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Trends in Precision Agriculture

# MULTI-GNSS BOOSTS SURVEY ACCURACY

First GPS III Inaugurates New Era

Experts Define the Multi-GNSS Advantage

Supercorrelator Super Powers

A NORTH COAST MEDIA PUBLICATION

JANUARY 2019 | Vol 30 | No 1

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## JANUARY 2019

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Cover Photo Creation: Leica Geosystem

COVER STORY

# CONTENTS

JANUARY **2019**

## OPINIONS AND DEPARTMENTS



## ADDED DEPTH

NEWSLETTER EXCERPT

# Geospatial Data Act Will Bring Huge Changes to America, and the World

BY **William Tewelow**
CONTRIBUTING EDITOR, GEOSPATIAL INTELLIGENCE

On Oct. 5, the FAA Reauthorization Bill passed into law with overwhelming bipartisan Congressional support. The Senate passed it 93-6, and the House passed it 398-23. Both parties came together to pass this important a piece of legislation. It happened without fanfare or recognition aside from certain circles, but within H.R. 302 was contained the entire Geospatial Data Act 2018.

Most people are unaware that the Geospatial Data Act (GDA) is now law. Even fewer realize that the GDA applies not only to the FAA, but to all government agencies except for the Department of Defense and the intelligence community.

Since Roger Tomlinson first created a geographic information system in the 1960s, GIS has become a multi-billion dollar global industry. By 2020, it is forecast to be nearly a half-trillion dollars annually. The global GIS market is expected to double in seven years.

GeoBuiz estimates that GIS influences 20 percent the world's entire $80.7 trillion global annual production. According to the Countries Geospatial Readiness Index, the United States leads the world in GIS. What is amazing is that all these estimates were made prior to the passage of the GDA — the gale force winds that have thus far blown will soon become a hurricane.

**Growth.** The sweet spot of opportunity is the forward edge of a growing industry. In the mid-90, the growth of the geospatial industry was led by state and local government (See GeoIntelligence Insider: In Jack Maple's Steps – Fighting Crime with GIS, May 2018). In the mid-2000s, growth accelerated due to the intelligence and military communities. The next big boom in GIS begins now as the federal government complies with the GDA. There will be an even longer growth trend internationally as other countries make their own conversions.

It is a common adage that forecasts usually overestimate the near term and underestimate the long-term, especially in regard to technology. Consider how one man's idea to sell books online in 1995 made him the wealthiest man in the world 23 years later, or how a simple search engine in 1998 is now a global behemoth. Of course, those references are to Jeff Bezos of Amazon and to Google.

And, consider the impact GPS has made since May 1, 2001, when President Clinton discontinued Selective Availability, opening GPS to the masses. Four years later, in June 2005, Google Earth was launched. The iPhone came out two years later. Then, a year later, Google Maps with real-time navigation was released.

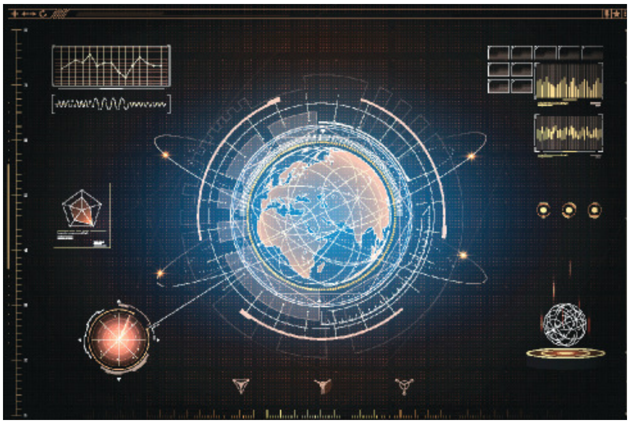

Image: iStock.com/Jirantanin Chanachaiviriyakul

Businesses like Uber that depend on GPS and GIS began in 2012. Now, industries such as drones and autonomous vehicles are on the verge of exponential growth.

Apply a similar trajectory to GIS and combine it with smart technologies like the internet of things, open data, data science, artificial intelligence, augmented reality, and other emerging technologies and the growth potential is unprecedented…

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

## HOTTEST PAGES @ GPSWORLD.COM

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| 3 | First GPS III launch delayed for rocket issues | LATEST NEWS |
| 4 | Dual-band GNSS market moving from insignificant to billions in less than 5 years | LATEST NEWS |
| 5 | Directions 2019: GPS program looks toward GPS III launch | FROM THE MAGAZINE |

# All Hail the Gold Standard's New Golden Era

**BY ALAN CAMERON**
EDITOR-IN-CHIEF

Elsewhere in this issue you'll find the hard facts — basic, but hard — concerning the inaugural launch of the long-awaited GPS III constellation. On pages 10 and 12, with some seasoned leavening between, on page 11.

This column instead waxes briefly on the phenomenon of time, and humankind's struggle to dominate it, to subject the fourth dimension to its own will.

Were my friend Don Jewell still with us, he would be justifiably proud of the Air Force for launching this new golden era of the gold standard in positioning — yet he would have seethed for years over the continued pushes to the right.

This reminds me a good deal of the drama and occasional comedy in the rise of Galileo, observed from afar. Next month I'll give a talk at the European Space Agency, provisionally titled "An Outside History of Galileo," the bemused viewpoint of one who only heard and interpreted the news, but did not participate in its forming.

> "There is a rhythm and a flow to life, and we are part of it. You can hurry neither sundown nor sunrise."

For GPS III has been, yes, long awaited, long debated, long victim to multiple delays of many colors and causes, scrutable and inscrutable, of technological challenges and institutional barriers, and of that base determinant, money. The Government Accounting Office has issued its fair and due share of reports pointing alarmed fingers at constellation gaps and fulfillment shortfalls and the trials of OCX, the ground control system without which GPS III satellites may some day, soon or not-soon, be capable of broadcasting powerful new signals from space, yet not able to do so because of lagging accomplishment on Earth.

It's often said that GPS is a victim of its own success, that older satellites living beyond their forecast lifetimes have allowed the Air Force to economize by not replenishing when unnecessary. There's wisdom in this, of course.

For such complex endeavors do not happen easily or speedily or exactly as planned by mere mortals. Nor should they. Despite much gnashing of teeth, no one — in the civil sphere at least — has suffered unduly from the longish delays in either satnav system's modernization. Perhaps a few lives could have been saved in the military, or greater strategic advantage gained, with the new capabilities that III will offer warfighters, had same been available on schedule, say, four to six years ago. But even this is mere conjecture.

There is a rhythm and a flow to life, and we are part of it. You can hurry neither sundown nor sunrise. Things happen in their own due course.

When full GPS III capabilities arrive — I don't believe 2023 — then it will still be in good time. In its own best time, actually, to be here.

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# When CSWaP Matters!

## EMCORE Inertial Measurement Units (IMU)

*Compact, High-Accuracy Navigation Solutions*



**Scale Reference:**
U.S. Quarter
1 Inch Diameter

### *THE EMCORE IMU ADVANTAGE:*

EMCORE's EN-300 is form, fit and function compatible with legacy IMUs, but delivers five- to ten-times the performance. EMCORE's EN-150 is the smallest, most affordable closed-loop FOG IMU available and delivers twice the performance of competing IMUs.

- Three-axis closed-loop FOG design for improved drift stability, higher linearity and greater flexibility
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- Low-noise line-of-sight stabilization
- Next-generation integrated optics and FPGA electronics
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- Dismounted soldier north finding and navigation
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# GPS III Finally Aloft, Benefits on the Way

BY Tracy Cozzens
MANAGING EDITOR

On December 23, the first GPS III satellite entered an orbit around Earth, after a five-day delay. This first of a new breed of GPS satellite also experienced a four-year delay, with its original launch scheduled for 2014.

While the system has experienced more than its share of problems, at the start of a new year I want to focus on the benefits to come.

Few of us realized how much our lives would change when the first GPS satellite was launched in 1978. GPS III could bring about a similar trajectory of changes. Civilians can expect a more reliable and accurate service. The smartphone message "searching for signal" could become a dim memory.

GPS III signals will be three times more accurate than the current GPS Block II models. The navigation payload has more than three times reduction in range error and up to eight times increase in power — its signals should be much easier to pick up under tree canopy, within urban canyons and inside buildings.

GPS III also has four civilian signals. The L1C signal is interoperable with international GNSS, meaning users can receive signals from any country's satellites. Also, using two civilian signals means GPS III can directly detect and correct ionospheric errors.

In addition to a standard wide-angle antenna for broad coverage, the GPS III satellites include a high-gain directional antenna that will operate with 100 times (+20 dB) the power of the wide-angle antenna, and will be exclusively for use with M-code (military) transmissions. This directional antenna's spot beam covers an area 120 miles at high power—boosting the power of military GPS signals by 100 times in specific regions, making military GPS even harder to jam.

These advantages may not reach the battlefield for a decade. The new constellation will take time to build. The GPS III constellation is projected to be fully capable in June 2023, when 10 Block IIIA satellites are expected to be in orbit. Ten follow-on satellites are planned to be placed into orbit from 2026 to 2034.

Back here on Earth, equipment makers will need time to develop and supply warfighters with military GPS user equipment (MGUE) that can take advantge of all that GPS III has to offer.

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PNT Q+A

## What is the "sweet spot" for high-precision multi-GNSS receivers, factoring cost, capability and robustness: processing of 2, 3 or 4 GNSS constellation signals?

"Users expect an available GNSS position in the most demanding environments, making the combination of all constellations and frequencies the real sweet spot. The benefits of using all constellations and frequencies is very important and will only increase in the future."



"Combining frequencies is a way of removing the impact of ionospheric disturbances. Some new GNSS signals such as Galileo E5 are so high-quality that the solution degrades when they are combined with lower quality signals on other frequencies. We must now use other, novel, approaches to remove the ionosphere disturbances."

"Four constellations are now virtually free, and incorporated into new, inexpensive GNSS phone chips. A more complex issue is using all frequency bands. Benefits are enormous. With volume, costs will plummet. So, the sweet spot moves to use of all frequencies, particularly L5 and equivalents."

Artist's rendering: Lockheed Martin

# First GPS III Satellite Flies to Historic Perch in Space

After several launch delays, the first GPS III satellite successfully deployed from a SpaceX Falcon 9 rocket, rising from Cape Canaveral on Dec. 23. By Jan. 2, the satellite had circularized its orbit at an altitude of 12,550 miles to begin a period of checkout and testing that could last up to 18 months, before entering service. The satellite, built by Lockheed Martin, will serve in space for 15 years.

Known as GPS III SV01 and nicknamed "Vespucci," it is the first in a new generation of GPS navigation stations with improved services and longer lifetimes to ensure the U.S. military-run network remains available to troops and civil users around the world for decades to come.

"Launch is always a monumental event, and especially so since this is the first GPS satellite of its generation launched on SpaceX's first national security space mission," said Lt. Gen. John Thompson, commander of the U.S. Air Force's Space and Missile Systems Center and the Air Force's program executive officer for space. "As more GPS III satellites join the constellation, it will bring better service at a lower cost to a technology that is now fully woven into the fabric of any modern civilization."

The satellite's earlier scheduled launch date of Dec. 18 was scrubbed, reportedly due to liquid oxygen thermal limit constraints aboard the SpaceX Falcon 9 Block 5 rocket's first stage reaching safety limits. A second attempt on Dec. 19 was also ruled out due to ongoing evaluations into the sensor issue. Then ensued three days of weather delay, awaiting favorable wind conditions, until Dec. 23.

GPS III SV01 was originally scheduled to ride aboard a United Launch Alliance (ULA) Delta IV M+ rocket. ULA and its prime partners, Lockheed-Martin and Boeing, have conducted every GPS satellite launch since the start of the program. However, due to an assortment of issues variously involving delayed technology development and lawsuits regarding competitive bidding, the Air Force re-opened the contract process as part of its Evolved Expendable Launch Vehicle (EELV) program — “evolved” signifying that the rocket can be recovered and reused.

**Recycling Rockets.** ULA did not bid on the re-opened contract, citing concerns over the selection process and potential risks with the anticipated lower launch cost. In 2016, the Air Force selected SpaceX to take over most GPS III launches.

SpaceX’s Falcon 9 for this launch used a new first stage core, the B1054. Although it has re-use capability, it flew in an expendable configuration this time, with no landing legs and no grid fins. It was disposed of into the Atlantic Ocean after separation from the second stage.

In other missions, after the satellite-bearing stage separates from the rest of the rocket, the remaining core launcher fires additional fuel to return intact to land or to sea aboard an Autonomous Spaceport Drone Ship (ASDS), a converted barge awaiting in the Atlantic or Pacific Ocean.

**New Generation.** The GPS III constellation, once fulfilled, will bring three times better accuracy and up to eight times improved anti-jamming capabilities. Spacecraft life will extend to 15 years, 25 percent longer than GPS satellites on-orbit today. GPS III’s new L1C civil signal also will make it the first GPS satellite broadcasting a compatible signal with other international global navigation satellite systems, like Galileo, improving connectivity for civilian users.

Lockheed Martin developed GPS III and manufactured GPS III SV01 at its GPS III Processing Facility near Denver. In September 2017, the Air Force declared the satellite “Available for Launch” (AFL) and had the company place it into storage.

In 2018, the Air Force called the satellite to Florida, and it was delivered on Aug. 20. At that time, the Air Force declared the second GPS III AFL and in November called it up for 2019 launch. GPS III satellites SV03-08 are now in various stages of assembly and test.

INERTIAL

# NavSight Powers Car Testing and Surveying

SBG Systems' Navsight Land & Air Solution is a high-performance inertial navigation +GNSS system designed to make data collection easier, whether for high-accuracy applications such as car testing, aerial and land surveying or "motion and navigation" applications such as mobile mapping, GIS or road inspection.

It consists of an inertial measurement unit (IMU), available at two different performance levels, connected to Navsight, a rugged processing unit embedding fusion intelligence and a GNSS receiver. It also has connections for external equipment such as lidar, cameras or computer.

The Ekinox IMU enables the NavSight system to offer up to 0.02° roll and pitch accuracy in an RTK mode, up to 0.05° GNSS-based heading on a 4-meter baseline, and up to 1-centimeter positioning accuracy, depending on the GNSS receiver employed. It can be connected to a vehicle odometer, and its data improved by post-processing with Qinertia PPK software. The Apogee mode offers up to 0.008° roll and pitch accuracy in an RTK mode, up to 0.025° GNSS-based heading on a 4-meter baseline, and the other features as stated above.

SBG's fusion algorithms enable the products to draw optimal performance from inertial, odometer and GNSS technologies; exclude false GNSS fixes; and improve the trajectory in areas such as urban canyons, forests and tunnels. The Navsight Land & Air Solution supports all GNSS constellations, real-time kinematic (RTK) and precise point positioning services such as Omnistar and TerraStar.

Photo: SBG Systems

NAVSIGHT **inertial plus GNSS system, shown here with Apogee option.**

SBG IMUs' sensor alignment and lever arms are automatically estimated and validated. Once connected to the Navsight processing unit, the web interface guides the user to configure the solution. A 3D view of the vehicle shows the entered parameters so that the user can check the installation. By choosing the vehicle, such as a plane or a car, the inner algorithms are automatically adjusted to the application. The Navsight unit also integrates LED indicators for satellite availability, RTK corrections and power.

**Post-Processing Software.** Qinertia, the SBG post-processing software, provides access to offline RTK corrections from more than 7,000 base stations in 164 countries. Trajectory and orientation are improved by processing inertial data and raw GNSS observables in forward and backward directions.

