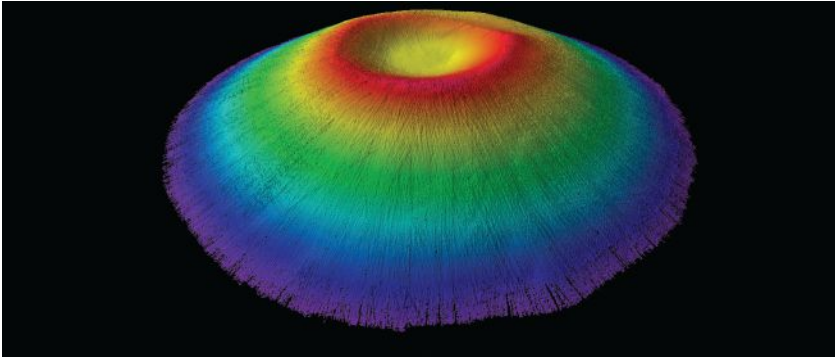
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MAPPING



Eos Positioning Systems

By adding high-accuracy locations with an average accuracy of 10 cm to 20 cm horizontal and vertical, the team was able to accurately georeference and further refine the detail of the bathymetry for their map inside the underwater Deception Island caldera.

First All-Canadian Antarctic Expedition Creates Underwater Maps Using GNSS Technology

Canadian scientists led their first Antarctic research expedition, using Montreal-made Arrow Gold+ GNSS technology for precise location data in remote and challenging conditions. The mission, which departed in early March aboard HMCS Margaret Brooke, included experts from multiple Canadian universities and government

agencies. Researchers conducted water, sediment, air, and sea-ice sampling to study climate change, glacial retreat and pollution such as mercury and microplastics.

The month-long journey around the South Shetland Islands and the northern Antarctic Peninsula yielded surveys of coastal and oceanic sites. The crew

relied on a small, unmanned surface vessel equipped with various systems for bathymetric surveys, including an onboard computer, an inertial measurement unit and a multibeam sonar.

To find the USV's precise position in an environment with no land-based RTK infrastructure, the team relied on the Arrow Gold+ GNSS receiver, designed and manufactured by Canadian-based Eos Positioning Systems. The Arrow Gold+ uses Galileo High Accuracy Service (GalHAS), a free satellite-based precise point positioning correction available worldwide from the European Agency for the Space Programme. While using GalHAS corrections, the Arrow Gold+ provided estimated accuracies of approximately 10 cm horizontally and 15 cm to 20 cm vertically. Sites surveyed include Admiralty Bay, Livingston Island and Deception Island, which contains an active, flooded volcano caldera. The resulting maps will support further scientific and oceanographic research, environmental monitoring and improvements to marine charts. 🌐

AUTONOMOUS SOLUTIONS

Septentrio Launches Various Mosaic-G5 Ultra-Compact GNSS Receiver Models

Septentrio, part of Hexagon, has introduced the mosaic-G5 series, expanding its line of compact GNSS receiver modules. The mosaic-G5 modules offer a 60% reduction in size and a 40% decrease in power consumption compared to the earlier mosaic-X5 receiver. The new modules measure 23 mm x 16 mm and weigh as little as 2.2 g, making them suitable for



Septentrio, part of Hexagon

applications where size, weight and power are critical considerations, such as commercial UAVs, robotics and high-volume industrial equipment.

The mosaic-G5 modules offer reliable, high-accuracy positioning even in environments where GNSS signals may be degraded or obstructed. The mosaic-G5 product line includes several variants tailored to

different use cases. The triple-band mosaic-G5 P1 is designed for high-volume applications, such as inspection drones and robotic mowers. The quad-band mosaic-G5 P3 and the triple-band heading module mosaic-G5 P3H offer enhanced positioning reliability in challenging conditions and are suited for applications such as delivery UAVs and light show UAVs. The P3H variant can calculate heading with a minimal

SEE SEPTENTRIO, NEXT PAGE. >>

DEFENSE

NATO Tests Prototype Sensor Against GNSS Signal Threats

A new prototype sensor developed by the NATO Communications and Information Agency has completed a significant round of testing, marking a step forward in NATO's electromagnetic warfare capabilities. The sensor, GANDALF 4, underwent a series of tests at an advanced anechoic chamber operated by the NATO Support and Procurement Agency. This facility serves as a controlled environment for precise calibration and detailed performance assessment of the sensor's antenna array, which is critical for ensuring the system's

accuracy and reliability.