LIDAR + SLAM

# Drones Map Without GPS

Researchers at the Massachusetts Institute of Technology (MIT) presented a project at the International Symposium on Experimental Robotics involving an autonomous drone fleet system that collaboratively mapped an environment under dense forest canopy. The drones used lidar, onboard computation and wireless communication, with no requirement for GPS positioning.

Each drone carries laser-range finders for position estimation, localization and path planning. As it flies, each drone creates its own 3-D map of the terrain. A ground station uses simultaneous localization and mapping (SLAM) technology to combine individual maps from multiple drones into a global 3-D map that can be monitored by operators. The MIT team tested its concept via simulations of randomly generated forests, and world-tested two drones in a forested area at NASA's Langley Research Center. In both experiments, each drone mapped a roughly 20-square-meter area in about two to five minutes, while the control system integrated their maps together in real-time.

The drones were programmed to identify multiple trees' orientations, as recognizing individual trees in impossible for the technology, and individual trees' orientation very difficult. When the lidar signal returns a cluster of trees, an algorithm calculates the angles and distances between trees to identify the cluster and determine if it has already been identified and mapped, or is a new mini-environment.

The technique also aids in merging maps from the separate drones. When two drones scan the same cluster of trees, the ground station merges the maps by calculating the relative transformation between the drones, and then fusing the individual maps to maintain consistent orientations.

# AP100 FAMILY

## HIGH-PRECISION OEM GNSS RECEIVER MODULES

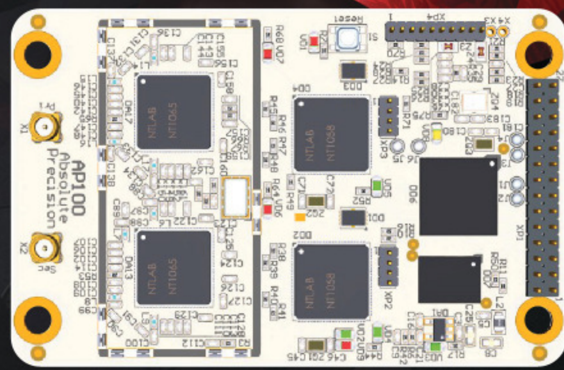
ABSOLUTE PRECISION
PROFESSIONAL NAVIGATION EQUIPMENT

Single/dual-antenna high-precision OEM GNSS receiver modules of AP100 family provide precise millimeter-level RTK positioning combined with 3D attitude (yaw, pitch, roll) determination.

With our OEM modules, navigation data can be concurrently received from: GPS L1/L2, GLONASS L1/L2, Galileo E1BC/E5a/E5b, BeiDou B1/B2, NavIC L5/S and SBAS.

The modules will be the best solution for a wide range of navigation applications owing to small power consumption, industry standard size (71x46x10 mm) and easy integration.

Moreover, the raw measurement data are available for user's secondary processing, as well as API functions to control the baseband chip. Using Absolute Precision OÜ open platform, users are free to create an effective solution for each specific application.



***Firmware freedom** for your effective GNSS solutions!*

### POWER CONSUMPTION FROM 0.25 W

### RAW DATA UPDATE RATE UP TO 100 HZ

### FEATURES

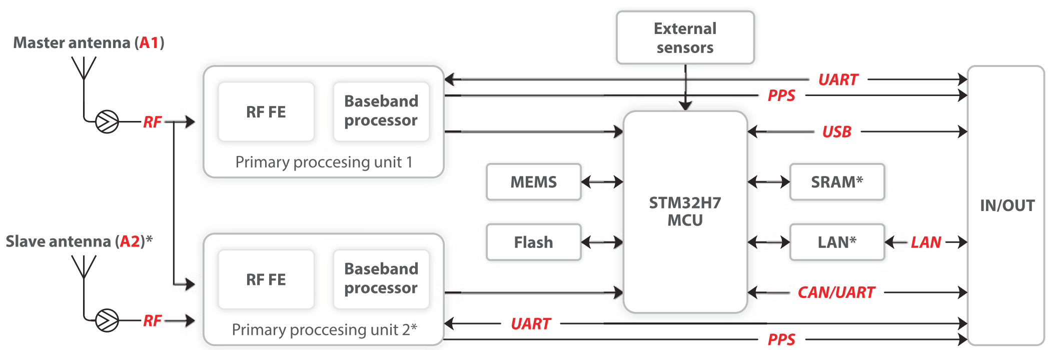
- On-board STM32H7 MCU for the development of user's applications
- On-board 9-axis MEMS IMU
- Loosely-coupled GNSS/INS integration algorithm
- Raw measurements data output: code and carrier phase measurements

### MEASUREMENT PRECISION

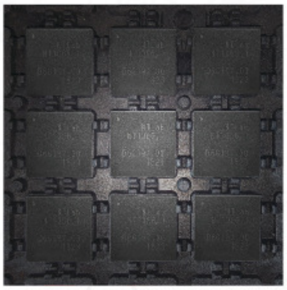
| | |
|---|---|
| Code phase accuracy | 20 cm |
| Carrier phase accuracy | 0.8 mm |

### POSITION ACCURACY

| | Horizontal | Vertical |
|---|---|---|
| Standalone mode | 1.5 m | 2 m |
| RTK mode | 3 mm+0.5 ppm | 7 mm+1 ppm |




*Optional. It depends on AP100 modification



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## 1. RF FRONT-END

### APPLICATION-SPECIFIC INTEGRATED CIRCUIT (ASIC) FOR GNSS

NT1066 is a four-channel RF front-end ASIC (three wideband IQ and one narrowband IQ) that covers all GNSS (GLONASS, GPS, Galileo, BeiDou, QZSS, NavIC) signals at all frequency bands, so users benefit from all the advantages of acquiring multiple system simultaneously. Channels A, B and C are designed with single-conversion low-IF architecture, individually programmable and intended to receive L1, E1, B1, E6, B3, L2, L3, B2, L5 and E5 in various combinations. IQ and image suppression modes are available. Channel D is dedicated to the S band of NavIC or L2, L3, L5 bands of GNSS and has zero-IF architecture. Combining channel D with channels A, B and C makes it possible to effectively eliminate ionospheric distortion using the large signal base of NavIC between the L5 and S bands. Alternatively, channel D can be software-reconfigured "on a fly" to receive real-time correction data transmitted over FM, VHF and UHF bands.
**NTLab, ntlab.com**

## 2. POSITION SENSOR

### FOR SMARTWATCHES, FITNESS TRACKERS AND SMARTPHONES

The BHI160BP is a position tracking smart sensor for consumer wearables that uses integrated inertial sensors to improve GPS location tracking. When used with a GPS or GNSS module, it enables users to take advantage of pedestrian position tracking with up to 80% saving in system power consumption compared with a typical GNSS-only solution, without compromising on accuracy. The BHI160BP tracks a person's position by intelligently applying an inertial-sensor-based algorithm for pedestrian dead reckoning. To maintain accuracy, it calculates the user's relative location based on data collected from the inertial sensors and then recalibrates itself every few minutes to obtain the absolute position provided by the GNSS/GPS module. This means that the GNSS/GPS module can be kept in sleep mode for most of the time, which drasticly reduces a device's power consumption and extends its operating time.
**Bosch Sensortec, www.bosch-sensortec.com**

## 3. NAVIC-ENABLED MODULE

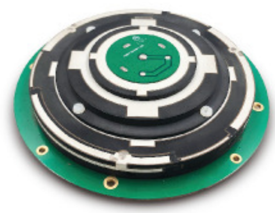
### DESIGNED TO MEET INDIAN MANDATE

The SL869T3-I GNSS module combines GPS with India's NavIC (IRNSS) navigation system and the country's satellite-based augmentation system SBAS known as GAGAN. The SL869T3-I module enables the creation of high-performance position reporting and navigation solutions. It complies with Automotive Industry Standard 140 (AIS-140) — an Indian government mandate that requires the use of NavIC for vehicle location tracking devices in all public transportation vehicles, effective in April.
**Telit, www.telit.com**

## 4. REFERENCE AND TRAINING

### TECHNICAL INFORMATION FOR DEFENSE AND AERONAUTICS APPLICATIONS

The Rohde & Schwarz Navigation and Guidance Solutions Learning Center now includes the latest Rohde & Schwarz solutions for GNSS testing. Updated material includes application brochures, white papers, articles, technical documents, training videos and products. Rohde & Schwarz provides accurate, flexible, high-performance test solutions, from design, development, calibration and production to operational maintenance for ground-based systems and advanced hybrid constellation simulations for GNSS systems. The navigation learning center also describes company products, including GNSS signal simulators.
**Rohde & Schwarz, www.rohde-schwarz.com**



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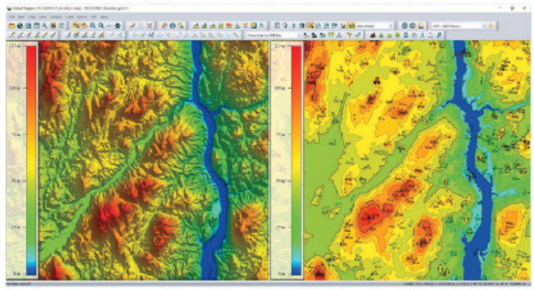
## 1. SURVEY ANTENNA

**DESIGNED FOR RTK APPLICATIONS**

The X-Survey antenna is a 4-in-1 OEM antenna for both navigation and communication in surveying applications. It provides standard Wi-Fi, Bluetooth and 4G, plus multiple constellation signal reception for GNSS positioning. The high-gain and wide-beamwidth GNSS antenna features a multi-point feeding technology, ensuring a high phase-center stability and positioning accuracy. Moreover, the array-arranged 4G antenna enables more stable signals and longer communication distance at 360-degree direction, increasing the overall machine efficiency over conventional antennas. The X-Survey antenna provides high isolation among each antenna to prevent self-interference, improving real-time kinematic (RTK) system compatibility. RF coaxial connectors are designed for plug-and-use, keeping high efficiency and lowering the impact of electromagnetic interference.

**Harxon, en.harxon.com**



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## 2. DEVELOPER'S TOOLKIT

**MIRRORS CAPABILITIES OF DESKTOP VERSION OF GLOBAL MAPPER**

Version 20 of the Global Mapper Software Development Kit (SDK) is now available, along with the accompanying Lidar Module SDK. The developer's toolkit provides software engineers with the means to embed the latest geospatial technology into custom applications.Highlights include dramatically improved vector data performance in both the 2D and 3D environments, updated 3D mesh rendering with colors now displayed in the 2D view, and faster display and export of online tiled datasets. The Global Mapper GIS application can display, convert and analyze virtually any type of geospatial data. The Global Mapper SDK and Lidar Module SDK provide software developers with a toolkit for accessing much of this functionality from within an existing or custom-built application.

**Blue Marble Geographics, www.bluemarblegeo.com**

# LAUNCHPAD | UAV




## 1. ARCTIC UAV

**ADAPTED FOR WORK IN EXTREME COLD**

The ZALA 421-08M and ZALA 421-16E Artic UAVs are suited for operation at freezing temperatures, making it possible to carry out surveillance operations and regularly monitor the ice. Its GIRSAM alternative navigation system was developed for navigation of UAVs in the suppression or the absence of GPS or GLONASS signals. The ZALA Arctic's capabilities facilitate oil and gas extraction planning in areas where accurate weather and ice situation forecasts are required.

**Kalashnikov, kalashnikov.com**

## 2. QUADCOPTER

**HYDROGEN-POWERED FOR ENDURANCE**

E-Drone Zero is a long endurance quadcopter managed by an advanced artificial-intelligence-powered operating system. The use of hydrogen fuel cells as the drone power source provides improved flight-time, less downtime due to quick refuelling, and increased payload capabilities. Advanced security is provided via NATO-validated military-level encryption. Additional safety features include computer vision assisted obstacle avoidance and various failure management features. Besides surveillance and security, e-Drone Zero is suitable for demanding survey, mapping and inspection tasks.

**Skycorp, sky-corp.eu**

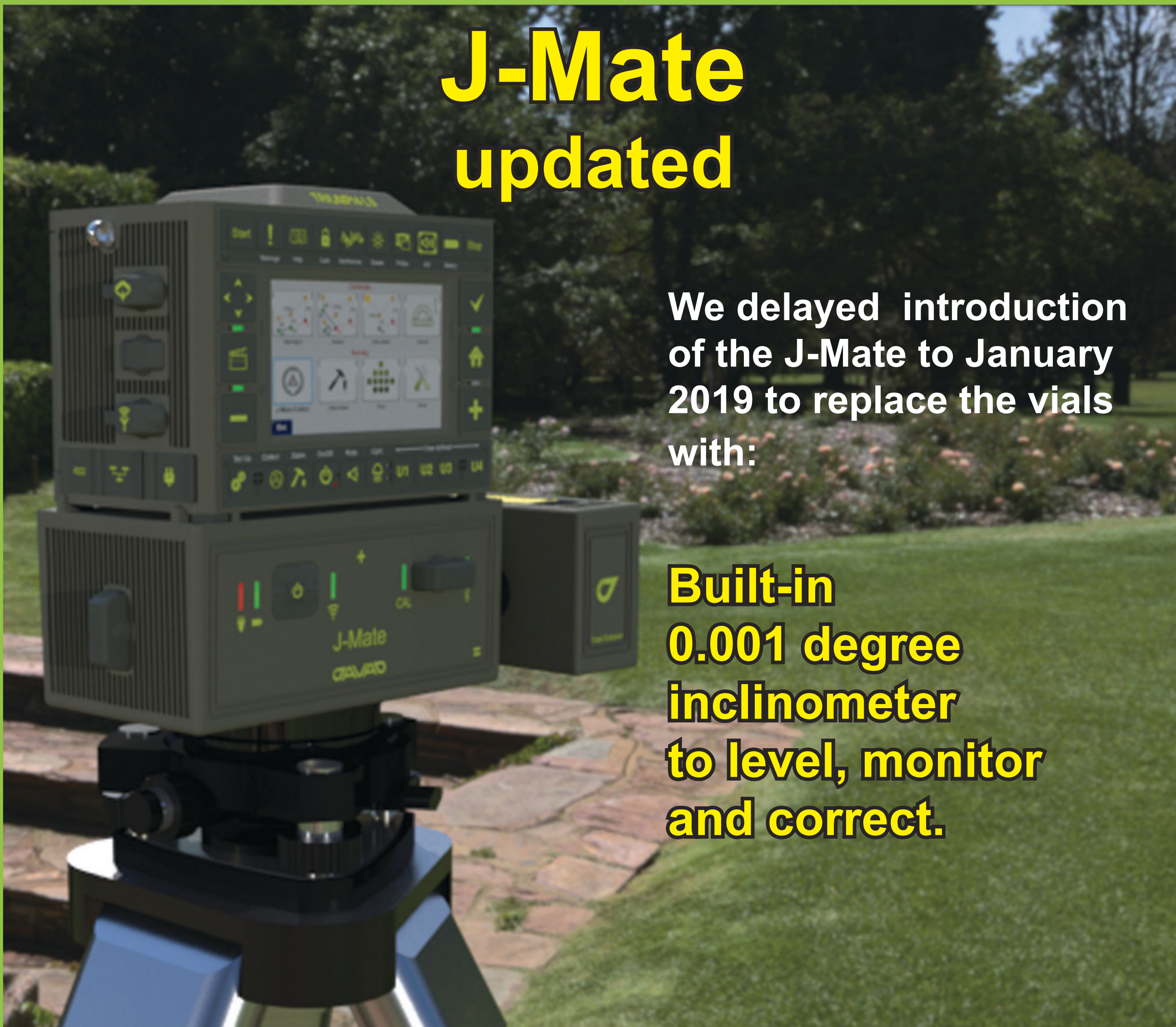
## 3. MAPPING SYSTEM

**3D CAPTURE AND PROCESSING**

The Stencil 2 improves mapping accuracy and workflow with a new user interface compared to the original Stencil, as well as GNSS localization, upgraded hardware, confidence metrics and enhanced software intelligence. Stencil 2 ships with an iPad to access operations and view real-time scanning on the fly. It records GNSS data for use in loop closure to georegister and geolocate datasets, correcting for drift and improving the fidelity of large area scans. Kaarta offers an optional GNSS kit with Emlid Reach RS+ RTK GNSS receiver and custom mounting bracket. Alternatively, Stencil 2 integrates with other NMEA 0183-compliant GNSS systems.

**Kaarta, www.kaarta.com**

# J-Mate updated




We delayed introduction of the J-Mate to January 2019 to replace the vials with:

**Built-in 0.001 degree inclinometer to level, monitor and correct.**

## TRIUMPH-3, Ideal as a base station

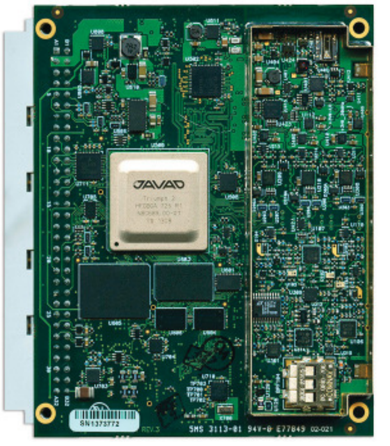

Top part exactly like TRIUMPH-LS

Half the height of TRIUMPH-LS

To be released February, 2019

# TRE-3 The state-of-the-art in GNSS technology…

# And this is why:




- **Three** ultra wide-band (**100 MHz**) fast sampling and processing, programmable digital filters and superior dynamic range. After **12-bit** digital conversion, **nine** separate digital filters are perfectly shaped for each of the nine GPS L1/Galileo E1, GPS L2, GPS L5/Galileo E5A, GLONASS L1, GLONASS L2, Galileo E5B/BeiDou B2/GLONASS L3, Galileo altBoc, Galileo E6/BeiDouB3/QZSS **LEX**, and BeiDou B1 bands.
- Each band consists of a combination of a digital Cascaded Integrator-Comb (**CIC**) filter and a digital Finite Impulse Response (**FIR**) filter (up to **60-th** order) where signal selection is performed.
- Two types of digital in-band anti-jamming filters (automatic **80-th** order and “user selectable” **256-th** order).
- We assign multiple channels to acquire and track each satellite signal. For example we can assign **20** channels to acquire the GPS L1 signal, each spaced one millisecond apart. We also assign up to **5 channels** to track each signal, each with different filter parameters and tracking strategies. This supports acquiring and tracking **weaker** signals in difficult conditions, especially under trees and canopy. People wonder why we need **864** channels! We put them to good use. Others use one channel per satellite signal. Several patents are pending (Patents and Pendings).
- **80 dB** out-of-band interference rejections: high dynamic range of wide RF bands and highly rectangular digital filters make the receiver much more resistant to out-of-band **jamming**.
- **High-speed** high-dynamic automatic gain control (AGC) to respond to interferences and signal variations.
- Programmable filter **width** (by commands).
- Highly stable digital filters (band characteristics do **not change** with age, input voltages, or temperature).
- Improved **GLONASS** inter-channel bias performance (due to our flat digital filter shape).
- Excellent new **multipath** rejection technique, the best ever.
- 60-MHZ-wide Galileo **altBoc** band unleashes the full benefit of this signal. Its excellent multipath resistance is improved even further with our new multipath reduction technique.
- **864** GNSS channels allow tracking all current and future satellite signals.
- Three wide band RF sections allow monitoring **spectrums** and interferences in three 100-MHz-wide bands.
- TRE-3 is the only receiver in the market that can track AND DECODE the QZSS **LEX signal messages**.
- Excellent features for **time transfer** applications: In time sources where the zero crossing of the input frequency defines the exact moment of the time second, we monitor **zero crossings** and accurately define the moment of the time second. External time interval measurement unit is not required to measure zero crossing and 1-PPS offset.
- Embedded **calibrator** measures phase and code delays of each of these nine bands in timing applications. External calibration is not required.

TRE-3 is form, pin-out, and command compatible with the TRE-G3T. It uses **7-Watts** of power, compared to 4-Watts of the TRE-G3T.

# LIVE at www.javad.com


G'day, Mate!

## Redefining Total Stations and GNSS workflow.

# The "Total Solution"

From the company who brought you the best GNSS receiver on the planet, our latest innovation will allow you to break away from decades-old methods of measurement and positioning. Why employ a workflow designed for yesterday's gear?



See the video at www.javad.com for proof!

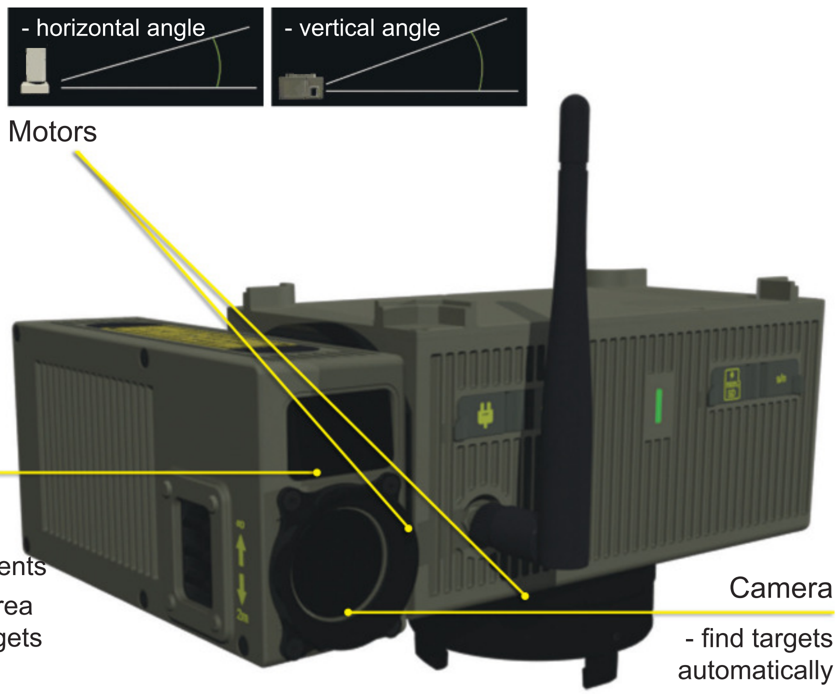
Why follow a workflow designed for yesterday’s equipment?

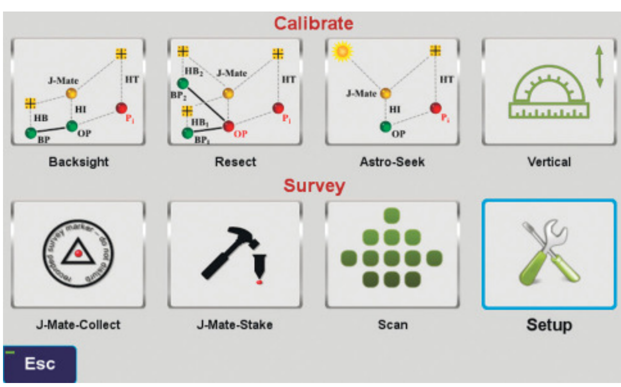
# This is J-Mate

J-Mate features a **camera** that can also find targets automatically, and a **laser module** for accurate distance measurements. It scans and examines the area around the intended target to ensure reliable identification. Two **precision encoders** measure vertical and horizontal angles to the target. Built-in **precision electronic inclinometer to level and monitor and correct continuously.**


## Take control with J-Mate + TRIUMPH-LS

Similar to using conventional total stations, to use the J-Mate you need first to establish its accurate position and calibrate its vertical and horizontal encoders. Then proceed to shoot the unknown points. This is similar to using any total station, but we have improved and automated the process.



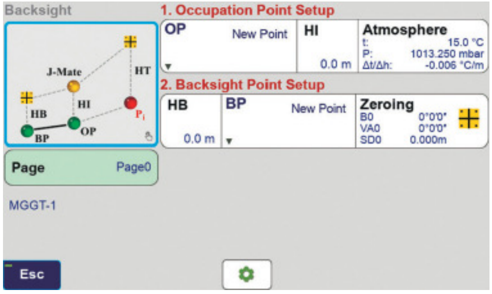

With J-Mate you can establish your occupied position via three different ways: 1) Backsight; 2) Resection; or 3) our new Astro-Seek (more of that later).

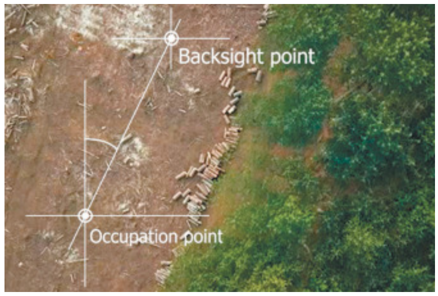
When you click the Setup icon of the J-Mate screen you get access to parameters that tunes J-Mate to your desire.

After the J-Mate is calibrated, you can proceed with your work as normal via the Collect or Stake icon.

# Backsight icon

If GNSS signals are available at the job site, click the J-Mate Backsight icon.

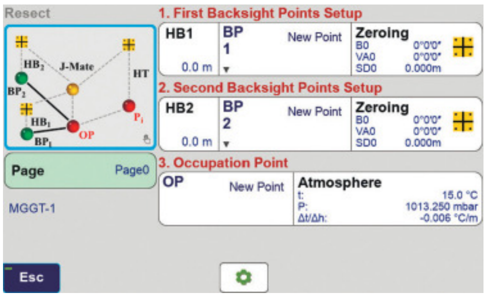


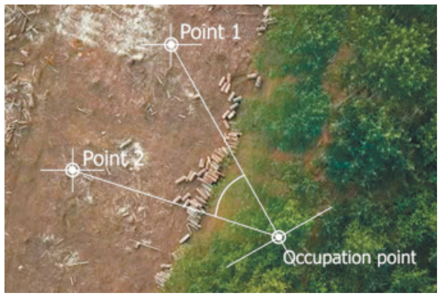



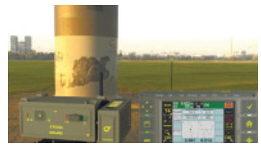

This screen appears which guides you to determine the accurate positions of the Occupation Point and the Backsight Point, to establish an azimuth and calibrate the J-Mate angular encoders.

# Resect icon

If GNSS signals are not available at the Occupation Point, click the “J-Mate-Resect” icon

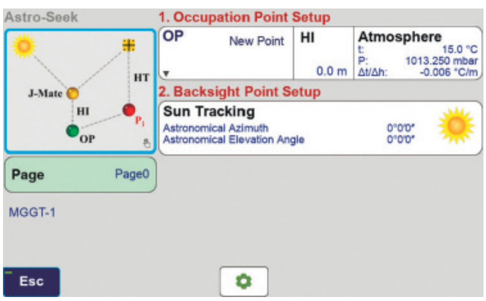


Shoot two or more known points to establish an accurate position and calibrate the encoders. Then continue to shoot the unknown points.

# Astro-Seek icon

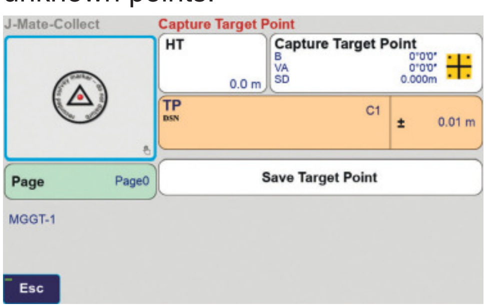



## And now our new feature!

We have added a new innovative feature to the J-Mate that it can automatically calibrate itself via its automatic Sun or other astronomical objects-Seeking feature.

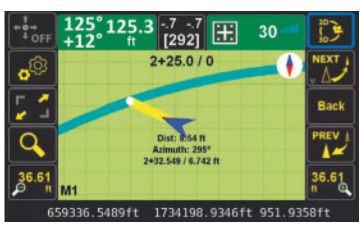
# J-Mate-Collect

After calibration is performed, click the J-Mate-Collect icon to shoot the unknown points.




# J-Mate-Stake

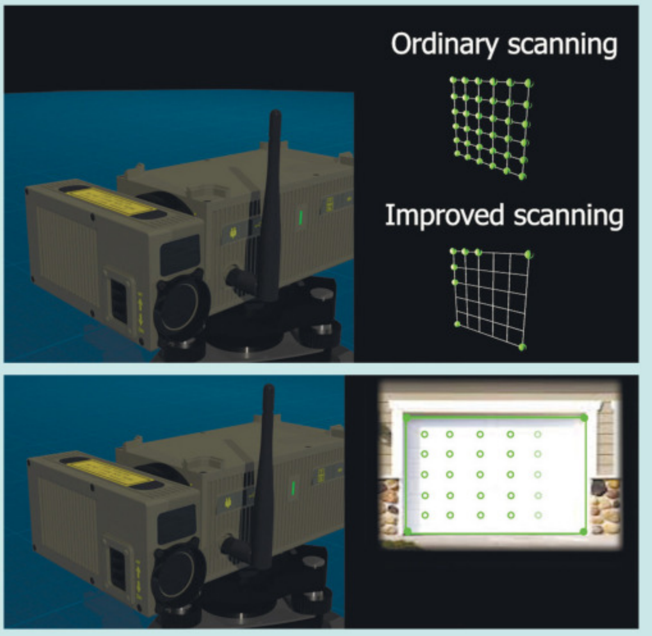
Click the J-Mate-Stake icon to use for stakeout.




The functions and features of the J-Mate stakeout are very similar to our conventional GNSS stakeout: RTK solutions guide you to the stake points. But with the J-Mate the camera follows the TRIUMPH-LS and then the encoders and laser measurements (shown on screenshots) provide guidance to the stakeout features. This is similar to Visual Stakeout and other useful and innovative features of our TRIUMPH-LS GNSS RTK stakeout.

## Smart laser scanner

J-Mate is also a camera-aided, smart laser scanner. The camera identifies redundant points that do not need to be scanned, but instead can be copied or interpolated from other readings without loss of information. That is, if the camera identifies a completely uniform flat area, it only scans the four corners of that area and interpolates in between. This feature can increase the effective speed of the scanner to much higher than its native 10-points-per-second speed.




The scanning feature can also be used to find items like wires and poles and “closest-in-view” items and shoot them automatically.

**Seize the day with J-Mate + TRIUMPH-LS**


**And all components fit in this small carrying case.**

So we have a “**Total GNSS**” with a “**Robotic Total Station**” and a “**Smart Laser Scanner**”. We call it our **“Total Solution”** and it can be operated by one person to perform jobs.

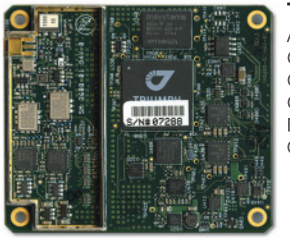
# and more...