GANDALF 4 was developed by specialists at the agency's Joint Intelligence, Surveillance and Reconnaissance Centre. The system is designed to detect, classify and locate deliberate attempts to interfere with or manipulate GNSS signals. GNSS jamming and spoofing are becoming more frequent and sophisticated, posing challenges to NATO's operational readiness and resilience. The development of GANDALF 4 is designed to enhance situational awareness in contested electromagnetic environments.

The recent testing phase focused on



NATO

GANDALF-4 prototype

evaluating the antenna performance of the sensor. Collaboration between the agency's Electromagnetic Warfare and Surveillance team and the procurement agency's Ground Based Defence group played a central role in the campaign, facilitating knowledge transfer and improving efficiency, according to the team. 🌐

US Army Selects AEVEX Aerospace for Short-Range Launched Effects Demonstration

The U.S. Army has selected AEVEX Aerospace to participate in the Launched Effects-Short Range Special User Demonstration, an initiative aimed at advancing the Army's integration of sophisticated uncrewed systems to improve battlefield effectiveness. AEVEX will present its Atlas Group II launched effect during the demonstration, a lightweight and agile system engineered for precision missions that directly support frontline troops. The Atlas system reflects



AEVEX Aerospace

AEVEX's commitment to developing innovative technologies that address the Army's evolving operational threats and mission requirements.

Throughout the demonstration, soldiers from various Army branches — including field artillery, infantry, and aviation — will operate the Atlas system to refine tactics, techniques and procedures. Their hands-on feedback will play a critical role in shaping how the Army employs launched effects in the future, influencing both requirements and operational strategies. 🌐

SEPTENTRIO

« CONTINUED FROM PREVIOUS PAGE.

baseline between two GNSS antennas, enabling accurate navigation for small autonomous devices.

The mosaic-G5 modules complement Septentrio's broader mosaic portfolio. The established mosaic-X5 receiver remains a benchmark for anti-jamming

and anti-spoofing performance in a compact form factor. The new modules are compatible with widely used open-source autopilots, including PX4 and ArduPilot, designed to simplify integration and reduce development time. An evaluation kit, mosaic-go G5, is available to facilitate testing, and the RxTools user interface is provided for setup and evaluation. 🌐

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UNDERWATER ARCHEOLOGY

Titanic's Digital Twin Surfaces

A full 3D scan of enables everyone to virtually visit the shipwreck of the luxury vessel — and could resolve long-standing questions

BY TRACY COZZENS, EDITOR-AT-LARGE

In 2022, deep-sea mapping company Magellan undertook the largest underwater 3D scanning project of its kind to create the first full-size digital scan of the Titanic. The luxury passenger liner sank in the North Atlantic Ocean on April 15, 1912, after striking an iceberg, and now rests 12,500 ft below the surface.

Over three weeks, the Magellan team worked around the clock to capture the luxury vessel in unparalleled detail. They used two remotely operated vehicles (ROVs) — dubbed Romeo and Juliet — to systematically canvass the site. In total, the ROVs collected 715,000 photos, 4K footage and millions of laser measurements — a total of 16 terabytes of data.

The scan itself was only the beginning. The Magellan team then processed

the collected data into a smooth, comprehensive 3D point cloud. Applying new processing techniques to the original Magellan IP and raw data sets provided a new data set with 35% better resolution and accuracy. Each point in the dense point cloud used to generate the model has its unique set of Cartesian coordinates (X, Y, Z), time stamp and texture.

Titanic analyst Parks Stephenson has visited the actual Titanic wreck twice, but the virtual scan revealed

details he never saw before. Aboard a submersible, with its six-inch viewport and limited camera views, details are easily missed. "It's like being in a dark room and you have a flashlight that's not very powerful," Stephenson told National Geographic. The digital twin gave him an unobstructed, 360° view of every nook and cranny.

The digital twin reconstructs Titanic's structural collapse in forensic detail. A video rendering

MAGELLAN created a near-perfect virtual replica of the famous wreck, known as a digital twin.



EXPLORE THE PROJECT

A National Geographic documentary about the project, "Titanic: The Digital Resurrection," is now streaming on Disney+ and Hulu. The 90-minute documentary was produced by Atlantic Productions for National Geographic.



of it can be projected to life-size in a warehouse, allowing experts to walk through its final moments. For instance, an open steam valve in the boiler room validates eyewitness accounts that the ship's engineers remained at their posts for more than two hours after impact, keeping the

electricity on and allowing wireless distress signals to be sent. The 35 men may have saved hundreds of lives while sacrificing their own.