**Available in all boards:** RAIM; On-Board Power supply; Reduced MinPad; RS232(A) 460 kbaud; USB; Fast acquisition channels; Advanced Multipath Reduction; 1PPS; Event; IRIG A/B; Up to 100 Hz update rate for real time position and raw data

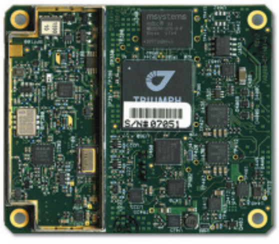

**TR-G2**
All-in-view
GPS L1; SBAS L1;
Galileo E1; BeiDou B1;
QZSS L1


**TRH-G2P**
All-in-view GPS L1;
SBAS L1; Galileo E1;
BeiDou B1; QZSS L1;
UART(A) 460 kbaud *

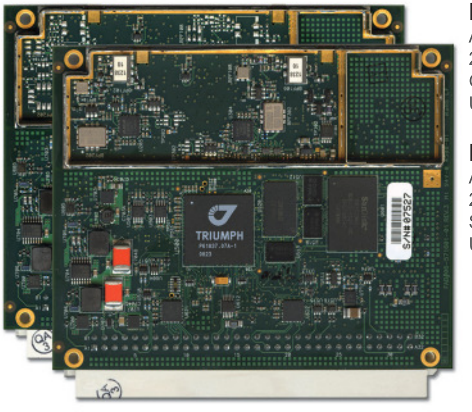
**TRH-G2**
All-in-view
GPS L1; Galileo E1;
BeiDou B1; QZSS L1;
UART(A) 460 kbaud **



**TR-G3**
All-in-view
GPS L1; SBAS L1;
GLONASS L1;
Galileo E1;
BeiDou B1;
QZSS L1

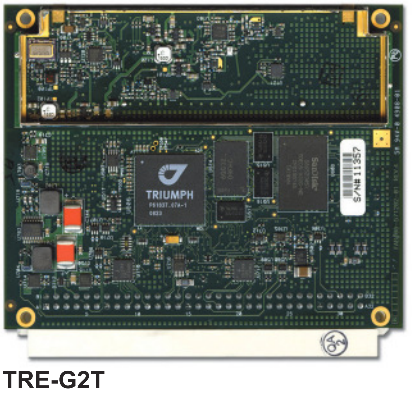


**TR-G2T**
All-in-view
GPS L1/L2/L5;
SBAS L1/L5;
Galileo E1/E5A;
BeiDou B1;
QZSS L1

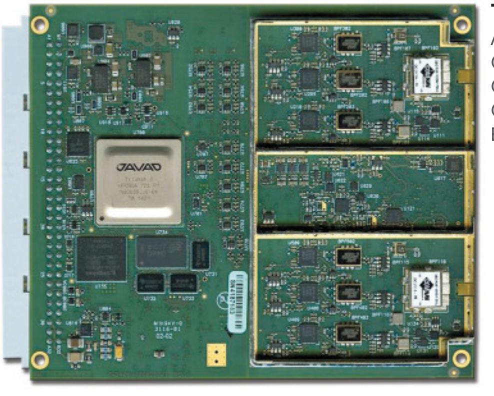



**Duo-G2**
All-in-view
2 groups of GPS L1; SBAS L1;
Galileo E1; Ethernet;
Up to 50 Hz Heading rate

**Duo-G2D**
All-in-view
2 groups of GPS L1/L2;
SBAS L1; Galileo E1; Ethernet;
Up to 50 Hz Heading rate

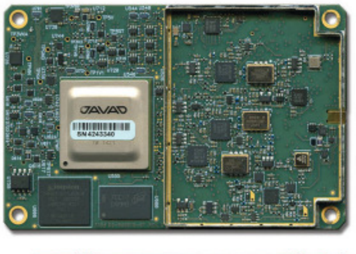


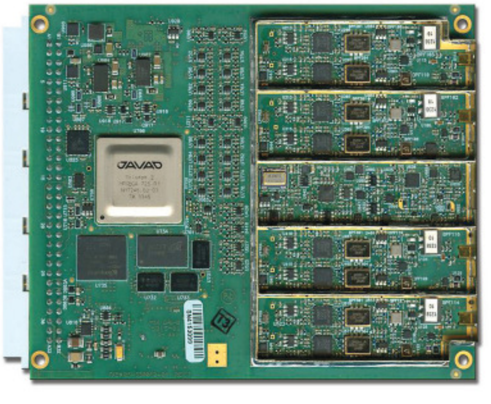

**TRE-G2T**
All-in-view GPS L1/L2/L5; SBAS L1/L5; Galileo E1/E5A; BeiDou B1; QZSS L1/L2/L5; Ethernet ***




**TRE_DUO**
All-in-view on 2 antennas
GPS L1/L2/L2C/L5;
Galileo E1/E5A/E5B/AltBoc;
GLONASS L1/L2/L3;
BeiDou B1/B2; QZSS L1/L2/L5

**TR-3N**
All-in-view GPS L1/L2/L2C/L5;
Galileo E1/E5A/E5B/AltBoc;
GLONASS L1/L2/L3; BeiDou B1/B2;
QZSS L1/L2/L5; SBAS L1/L5




**TRE-Quattro**
All-in-view on 2 antennas
GPS L1/L2/L2C/L5, Galileo E1/E5A/E5B/AltBoc; GLONASS L1/L2/L3;
BeiDou B1/B2; QZSS L1/L2/L5

** Not available in this board: Reduced MinPad; RS232(A) 460 kbaud; USB; Event; IRIG A/B*
*** Not available in this board: Reduced MinPad; RS232(A) 460 kbaud; USB; 1PPS; Event; IRIG A/B*
**** May be not applicable for simultaneous tracking of Galileo and BeiDou*


**TRE-3N**
All-in-view GPS L1/L2/L5
Galileo E1/E5A/E5B/AltBoc;
GLONASS L1/L2/L3;
BeiDou B1/B2; SBAS L1/L5;
QSZZ L1/L2/L5/LEX

**Spoofer detection available in all of our OEM boards.**

FR

# BeiDou AltBoc Signal is Being Tracked

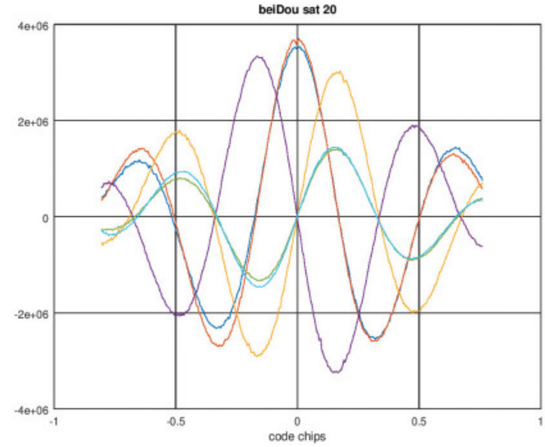
New phase 3 satellites of Chinese BeiDou satellite system have several new signals. ICD for B1C and B2A signals are available, while for the other signal(call it B2B) is not. We were able to track the signal that is on 1207140000 MHz frequency on BeiDou's satellites #32,33,34. Now we see that this signal is available on all recently launched BeiDou phase 3 satellites and we track it successfully.

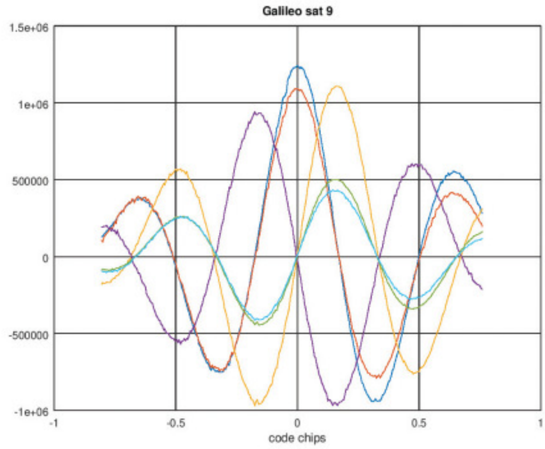
This B2B signal plus B2A signal together form altBoc(10,15) signal on 1191795000 MHz (call it BaltBoc). Assuming, that BOC parameters of this signal are similar to Galileo's, we managed to track it. Below graphs show BeiDou and Galileo (BaltBoc and altBoc) discriminator curves. They look identical.

Red and Blue - I of B2A(E5A) and B2B(E5b) sub-signals.

Purple and Yellow - Q of B2A(E5A) and B2B(E5b) sub-signals (their sum is zero).

Green and Aqua - dI (early-minus-late) of B2A(E5A) and B2B(E5b) sub-signals.

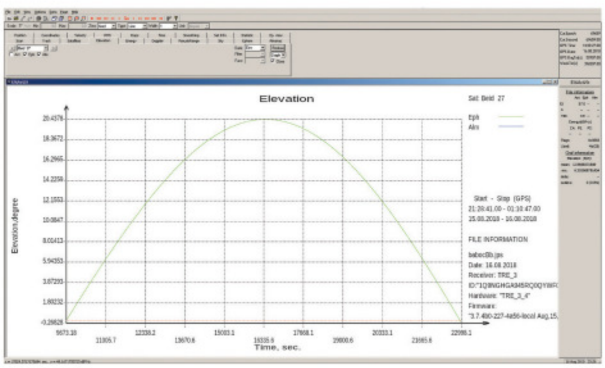


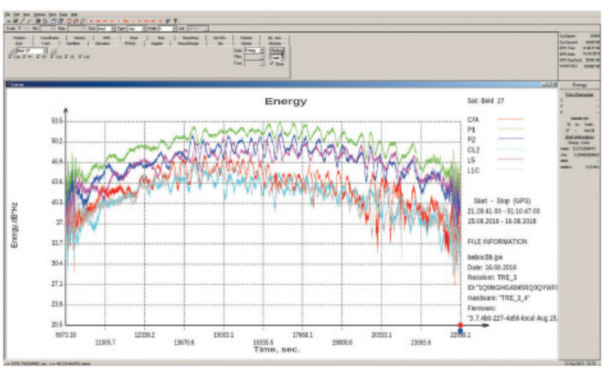



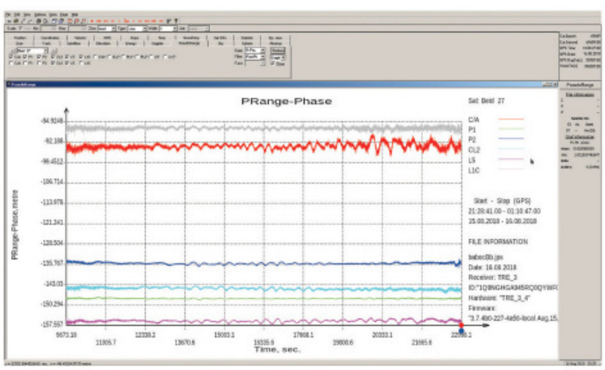

Next graphs show satellite #27 path: range-minus-phase (iono-free), energy and elevation.

Legend: C/A - B1 P1 - BaltBoc P2 - B2B L2C - B3 L5 - B2A L1C - B1C

Tracking of B2B and BaltBoc signal will be available on most of our receivers with 3.7.4 firmware or higher, which should be released by Mid October 2018.

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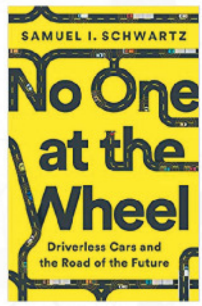



④

## 1. VESSEL MONITORING

**REAL-TIME LOCATION REPORTING**

Now type-approved by the U.S. National Marine Fisheries Service (NMFS) Office of Law Enforcement (OLE), the Addvalue iFleetONE-VMS provides commercial fishing vessels with a technologically advanced vessel monitoring system that satisfies regulatory requirements to routinely and securely report GPS positioning. The Addvalue iFleetONE-VMS, with its broadband capability, will enable fisheries management officials, biologists, researchers, analysts and NMFS Law Enforcement to have a cost-effective and suitable platform for applications that previously had been severely limited by available technologies.

**Network Innovations, www.networkinv.com**
**Addvalue Communications, www.addvaluetech.com**

## 2. VEHICLE-TO-EVERYTHING MODULE

**V2X UNIT READY FOR SMART CITY DEPLOYMENTS**

The MK5 On-Board Unit (OBU) is a fifth-generation low-cost, rugged module that can be retrofitted to vehicles for aftermarket deployment or field trials, and can also serve as a design reference for automotive production. The MK5 exchanges data at high speeds over extended distances, providing quick reaction times to potential hazards and safety-critical scenarios. Features include a dual IEEE 802.11p radio; a powerful processor running Cohda software applications; a GNSS receiver with lane-level accuracy; integrated security; hardware acceleration; and NXP chips with Cohda firmware. It supports DSRC (IEEE 802.11p), Wi-Fi (802.11a/b/g/n) wireless standards.

**Cohda Wireless, cohdawireless.com**

## 3. FLEET DATA PLATFORM

**PROVIDES A SINGLE ON-BOARD DATA COLLECTION HUB**

The SmartDrive SR3 and SR4 platforms provide a unified video and telematics data stream of time, location and driver and vehicle performance for third-party applications. Its single-box architecture and unified data stream eliminates redundancy across hardware, cellular connectivity, GPS modules, connections to the ECU and cabling. It also provides data alignment across the applications, unlocking new fleet performance insights and eliminating problematic data discrepancies.The platform provides analytics powered by SmartDrive SmartIQ; Geotab tracking, which delivers real-time and historical visibility to location, speed and geofencing information; Geotab regulatory compliance, including hours of service, driver vehicle inspection reports, International Fuel Tax Agreement (IFTA) recording and tax reports; and access and integration to Geotab Marketplace partners.

**SmartDrive Systems, www.smartdrive.net; Geotab, www.geotab.com**

## 4. AUTONOMOUS VEHICLES

**HARDCOVER BOOK**

In his new book *No One at the Wheel: Driverless Cars and the Road of the Future*, Transportation expert Samuel I. Schwartz (who coined the term "gridlock") describes how the driverless vehicle revolution will transform highways, cities, workplaces and laws across the globe. Every major car maker in the U.S., and abroad is working on bringing autonomous vehicles to consumers. The fleets are getting ready to roll and nothing will ever be the same; this book discusses what the future has in store. *272 pages, ISBN: 1610398653.*

**PublicAffairs,**
**www.publicaffairsbooks.com**

Photo: Wes Cole, courtesy JAVAD GNSS

# THE FUTURE OF PRECISION

## WITH FIVE GNSS CONSTELLATIONS

TODAY'S GNSS SATELLITES TRANSMIT ON THREE OR MORE CARRIER FREQUENCIES.

**The quality of the data in these signals from GPS, BeiDou, Galileo, GLONASS and QZSS reveals the expected measurement precisions. This article explores the noise of the range residual and ionospheric residual to indicate the oncoming capabilities.**

BY GETHIN WYN ROBERTS, CRAIG M. HANCOCK AND XU TANG

Today, four GNSSs transmit various codes on various carrier frequencies: the USA's GPS, Russia's GLONASS, Europe's Galileo and China's BeiDou. Most of the carrier phase and pseudorange data are available using civilian GNSS receivers. Improvements in signal quality as well as reliability of the satellites are foreseen through the generations, as well as the introduction of new signals, such as L1C, L2C, L5 carrier and codes, and M-codes, on top of the existing L1-C/A code and the P(Y) code on both L1 and L2. Improvements are also seen in boosting the transmitting power.

This article investigates the use of two approaches to analyze the relative noise in the various carrier phase and pseudorange observable for GPS, BeiDou, Galileo, GLONASS and Japan's Quasi-Zenith Satellite System (QZSS) augmentation. Two approaches analyze the relative noise in the observables: the range residual and the ionospheric residual. Both techniques can also be used to detect cycle slips.

### RANGE RESIDUAL

The range residual is simply the change from one epoch to the next in the difference in the range calculated using the pseudorange and the range calculated by the carrier phase on a specific frequency. The pseudorange values are scaled using the wavelength to an equivalent range in units of the carrier's cycles rather than meters. **EQUATION 1** illustrates the range residual between the pseudorange $\rho$ on a specific carrier frequency and the

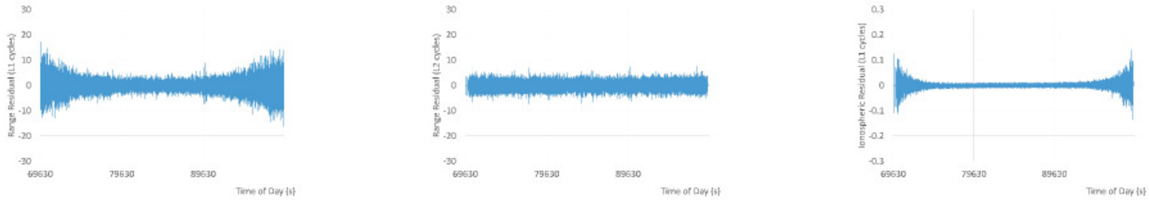



**FIGURE 1** L1 range residual (left) L2 range residual (center) and L1L2 ionospheric residual (right) for GPS PRN32 (Block IIA) satellite.

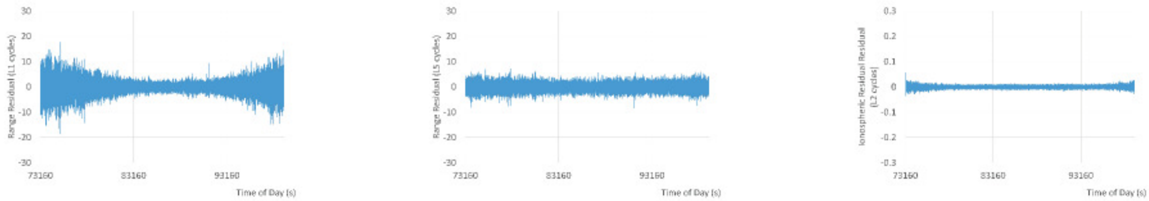



**FIGURE 2** L1 range residual (left) L5 range residual (center) and L2 (C code) L5 ionospheric residual (right) for GPS PRN01 (Block IIF) satellite.

All figures supplied by the authors.

carrier phase observable φ, using the wavelength λ of the carrier to scale the pseudorange. The values of these observables are compared between adjacent epochs.

$$RR = (\rho / \lambda) - \varphi \tag{1}$$

Two adjacent epochs are used, as then the integer ambiguity value, as well as the ionospheric and tropospheric errors, and satellite and receiver clock errors are the same, or negligibly different at such small (<1s) epoch intervals. Therefore, these are all canceled out, and the resulting value is the measurement receiver and observable noise. The pseudorange observable will be significantly noisier than the carrier phase observable, therefore this method is a good way to calculate the measurement noise for the pseudoranges.

## IONOSPHERIC RESIDUAL

If the carrier waves traveled only through a vacuum, then a phase observation from a specific satellite to a specific GNSS receiver could be scaled and converted to an equivalent phase measurement on another frequency using the frequencies of the carrier waves. However, as the signal passes through the ionosphere, systematic errors that are frequency dependent are introduced, so it is not possible to directly convert from one carrier phase value to another for a specific range measurement. The error is known as the ionospheric residual, and this will change slowly over time as the satellite passes overhead and the ionosphere being passed through changes, and also as the ionosphere slowly changes its characteristics over time, mainly due to the sun's activities.

**EQUATION 2** shows the calculation, using L1 and L2 carrier phase readings and corresponding frequencies, used to calculate the ionospheric residual. Again, the difference in the ionospheric residual values between adjacent epochs is used, as in the same way as the range residual values, external noise sources are eliminated.

$$IR = \phi_{L1} - \frac{f_{L1}}{f_{L2}}\phi_{L2} \tag{2}$$

## RESULTS

The results presented here are a subset of a much larger set. **FIGURE 1** illustrates the range residuals for L1 and L2 as well as the L1L2 ionospheric residual for PRN32 (Block IIA satellite). **FIGURE 2** illustrates the L1 and L5 range residuals and the L2 (C-code) L5 ionospheric residual for PRN01 (Block IIF satellite).Both figures' data are for the complete passing of the satellites from horizon over and back down again.The data for PRN32 is all that exists in the datafile, as this satellite only transmits L1 CA code and P(Y) code, as well as L2 P(Y) code, and corresponding carrier values.PRN01 is a block IIF satellite, and data for L1 CA code, L2 P(Y) code as well as L2 C-code, L5 code, and corresponding carrier phase values are recorded in the datafile. The block IIF satellites can result in four range residual values and five ionospheric residual combinations. Figure 2 only illustrates three of these combinations.The data were obtained from the Curtin University GNSS repository on Sept. 1, 2015, gathered at a 1-Hz epoch interval; 29,908 epoch of data were gathered for PRN32, and 26,073 epochs for PRN01.

It can be seen from these figures that the L1 range residuals are similar in characteristics for both PRN01 and PRN32.The values are noisy at the start and the end of the time series, indicating that the CA code is more prone to noise at low elevations.Comparing these to the L2 (PRN32) and L5 (PRN01) range residuals, we can see that both the L2 and L5 range residuals are not as prone to low elevation noise. Also, the two L2 and L5 range residuals

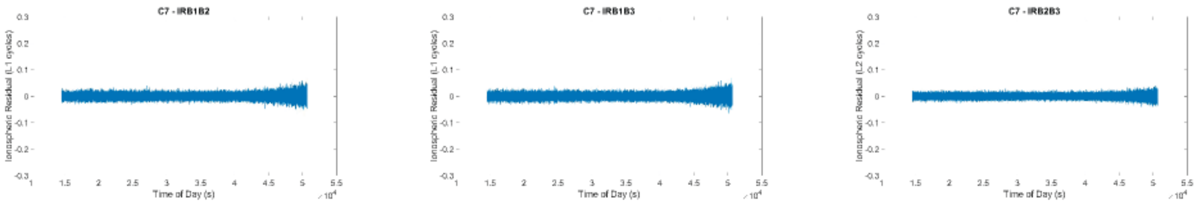



**FIGURE 3** **Ionospheric residual results for BeiDou PRN07 (IGSO) for combinations B1B2 (left), B1B3 (center), B2B3 (right).**

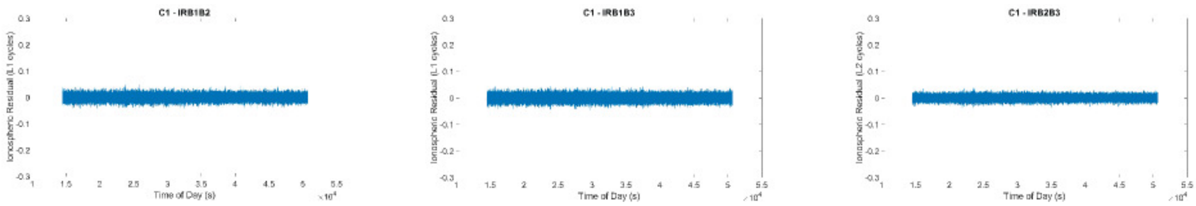



**FIGURE 4** **Ionospheric residual results for BeiDou PRN01 (GEO) for combinations B1B2 (left), B1B3 (center), B2B3 (right).**

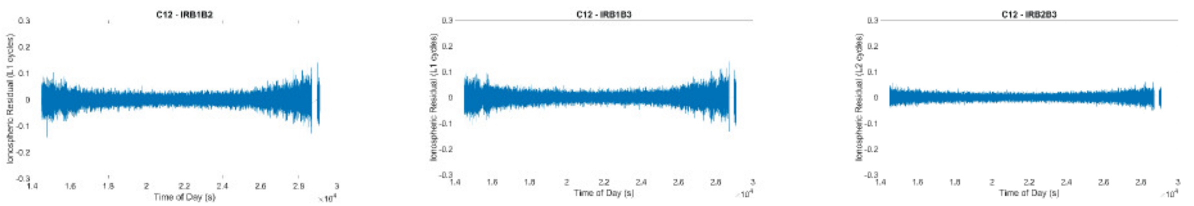



**FIGURE 5** **Ionospheric residual results for BeiDou PRN12 (MEO) for combinations B1B2 (left), B1B3 (center), B2B3 (right).**

are visually similar in characteristcs. By comparing the L1L2 and L2L5 ionospheric residuals (Figure 1, right, and Figure 2, right), we can see that the L1L2 combination is slightly noisier than the L2L5, in particular at low elevation angles.

If we compare BeiDou ionospheric residual results, we can see the comparison of noise on the three ionospheric residual combinations, B1B2, B1B3 and B2B3, as well as the results from the three types of satellite orbits, ie MEO, IGSO and GEO. **FIGURE 3** illustrates the ionospheric residual results for PRN07 (IGSO) for the three frequency combinations, from data gathered on a static pillar located on top of the University of Nottingham Ningbo China's Science and Engineering Building.

**FIGURE 4** illustrates the ionospheric residual results for PRN01 (GEO) for the three frequency combinations.

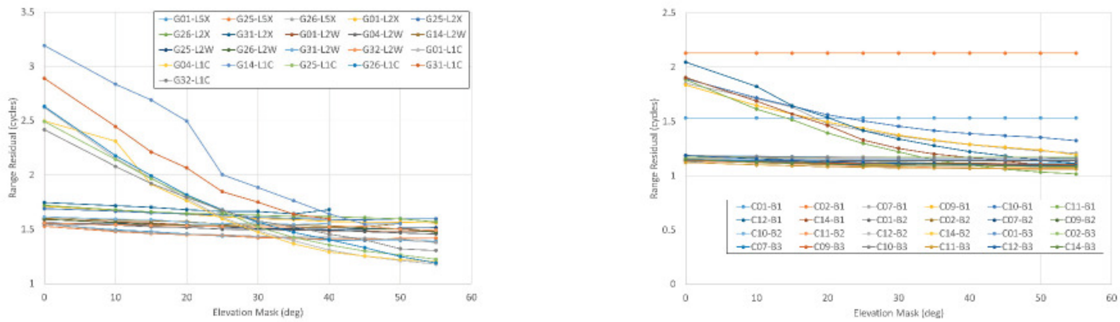
**FIGURE 5** illustrates the ionospheric residual results for PRN12 (MEO) for the three frequency combinations. Here it can be seen that the B2B3 combination is generally less noisy than the B1B2 and B1B3. In addition to this, it can be seen that when the MEO and IGSO satellites are at lower elevation angles, the observables also become noisier. The GEO satellites have a constant elevation angle, and do not experience this phenomenon.

## DETAILED RESULTS

The data, gathered on a single GNSS receiver located at the University of Curtin's GNSS research center, was downloaded in BINEX format and converted into RINEX 3.02 format using RTKLIB software. Software was developed by the authors in Matlab in order to interrogate the data files and implement the range residual and ionospheric residual algorithms. RINEX 3.02 format was chosen due to its compatibility with multi-GNSS and multi-frequencies.

Results are presented for both ionospheric residual and range residual results for various GNSS. These results have been calculated with varying elevation mask angles, ranging from 0° to 55 ° at 5 ° intervals. The RMS values of the resulting ionospheric residuals and range residuals were calculated and plotted against the respective elevation mask angle for each satellite and frequency combinations. This illustrates the influence of the elevation mask angle used on the results.

Typically, tens of thousands of epochs of data were used for every plotted point in the following figures. Further to this, not only are the results for the various frequencies and frequency combinations for the various GNSS illustrated, but also the various satellite types, MEO, GEO and IGSO, and various satellite Blocks for GNSS. GPS Block IIA (PRN04 and PRN32), Block IIR (PRN14), Block IIR-M (PRN31) and Block IIF (PRN01, PRN26, PRN25) data were all analyzed. Thus, the comparison of the various frequencies within each satellite system are illustrated, as




**FIGURES 6A AND 6B** **RMS range residual results for GPS (left) and BeiDou (right).**

well as the variations by comparing the various satellite constellation types and the various generations of GPS satellites. The BeiDou data illustrated are MEO (C12, C14, C11), IGSO (C09, C10, C07) and GEO (C01, C02). The data used were gathered on Sept. 1, 2015, in order to include GPS Block IIA satellites (PRN04 and PRN32). PRN32 was retired in June 2016, and PRN04 was taken out of active service in November 2015, but the satellite was reactivated in March 2018, this time broadcasting PRN18.

**FIGURE 6** illustrates RMS of the range residual results for GPS (a), BeiDou (b), Galileo (c), GLONASS (d) and QZSS (e) respectively. These figures have been drawn so that the y-axis ranges are the same for each, hence illustrating the relative values.

Figure 6A illustrates the range residual results for GPS. It can be seen that the L1 CA code results are the noisiest, with PRN14 being the noisiest, followed by PRN31, PRN26, PRN01, PRN04, PRN25 and PRN32. It can also be seen with these results that lower elevation angle mask increases the noise level. Both the L2 and L5 code results are less noisy. Looking at the detail, the L5 code results is less noisy than the L2 and affected less than the L1 results by the changes in elevation mask angles

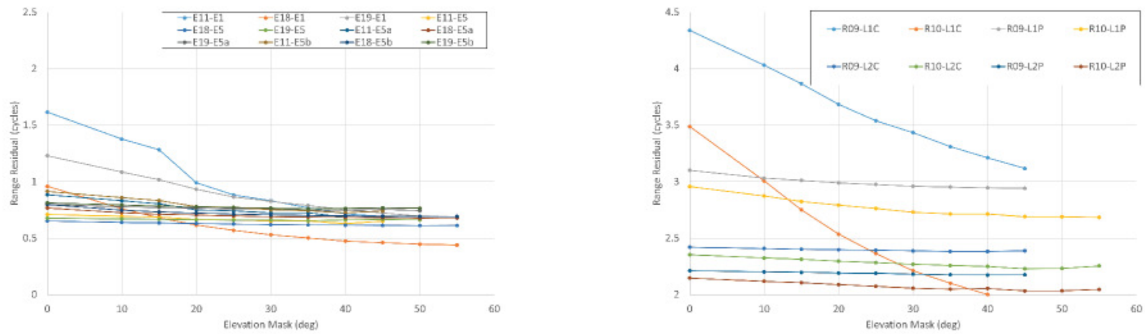



**FIGURE 6C AND 6D** **RMS range residual results for Galileo (left) and GLONASS (right).**

used. Interestingly enough, the data file includes both the L2 P(Y) code and L2C code results. L2C only exists on the Block IIR-M and Block IIF satellites. The L2C code results are generally noisier than the L2 P(Y) code.