The digital scan also helps exonerate First Officer Murdoch, long accused of abandoning his post. The position of a lifeboat davit suggests his crew was preparing a launch moments before the starboard side was engulfed, corroborating Second Officer Charles Lightoller's testimony that Murdoch was swept away by the sea.

The scans reveal the wreck's alarming deterioration, with iconic areas collapsing. But the mapping project means the ship is now digitally preserved, along with similar models of historic sites around the world. 🌐

TAKE THE PILOT'S SEAT

Magellan has launched an app built on the Titanic's scans, available in Early Access on the Steam platform. "vROVpilot: TITANIC" puts users in the pilot seat of a virtual ROV to explore the wreck and complete missions to scan its key features. The experience comprises an accurate ROV user interface, along with realistic underwater condition visual effects and comprehensive sound effects, according to the developer.

So far, the app is using only the data on the bow, which is less than 35% of the full data set. The stern is expected to be added next, followed by the 15-square-mile debris field, which shows personal effects such as pocket watches, purses, gold coins, hair combs, shoes and a Megalodon-tooth necklace.





WEST POINT CADETS MAP ELECTRONIC WARFARE

West Point cadets conducted a senior thesis project investigating the use of GNSS technology

to map and visualize electronic warfare activities in the South Pacific, specifically focusing on GNSS spoofing. Their research, centered on the Huangpu River and Northeastern Shanghai, aimed to identify patterns of malicious GNSS interference and potential perpetrators, highlighting the strategic and economic motivations behind these actions in the region. By developing data visualizations of spoofing incidents, the cadets created a model that could be scaled up to analyze larger areas.

TÜRKIYE TO LAUNCH HOMEGROWN SATELLITE NAVIGATION AND MAPPING SYSTEM

Türkiye is developing the Regional Positioning and Timing System (BKZS) to launch its own GPS and mapping application, in an effort to reduce dependence on foreign technology and enhance cybersecurity amid growing industrial automation. The system will provide precise location, navigation and timing data via Turkish satellites as an alternative to global systems including



GPS, supporting critical sectors such as military operations, civilian communications, smart transportation, and precision agriculture.



SOUTH AFRICA RISING ABOVE WATER

Researchers from the University of Bonn have found that South Africa's land is rising by up to 2 mm per year, not because of deep mantle activity, but due to water loss from severe droughts. This uplift was detected using the TrigNet network of GNSS stations, which precisely measures changes in land elevation. As groundwater is depleted, the Earth's crust rebounds upward — a process GNSS stations can monitor in real time.



QUANTUM NAVIGATION SYSTEM SERVES AS GPS BACKUP

Q-CTRL, a quantum infrastructure software company based in Sydney, Australia, has demonstrated a new quantum navigation system, Ironstone Opal, as a backup to GPS technology. The Ironstone Opal system uses quantum sensors to detect variations in the Earth's magnetic field, determining precise geographic coordinates with the help of artificial intelligence-based software. Ironstone Opal is passive and does not emit signals, making it resistant to detection and jamming. Field trials showed the system outperformed a high-end inertial navigation system and served as a reliable GPS backup by up to 50 times in ground vehicles and 11 times in aircraft.

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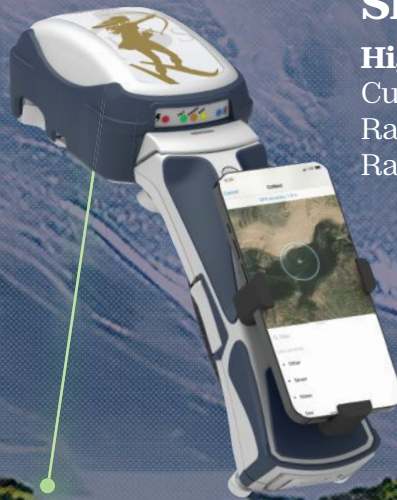
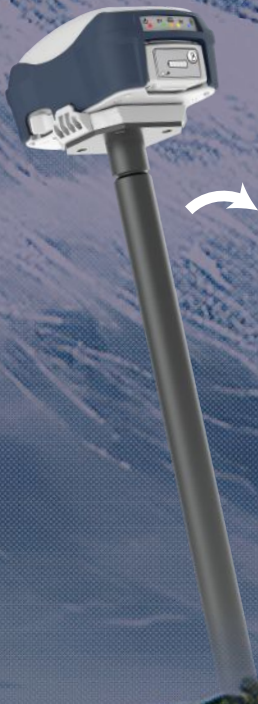
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