Figure 6B illustrates the results for the range residuals for the BeiDou satellites. Here it can be seen that the B1 code is affected more by low elevation mask angles than B2 and B3. It can also be seen that both the geostationary satellites' B1 results stand out, with satellite C02 being noisier than C01. The B2 and B3 values for both these GEO satellites are bunched up with the majority of the other results towards the middle of the figure. The pairs of B2 and B3 results for the GEO satellites are close to each other in values, and the pairs of B2 and B3 results for the other satellites are also close to each other. It can also be seen that the range residual results for BeiDou are generally less noisy than than GPS, in units of cycles.

Similarly, for Galileo, Figure 6C, the E1 results are worst, and affected more by low elevation masks. Again, generally the Galileo results are seen to be improved over GPS. The GLONASS results, Figure 6D, illustrate that the L1C results are generally noisier, and then the L1P, followed by L2C and L2P. PRN09 is also consistently generally noisier than PRN10. Finally, Figure 6E illustrates the results for

**These high-precision survey receivers are among those offering multi-GNSS capability.**

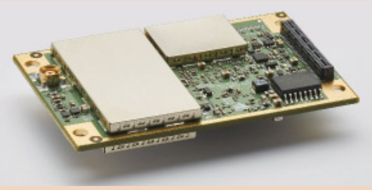
## COMNAV


The **K705** is a full-constellation triple-frequency GNSS OEM board featuring superior performance and compact design. With the QUANTUMTM technology and second-generation SinoGNSS ASIC chip inside, the K705 can optionally track signals from BeiDou and Galileo. Ensuring the K705 is easy to integrate for diverse applications, the K705 GNSS OEM board provides an excellent level of accuracy, strong compatibility and compact design. The K705 has been designed to use a shielded module with 50mm×40mm×9mm form factor; this design ensures that the high-quality GNSS signals are protected from the source of EMI on the host platform.

## JAVAD


The **Triumph-LS** is an RTK land survey machine providing visual stake-out, navigation, six parallel RTK engines, more than 3,000 coordinate conversions, advanced CoGo features, rich attribute tagging on a high-resolution, large, bright display. It combines a high performance 864-channel GNSS receiver, all-frequency GNSS antenna and a modern-featured handheld. It also has versatile attribute tagging, feature coding and automatic photo and voice documentation. The TRIUMPH-LS automatically updates all firmware when connected to a Wi-Fi internet connection.

## NOVATEL



The **OEM7700** receiver provides high-precision solutions using 555 channels to access multi-frequency measurements from GPS, GLONASS, Galileo, BeiDou and QZSS. The receiver also features a variety of interface options, including 5 serial and 2 CAN ports and ethernet coms lines to facilitate system integration. Adding RTK delivers 1-cm accuracy, while TerraStar-C Pro corrections offer 2.5-cm accuracy without a base station. NovAtel's Interference Toolkit brings identification, illustration and mitigation of nearby noisy interference sources to this high-performance receiver. These features combine to deliver optimal positioning for space-constrained applications.

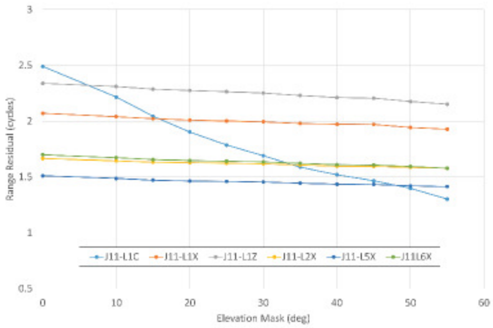



**FIGURE 6E** **RMS range residual results for QZSS.**

Photo: Septentrio

**UAV SURVEY** **operations can also benefit from multi-GNSS receivers.**

QZSS. Again, L1C is the noisiest and affected most by low elevation mask angles.

**FIGURE 7** illustrates the ionspheric residual results for the same satellites as Figure 6. This time, however, the resulting ionospheric residual values are calculated using pairs of data from the same satellite on different carrier frequencies. The range residual results compare the code and carrier from specific satellites and frequencies. Figure 7(a) shows that the ionospheric residual results are affected by low elevation masks, and that the L1L2CW (L1 CA code and L2 P(Y) code available on all the satellites) combinations are the noisiest, followed by L2L5WX (L2 P(Y) code and L5 code available on Block IIF satellites, PRN 26, PRN01, PRN25), followed by L1L2CX (L1 CA code and L2 C code available on Block IIF and Block IIR-M satellites, PRN31, PRN26, PRN01 and PRN25), followed by L1L5CX (L1 CA code and L5 code, Block IIF satellites, PRN01, PRN25, PRN26) and finally the least noisy were the L2L5XX results (L2 C code and L5 code available on Block IIF satellites, PRN26, PRN25 and PRN01).

Figure 7(b) illustrates the BeiDou ionospheric residual plots, illustrating that satellite C14 is much noisier for all three combinations of B1B3, BB1B2 and B2B3 in that order. The B1B2 combinations for the satellites are generally the noisiest, and then the B1B3 and B2B3 combinations are intertwined. The Galileo results again illustrate that the E1 combinations are generally noisier, and again we see the effect of low elevation angle masks, Figure 7(c). Generally, however, the Galileo results are less noisy than GPS, as are the BeiDou results.

The GLONASS results are again generally the noisiest, and again PRN09 is noisier than PRN10, with the L1P combinations being noisier, Figure 7(d). Figure 7(e) for QZSS shows that there are generally two groups of results. The upper set consists of L1L2ZX, L1L5ZX, L1L2XX, L1L5XX, L1L6ZX and L1L6XX from highest to lowest noise respectively. The lower, less noisy, group consists of L1L2CX, L1L5CX, L2L5XX, L2L6XX, L1L6CX and L5L6XX from highest to lowest noise respectively. Further details about the various codes and carrier values can be found in the RINEX 3.02 manual produced by the IGS.

## CONCLUSIONS

These preliminary results illustrate that there are differences in the noise values for various GNSS, frequencies as well as satellite generations and orbit types. It can be seen that generally L1, B1 and E1 have noisier results, and are affected moreso by low elevation mask data, and hence multipath. It can also be seen that newer generations of satellites do indeed produce better quality data.

Some specific satellites produce lower quality data such as GLONASS PRN09 and BeiDou C14. This could be due to multipath produced at the satellite.

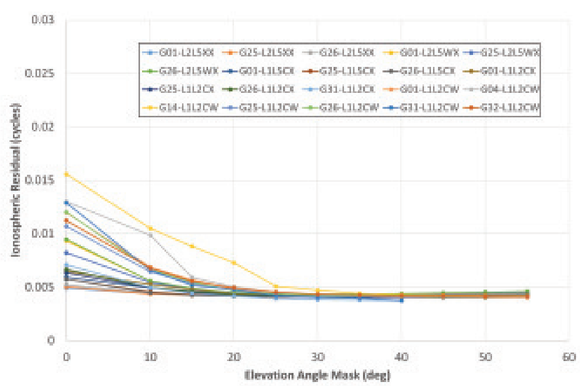
Today roughly 100 GNSS transmit data, and typically users can gather data from 30 to 50 at any time. Positioning requires nowhere near this number of satellites, therefore decisions are needed as to which satellites and which data to use in a positioning solution. Our findings imply that our approach could be used in such decision-making in GNSS processing software, helping the software to choose the optimum satellites to draw from in a positioning solution.

## ACKNOWLEDGMENTS

This work described in this article was first presented at the FIG 2018 conference held in Istanbul, Turkey. The authors acknowledge the use of data supplied from the Curtin University GNSS Centre.

## MANUFACTURERS

The GNSS receiver used is a Trimble NET R9, and the antenna is a Trimble TRM 59800.00 SCIS choke ring antenna. A ComNav K508 GNSS receiver supplied some of the BeiDou results.



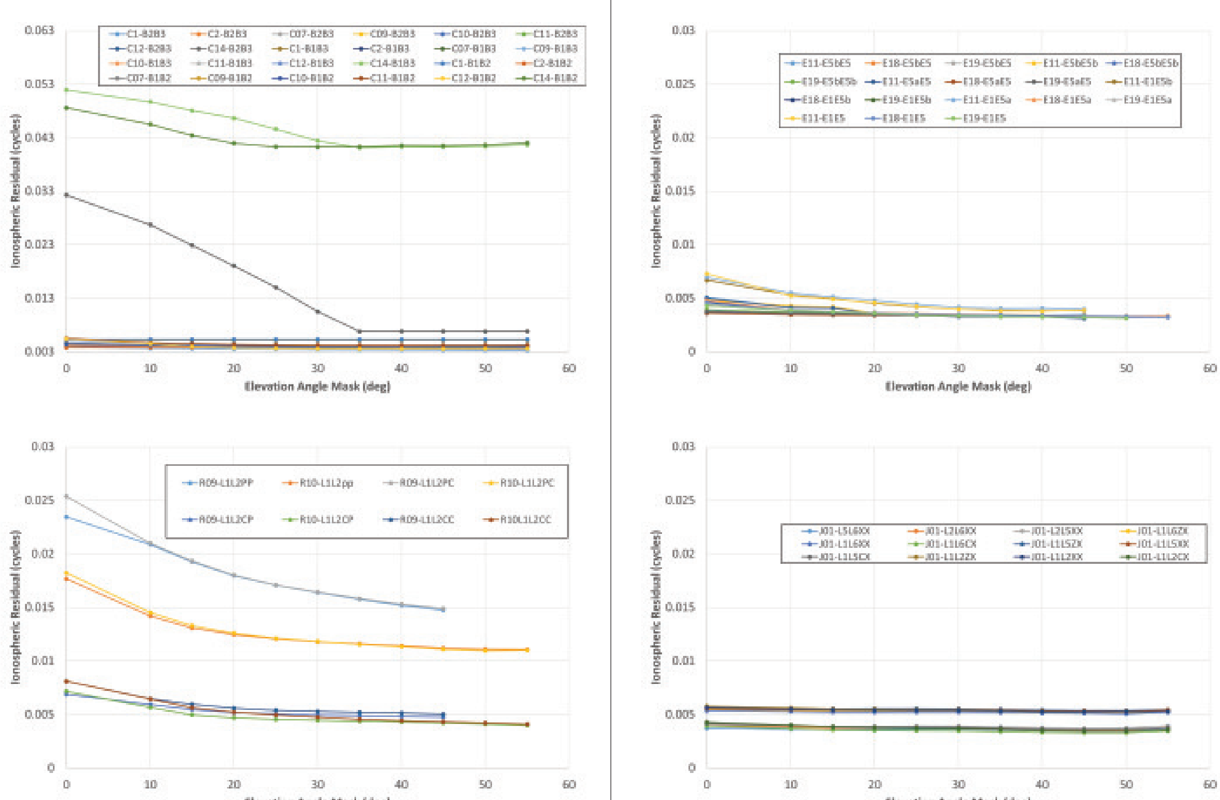




**FIGURE 7** **Ionospheric residual results for GPS (top), BeiDou (mid-left), Galileo (mid-right), GLONASS (lower left) and QZSS (lower right).**

Photo: Skycatch, Swift Navigation

**INDUSTRIAL UAV applications such as construction draw benefits from multi-GNSS receivers' capabilities.**

Photo: Trimble

**MOUNTAINOUS AREAS present special problems for surveyors, overcome by the expanded availability of multi-GNSS.**

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**XU TANG** is a research fellow at the University of Nottingham, Ningbo, China. He holds a PhD from Nanjing University.

Photo: JAVAD GNSS

**These high-precision survey receivers offer multi-GNSS capability.**

## TOPCON

The **HiPer VR** is compact, light and packed with advanced GNSS technology in a design built to withstand the harshest field environments. Using Topcon's advanced GNSS chipset with Universal Tracking Channels technology, the HiPer VR automatically tracks every satellite signal above, now and into the future.

## TRIMBLE


The **Alloy** reference receiver is ready for real-time GNSS networks worldwide. With a rugged IP68 housing and multi-constellation satellite tracking, it can be used as a campaign receiver for post-processing, a CORS receiver, a portable base station for RTK applications, and even a scientific reference station. Leveraging Trimble RTX technology, the Alloy receiver can derive its position at centimeter-level accuracy in real time. Combined with Trimble's advanced Sentry monitoring technology, the receiver will automatically notify the operator of any status change including positional changes. The technology ensures users are receiving the most accurate correction data.

## UNICORE


The **UB4B0M** is an all-constellation, multi-frequency compact RTK board with integrated inertial navigation. The board is particularly suitable for high-precision surveying and positioning. Based on a proprietary Nebulas-II GNSS system-on-chip, the board provides centimeter-level RTK positioning result with low power consumption.

- 71 mm x 46 mm
- Supports GPS L1/L2/L5 + BDS B1/B2/B3 + GLONASS L1/L2 + Galileo E1/E5a/E5b
- Millimeter-level carrier-phase observation
- Stable, reliable high-precision RTK positioning
- Low-elevation tracking and multipath mitigation

MARKET WATCH

Segment Snapshot: Applications, Trends & News

OEM

# JLT Micro-Transcoder Provides Firewall Retrofit

The tiny, new Micro-Transcoder is a full-constellation, stand-alone, real-time 10-channel GPS simulator by Jackson Labs Technologies Inc. (JLT). The unit can act as a GPS firewall to identify and block jamming and spoofing attempts, and to provide an alternate PNT source during fully GPS-denied operation.

The one-inch-square Micro-Transcoder module allows glueless retrofitting of existing GPS equipment by upgrading systems with secure and assured positioning, navigation and timing (PNT) capability. It achieves hardening of the customers' GPS equipment by splicing the unit in between the existing antenna and the users' GPS receiver.


Photo: JLT

**RF Encoder.** It takes the output of any secure PNT source — inertial navigation system (INS), SAASM, M-code, Iridium STL, or concurrent GNSS receiver — and encodes (RF modulates) the baseband PNT and UTC timing information into a standard GPS L1 RF signal. This RF signal can then be received by any legacy GPS receiver.

The unit is based on JLT's CLAW GPS simulator and RSR transcoder technologies, and includes a stand-alone full-constellation 10-channels real-time GPS simulator with integrated high-stability timing reference, as well as an internal GNSS receiver for monitoring the RF output signal for quality and accuracy.

The unit will transmit a standard UTC time, position, velocity and heading GPS L1 RF signal by simply applying 3.3V power to it.

**Windows App.** The Micro-Transcoder can also be operated as a generic high-performance GPS simulator with built-in GPS Disciplined Oscillator (GPSDO), and is supported by a comprehensive free Windows application program downloadable from the JLT website.

The Windows application allows control of all the simulation aspects, creating and storing simulation

*See* **TRANSCODER**, *next page.*

# Septentrio Launches Mosaic High-Precision Module

Septentrio has launched the Mosaic high-precision GNSS receiver module.

Despite its compact size (31 x 31 x 4 millimeters, 1.29 x 1.29 x 0.15 inches), the Mosaic module supports more than 30 signals from all six GNSS constellations, L-band and various satellite-based augmentation systems, the company said.

As a multi-band module tracking all GNSS satellites in view, it is also designed to support future GNSS signals.

It also supports correction services, and uses real-time kinematic (RTK) technology, together with Septentrio's algorithms, to guarantee maximum accuracy and availability. The surface-mount design of Mosaic is optimized for automated assembly and ease of integration, with a full library of well-documented and flexible interfaces.

Mosaic provides RTK positioning with a power consumption of 0.6-1 W, and requires no or minimal additional components for the design-in, making it suitable for mass market UAV, autonomous and robotics applications.

**Threat Defense.** Due to the natural weaknesses of distant GNSS signals and a crowded radio-frequency spectrum, GNSS-based services are vulnerable to unintentional radio-frequency interference (RFI). They are also vulnerable to intentional RFI, attacks intended to disrupt receivers by means of counterfeit GNSS-like signals (known as spoofing), and to intentional transmission of RF energy to mask GNSS signals with noise (known as jamming).

To defend against these threats, Mosaic features Septentrio's AIM+ technology. AIM+ can suppress the widest variety of interferers, from simple continuous narrowband sig-

*See* **MOSIAC**, *next page.*

## OEM

**TRANSCODER**, *continued from previous page.*
vector commands, and testing user equipment for leap-second and GPS week rollover event compatibility to identify weaknesses in user equipment.

The unit does not require a PC to be connected to it to function. This makes embedded operation as easy as applying power, and connecting the units' RF output to the antenna input of any GPS receiver.

**Legacy Upgrades.** By generating a legacy RF GPS signal from any secure PNT source, the Micro-Transcoder allows users to maintain their investment in fielded legacy GPS equipment. Example applications include retrofitting financial transaction time servers with CSAC or rubidium atomic clock holdover capability, and adding GPS RF output capability to concurrent GNSS receivers to allow reception of L1, L2, L3, L5 GPS, GLONASS, Galileo, BeiDou, QZSS, Iridium STL, or any other satellite-based navigation signal to legacy GPS receivers.

It can also be used to add inertial navigation system (INS) capability to vehicles and aircraft. ◍

**MOSAIC**, *continued from previous page.*
nals to complex wideband and pulsed jammers, the company said. In addition, the integrated spectrum analyzer allows the RF environment around any Mosaic module to be viewed in real time in both time and frequency domains.

Photo: Septentrio

Effective interference countermeasures against threats to GNSS signals also require constant knowledge of the changing RF environment.

The Mosaic module helps analyze these threats by continuously and automatically monitoring the GNSS frequency spectrum to detect, characterize, log and mitigate interference events when needed. ◍

SURVEY

# Oscar Follows David in Tersus GNSS Portfolio

Tersus GNSS Inc. has launched Tersus Oscar, its new generation GNSS real-time kinematic (RTK) system.

Oscar is an all-in-one GNSS receiver that can be used as rover or base system. Paired with a Tersus TC20 controller or A11 mobile terminal, Oscar can efficiently meet customer application requirements for a surveying solution. Oscar is an advanced version of the David, introduced in 2017.

Oscar supports calibration-free tilt compensation function, meaning a leveling pole is no longer required. Configuration is made easy with a 1.3-inch interactive screen. With an internal high-performance multi-constellation and multi-frequency GNSS board, the Oscar GNSS receiver can provide high accuracy and stable signal detection, the company said.

The high-performance antenna can speed the time to first fix and improve anti-jamming performance. The built-in large capacity battery can support up to 10 hours of fieldwork.

A radio module in the package supports long-distance communication. With its rugged housing material, Oscar is protected from harsh environments.

## OSCAR HIGHLIGHTS

- Supports multiple constellations and frequencies
  - GPS L1/L2
  - GLONASS L1/L2
  - BeiDou B1/B2
  - GALILEO E1, E5B
  - SBAS L1C/A
- 410–470MHz UHF, 4G network
- Wi-Fi, Bluetooth, NFC
- More than 20 working modes including CORS, UHF, Ntrip server
- Tilt compensation without calibration
- 16GB internal storage
- Up to 10 hours of battery life


Photo: Tersus GNSS

# GeoCue Enables Third-Party GNSS Use with Phantom 4 RTK

GeoCue Group (via its wholly owned AirGon subsidiary) has completed the integration of the new DJI Phantom 4 Pro RTK (P4R) into its AirGon Sensor Processing Suite (ASPSuite).

ASPSuite is a post-processing solution for GeoCue's Loki direct geopositioning system for DJI and other manufacturer's drones.

ASPSuite enables integration of the P4R with third-party L1/L2 GNSS base stations such as systems from Septentrio, Leica, Trimble, TopCon, CHC and others in a high accuracy Post-Process Kinematic (PPK) workflow. In addition to PPK processing, ASPSuite includes support for options often required in engineering-grade surveys such as:

- vertical transforms (such as ellipsoid to country-specific geoids)
- creation of and transformation between collection datums and local coordinate systems (site calibration)
- application of antenna static and dynamic lever arm corrections
- full support for Loki direct geopositioning systems.

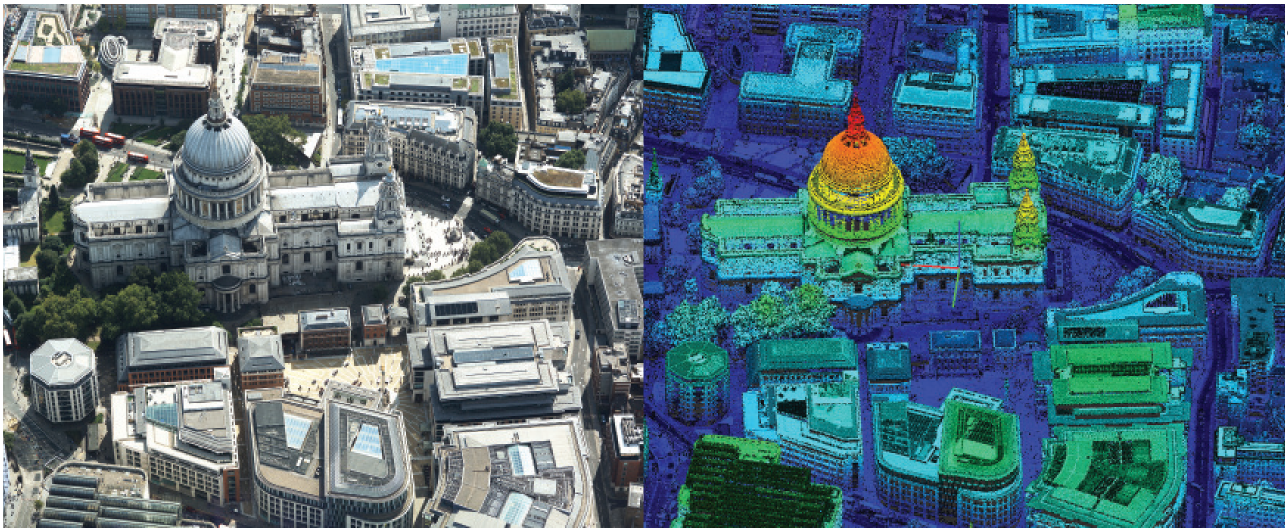
Photo: GeoCue

DJI PHANTOM 4 **Pro with Loki PPK system.**

The DJI D-RTK-2 base station (optionally available) for the P4R can only be used in RTK mode, and then only if it is being sited on a known location. The D-RTK-2 does not currently allow access to an observation file, preventing it from being stationed using an online positioning service such as OPUS, AUSPOS, Canadian Geodetic Survey services and so forth. An additional consideration in our integration into ASPSuite was that professional surveyors already have survey kit that they need incorporated into this workflow.

GeoCue is offering camera calibration services for the P4R for customers who wish to do minimal or control-free high-accuracy mapping projects (the DJI "calibration" is an image de-warping algorithm, not a proper photogrammetric calibration). A test of a GeoCue-calibrated P4R using an OPUS-positioned base station and ASPSuite achieved about 4-cm horizontal and 5-cm vertical network accuracy (RMSE) with no ground control points.

# MAPPING


Images: Bluesky

ST. PAUL'S CATHEDRAL **in London was captured in RGB (left) and lidar point-cloud data.**

# Bluesky with CityMapper Captures Cities in 3D

Aerial survey company Bluesky International Ltd. is using the Leica CityMapper to capture major cities throughout the United Kingdom.

CityMapper is a hybrid airborne sensor combining vertical and oblique imagery with 3D laser scanning designed for 3D city modeling and urban mapping.

Using the CityMapper, Bluesky was able to capture parts of London, Manchester and Birmingham as well as Brighton, Bristol, Cambridge, Norwich, Nottingham and Oxford. Bluesky intends to increase its coverage by capturing additional towns and cities across the UK and Ireland in 2019.

According to Bluesky, this is the first time the technology has been used commercially in the UK to this level. The captured city data is available from Bluesky and Leica Geosystems, part of Hexagon, in its constituent components of vertical orthorectified aerial imagery, oblique photographs and lidar point cloud data. Plans are in place to also include the imagery in the HxGN Content Program.


Photo: Leica

THE CITYMAPPER SENSOR **is designed for 3D city modeling and urban mapping.**

The combination of multiple survey-grade cameras and lidar enables the simultaneous capture of data for the automatic creation of highly accurate and detailed citywide 3D models, with one sensor, according to Bluesky.

Previous 3D models have either been prohibitively expensive for use across larger areas or of insufficient detail or accuracy. The CityMapper sensor enabled efficient, cost-effectivecapture of highly detailed and accurate data, and could make possible widespread use of 3D models possible.

CityMapper includes a traditional vertical camera as well as survey-grade oblique cameras. The sensor also includes high-performance lidar technology to accurately collect elevation data even into the shadows, which are common in urban environments and make photo-based data collection difficult.

The CityMapper sensor also collects color infrared data, which can be used to aid greenspace mapping and vegetation studies.

Applications of the new Bluesky 3D models are expected to include urban planning, line-of-sight analysis, new development visualizations and environmental modeling, as well as potentially 3D fly throughs and virtual reality experiences. Early adopters of the data include architects, planning consultants and other map publishers.

UAV

# UAV Can Lift 200 Pounds

Mobile Recon Systems is offering an unmanned aerial vehicle that can lift more than its own weight.

At 78 pounds, the Dauntless multi-rotor UAV has lifted an additional payload of 100 pounds as a tethered quadcopter, the company said. It is designed to lift more than 200 pounds as an octocopter, with a generator-powered flight time of several hours.

The multi-functional platform can carry up to 160 pounds of supplies in a climate-controlled transport box. It can be outfitted with sensors, radiation detectors, radar, weather stations, multi-spectral, thermal and infrared cameras, and other devices, and can perform eight or more different functions at once. Users can swap or combine devices to meet their needs.

Uses include border and perimeter security, natural disaster response, medical emergency first response, routine inspections and mapping.

The Dauntless has a full 3K (military-grade) carbon-fiber body and titanium and aircraft aluminum frame. The propellers are carbon fiber, and are safely surrounded by the body. It is waterproof and sandproof.

Photo: Recon Systems

Photo: Audi

# Audi, Airbus and Italdesign Test Flying Taxi Concept

Audi, Airbus and Italdesign presented for the first time a flying and driving prototype of Pop.Up Next, a flying taxi. The companies demonstrated the concept at Drone Week, held Nov. 27-29 in Amsterdam.

The concept combines a self-driving electric car with a passenger drone. In the first public test flight, the flight module accurately placed a passenger capsule on the ground module, which then drove from the test grounds autonomously.

The demonstration was done with a 1:4 scale model. But as soon as the coming decade, Audi customers could use the flying taxi service in large cities — in the air and on the road without changing vehicles. Audi is conducting tests of such a service in South America in cooperation with Airbus subsidiary Voom. Customers book helicopter flights in Mexico City or Sao Paulo, while an Audi is at the ready for the journey to or from the landing site.

The next step is for a full-size prototype to fly and drive.

Audi is also supporting the Urban Air Mobility flying taxi project in Ingolstadt. This initiative is preparing test operations for a flying taxi at Audi's site, and is part of a joint project of the European Union in the framework of the marketplace for the European Innovation Partnership on Smart Cities and Communities.

The project aims to convince the public of the benefits of the new technology and answer questions concerning battery technology, regulation, certification and infrastructure.

# DEFENSE

Artist's rendering: Collins Aerospace

## US Air Force Selects Collins Aerospace Anti-Jam Receiver

The U.S. Air Force has selected an anti-jam GPS receiver from Collins Aerospace. The U.S. Air Force Life Cycle Management Center (USAF AFLCMC) chose the company to supply its latest generation Digital GPS Anti-Jam Receiver (DIGAR), which will provide highly reliable navigation for U.S. Air National Guard and U.S. Air Force Reserve F-16 aircraft operating in contested, electromagnetic environments.

The F-16 will be the first combat fighter aircraft to be installed with the latest version of the receiver.

Integration of the DIGAR requires no changes to existing operational flight programs or A-kit aircraft wiring, lowering the risk and cost involved to upgrade, Collins Aerospace said.

Built on an open systems architecture, the DIGAR is designed for use across a variety of aircraft platforms that include rotary wing, fixed-wing fighter, bomber, transport aircraft and small to large unmanned aerial systems.

DIGAR is a form, fit replacement for existing antenna electronic systems with demonstrated performance that exceeds legacy capability, Collins Aerospace said.

### DIGAR FEATURES

- Superior digital beamforming or nulling anti-jam
- Up to 16 simultaneous beams for superior jamming immunity to 125+ dB J/S performance (beamsteering mode, actual performance is classified.)
- Two- to seven-element CRPA compatible
- Simultaneous L1/L2 protection
- Supports Y-code and M-code Anti-jam
- Supports STAP/SFAP beamforming
- Two form factors: DIGAR-200 (218 cubic inches) or DIGAR-300 (75 cubic inches)
- Supports retrofit AE-1/GAS-1/ADAP platforms

## NEWSBRIEFS

### UTC ACQUIRES ROCKWELL COLLINS

UNITED TECHNOLOGIES CORP. (UTC) completed its $30 billion acquisition of Rockwell Collins in November. The two companies will now combine to form Collins Aerospace Systems and be based in Palm Beach City, Florida. Collins Aerospace Systems will have about 70,000 employees. Rockwell Collins CEO and President Kelly Ortberg will be the CEO of the newly formed company. UTC Aerospace President Dave Gitlin will serve as president. The company's avionics and mission systems will be based in Cedar Rapids, Iowa.

### BOUNDLESS RECEIVES ARMY OK FOR GIS SOFTWARE

BOUNDLESS DESKTOP has received the U.S. Army Certificate of Networthiness (CoN), an accreditation that ensures the product meets stringent Department of Defense and Army guidelines, regulations and requirements for security, sustainability and usability. Boundless Desktop is a native, cross-platform geospatial information system (GIS) built upon open source software, including QGIS, PgAdmin, Qt Designer and GDAL/OGR. The product builds maps, manages data, models and analyzes, and disseminates results with users globally. Desktop is used to conduct geospatial analysis, including creation of common operating pictures, route and area analysis, and other geospatial intelligence operations.

### DRONESHIELD JOINS THALES

DroneShield Ltd has entered into a teaming agreement with Thales Programas De Electronica Y Comunicaciones S.A.U. ("Thales") (a Spanish subsidiary of Thales S.A.), whereby Thales will utilise and promote DroneShield's products in its defence and security contract bids in Spain involving counterdrone aspects.

# TRANSPORTATION

## Rohde & Schwarz and Huawei Conduct Field Trials for 5G and V2X Precision

Rohde & Schwarz and Huawei have successfully conducted cellular-based 5G V2X latency measurements in vehicular environments in field tests in Munich and Shanghai.

In a joint project between Huawei and Rohde & Schwarz, a precision end-to-end delay measurement system for over-the-air internet protocol (IP) transmissions was applied to 5G V2X communication for cooperative driving applications in field tests in a moving car.

The precision absolute time standards on both ends were derived from two independent GPS receivers.

Initial measurements show that it is possible to achieve delays in the millisecond regime in a 5G network, demonstrating superior latency performance in comparison to LTE.

One of the key use cases of 5G is ultra-reliable low-latency communication (URLLC). Important for advanced vehicle-to-X communication use cases, URLLC will enable automated driving in the future.

A measurement accuracy below 2 μs for each transmitted IP packet was demonstrated. The transmitted data contained various IP traffic streams including video, lidar and control data (ITS messages) for a tele-operated vehicle.

The tests in Shanghai were related to a platoon V2X testing site, connecting several vehicles traveling together.

## Septentrio Partners on Autonomous Vehicle Demo

Septentrio teamed up with Point One Navigation, a provider of precise location as a service, for autonomous vehicle demonstrations at the 2019 International Consumer Electronics Show, held Jan. 8–11 in Las Vegas.

During CES, attendees rode in a fully autonomous demonstration vehicle that incorporates technology from both companies.

Point One showcased its proof-of-concept autonomous vehicle equipped with FusionEngine vehicle localization software. Demonstrations used corrections from Point One's Polaris Cloud, which enables high-precision GPS and computer vision-based localization.

Point One's solution is powered by Septentrio's GNSS receivers, using at least two frequencies broadcast by each GNSS constellation. For users operating in open sky scenarios, a Septentrio RTK receiver can be used directly with Polaris Cloud to provide centimeter-level accuracy.

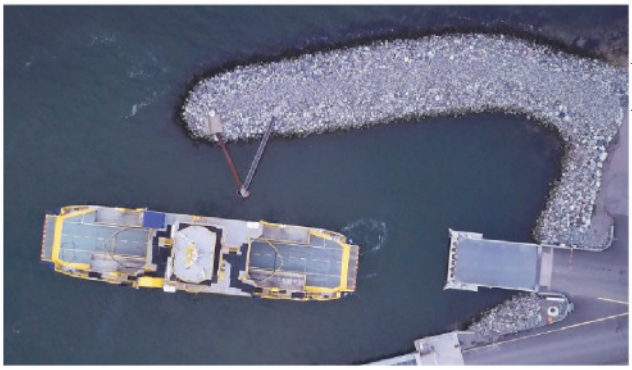


Photo: Rolls-Royce

## Rolls-Royce Demos Autonomous Ferry

Rolls-Royce and Finnish state-owned ferry operator Finferries have successfully demonstrated a fully autonomous ferry in the archipelago south of the city of Turku, Finland.

The car ferry Falco used a combination of Rolls-Royce Ship Intelligence technologies to successfully navigate autonomously during its voyage between Parainen and Nauvo. The return journey was conducted under remote control.

During the demonstration, the Falco, with 80 guests aboard, conducted the voyage under fully autonomous control. The vessel detected objects utilizing sensor fusion and artificial intelligence and conducted collision avoidance. It also demonstrated automatic berthing — the vessel automatically altered course and speed when approaching the quay and carried out docking without human intervention.

The Falco is equipped with advanced sensors that allow it to build a detailed picture of its surroundings, in real time and with a level of accuracy beyond that of the human eye. The situational awareness picture is created by fusing sensor data, and is relayed to Finferries' remote operating center 50 kilometers away in Turku city center, where a captain monitors the autonomous operations and can take control of the vessel if necessary.

Rolls-Royce has so far clocked close to 400 hours of sea trials testing the autodocking system as well as the collision avoidance system in various conditions.

Earlier this year, Rolls-Royce and Finferries began collaborating on a new research project called SVAN (Safer Vessel with Autonomous Navigation), to continue implementing the findings from the earlier Advanced Autonomous Waterborne Applications (AAWA) research project, funded by Business Finland.

## MOBILE

# U-blox, Arvento Partner on Tracker

U-blox is partnering with Arvento Mobile Systems, a Turkey-based fleet telematics company, to develop a compact people and asset tracking device with a long battery life.

The Arvento Treyki Mini has eight operating modes, including special settings for tracking children (with geofencing) and senior citizens (with an integrated fall sensor). It is also suitable for use in sports, racing and asset management. It can also be used as an emergency beacon.

The tracker has an onboard positioning receiver, and reports its location using an internal GSM/GRPS modem. It can operate for up to seven days from its 900mAh LiPo rechargeable battery before it needs to be recharged.

The Treyki Mini relies on the u-blox ZOE-M8Q concurrent multi-GNSS module to discover its location. This system-in-package (SiP) offering is 4.5 x 4.5 x 1.0 millimeters. It provides high accuracy thanks to its ability to receive 72 channels simultaneously, from up to three different GNSS constellations, the company said.

It also offers reliable positioning in challenging environments because it has a sensitivity of –167 dBm and is energy efficient.

Communications for the Treyki Mini are provided by the u-blox SARA-G340 dual-band GSM/GPRS module — its very low standby power of less than 0.90 mA helps extend the Mini's battery life. The SARA-G340 module also supports firmware-over-the-air (FOTA) updates, enabling Arvento to continue to refine the Treyki Mini after production.


Photo: Arvento

**Treyki Mini relies on u-blox positioning and wireless communication technologies.**

## SUPERCORRELATION: ENHANCING ACCURACY, SENSITIVITY OF COMMERCIAL RECEIVERS

BY RAMSEY FARAGHER, *FOCAL POINT POSITIONING*

The SGPS/SGNSS technology is a patent-protected suite of methods that provides software-based improvements to existing GNSS receivers. All methods within the software suite build upon a core technology called supercorrelation, which enables over a second of coherent integration while undergoing complex motions on low-cost platforms. The benefit is high sensitivity coupled with strong multipath mitigation capabilities, providing a high-accuracy and high-integrity positioning solution in traditionally difficult environments.

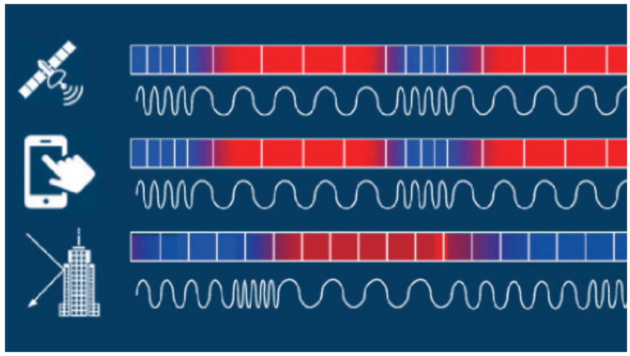
Many GNSS receivers perform a small amount of coherent integration, typically less than 20 milliseconds, and then optionally incoherently integrate over many hundreds of milliseconds to boost sensitivity if needed. The major problem with this approach is the resulting susceptibility to multipath interference. Incoherent integration destroys the phase information stored within the captured data before combining it, resulting in line-of-sight and non-line-of-sight signals accumulating within the same correlation peak, producing a distortion of the desired line-of-sight information. This distortion leads to erroneous codephase estimates, which in turn leads to erroneous position estimates.

Coherent integration can decorrelate signals arriving from different directions, but the degree of decorrelation depends on the user speed and the coherent integration time. Supercorrelator technology creates a clock-and-motion-compensated phasor correction sequence that provides over a second of coherent integration on low-cost consumer platforms. The outcome is signal tracking sensitivities down to nearly zero dBHz, combined with high multipath mitigation performance. Such long coherent integration times allow signals arriving from different directions to be separated out in the frequency domain, permitting new capabilities in anti-spoofing and 3D map-aiding methods by directly resolving GNSS angle-of-arrival using a single moving antenna.

Traditionally, very long coherent integration times were not practical on consumer devices due to limitations of data modulation bits, crystal oscillator stability, and unknown (often complicated) receiver motion. Supercorrelation overcomes these limitations with signal processing and sensor fusion. Data modulation bits are not an issue for modern pilot signals, and for legacy signals they can be removed with a variety of methods, ranging from prediction or provision of the bits over a datalink, to stripping them directly with signal-squaring methods. Receiver motion can be inferred from inertial sensors mounted alongside the GNSS receiver, as is the case for smartphones and smartwatches, or can be modelled using multi-hypothesis methods. Low-cost crystal oscillators cause phase instabilities which traditionally reduce coherent integration time, but can also be accounted for by multi-hypothesis testing and by joint estimation processes across multiple channels.

A decade ago, consumer GNSS receivers were typically an ASIC or similar hard-wired design. Modern designs incorporate a front-end correlator bank which may or may not be reprogrammable, feeding into a DSP stage which handles all tracking and navigation processing from the DLL, PLL, FLL stages onwards. The flexibility of reprogramming the code running on the DSP stage permits existing GNSS chipsets to be easily upgraded to support supercorrelation, without needing to design and fabricate a new receiver.

Focal Point aims to have S-GNSS enabled chips by early 2020, with licensing opportunities available from summer 2019 onwards.



Images: Focal Point Positioning

FIGURE 1 **Reflected signals in the local environment suffer different Doppler variations than the desired lineofsight signal. This means that the supercorrelator that is created for a given satellite broadcast couples strongly to the desired line of sight version of the signal, but attenuates any reflected signals arriving from different directions.**

FIGURE 2 **The result of supercorrelation on positioning performance in the urban canyons of central San Francisco. The red line is a standard state-of-the-art vector tracking GPS solution, and the green line is the same positioning engine with supercorrelation processing enabled.**

## SPOOFING RESISTANT UAVS

**BY ALEXANDER RÜGAMER, DANIEL RUBINO, XABIER ZUBIZARRETA, WOLFGANG FELBER,** *FRAUNHOFER IIS,* **AND JAN WENDEL AND DANIEL PFAFFELHUBER,** *AIRBUS DEFENSE AND SPACE GMBH*

This work presents a new secure localization method that can be used for UAVs to obtain a new level of protection against hostile and unauthorized UAVs. While non-spreading code-encrypted (SCE) GNSS devices can be blocked, authorized UAVs using this method have unrestricted access to the non-spoofable and trusted SCE GNSS. The proposed method is to store short sequences of SCE PRN code chips on the user receiver before the mission.

These SCE PRN code chips allow the user receiver to calculate at pre-defined points in time a secure and trustable SCE PVT position. Since no communication channel is required, this method mitigates the risk that hostile forces may try to jam the UAV's radio control. Moreover, radio silence can be realized, which is beneficial or even required for some missions.

No dedicated security module required on the user terminal, no SWaP problems, no keying issues, no handling of controlled items on user side, no need for a communication link giving rise to the availability and radio silence issues, and no security issues due to the short SCE PRN code chip sequences valid only for the limited mission duration and inside a limited area.

Potential target markets for this method are police and special forces and other authorized users which are allowed to use certain SCE GNSS and would like to equip their UAVs with a secure, unspoofable positioning solution. More info at **www.ion.org/publications/ browse.cfm**.

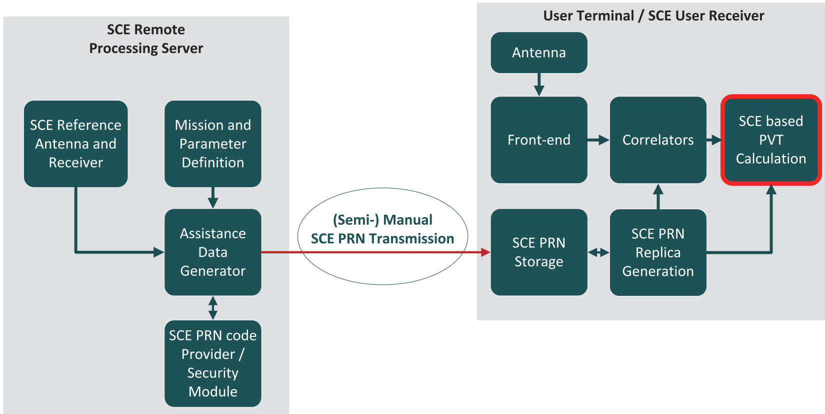



FIGURE 1 **The Precalculate & Process architecture.**

## FLAMINGO: FULFILLING ENHANCED LOCATION ACCURACY WITH INITIAL GALILEO SERVICES

**BY WILLIAM ROBERTS, JOSHUA CRITCHLEY-MARROWS, MARCO FORTUNATO, MARIA IVANOVICI,** *NOTTINGHAM SCIENTIFIC LTD.,* **KAREL CALLEWAERT, THIAGO TAVARES,** *VVA BRUSSELS,* **LAURENT ARZEL AND AXELLE POMIES,** *TELESPAZIO FRANCE.*

The FLAMINGO initiative is developing the infrastructure, solutions and services to enable use of accurate, precise GNSS in the mass-market, operating predominantly in an urban environment. Whilst mass-market receivers are yet to achieve accuracies below one meter for standard positioning, the introduction of Android raw GNSS measurements and the Broadcom dual frequency chipset present such an opportunity.

FLAMINGO will enable high-accuracy positioning and navigation information on devices such as smartphones and internet of things (IoT) devices by producing a service delivering accuracies of 50 cm (at 95%) and better, employing multi-constellation, PPP and RTK mechanisms, power consumption optimisation techniques.

Whereas the Galileo High Accuracy Service targets 10-cm precision for professional users, FLAMINGO targets 50-cm precision for consumers. With accuracies of a few decimetres, a range of improved and new applications in diverse market sectors are introduced, including, but are not limited to, mapping and GIS, autonomous vehicles, augmented reality environments, location-based gaming and people tracking.

To obtain such high accuracies with mass market devices, FLAMINGO must overcome several challenges which are technical, operational and environmental. This includes the hardware capabilities of most mass-market devices, where components such as antennas and processors are prioritised for other purposes. We demonstrate that, despite these challenges, FLAMINGO has the potential to meet the accuracy required. Tests with the current smartphones that provide access to multi-constellation raw measurements (the dual-frequency Xiaomi Mi 8 and single-frequency Samsung S8 and Huawei P10) demonstrate significant improvements to the PVT solution when processing using both RTK and PPP techniques. More info at **www.ion.org/publications/ browse.cfm**.

# Precision Ag Aided by Internet, SBAS

## A reliable, repeatable, free solution with better than 20-centimeter pass-to-pass accuracy

Differential GNSS corrections via the EGNOS Data Access Service (EDAS) enable pass-to-pass accuracy for a range of precision agriculture applications: spraying and sowing of any crop type, tilling and harvesting of grains. Tests with auto-steering systems looked at key performance indicators.

BY **Juan Vázquez, Elisabet Lacarra, Jorge Morán and Miguel A. Sánchez,** *ESSP SAS*, **and Julian Rioja and Jimmy Bruzual,** *Topcon Agriculture*

The European Geostationary Navigation Overlay Service (EGNOS), a satellite-based augmentation system (SBAS), provides corrections and integrity information to GPS signals over Europe and is fully interoperable with other SBAS such as North America's WAAS. Among its services is the internet-based EGNOS Data Access Service (EDAS).

EDAS gathers raw data from GPS, GLONASS and EGNOS GEO satellites collected by receivers at approximately 40 EGNOS ground stations distributed over Europe and North Africa. EDAS reformats and disseminates GNSS data in real time and through an FTP archive to EDAS users and service providers.

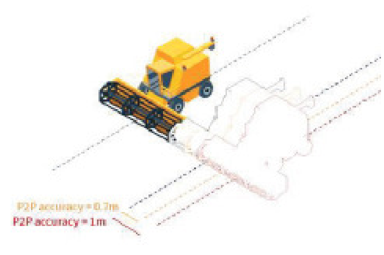
Additionally, EDAS provides differential GNSS corrections to the GPS and GLONASS satellites in view by the EGNOS system network through its Ntrip service.

The tests summarized in this article focused on the EDAS Ntrip Service, which can be used for differential positioning. An earlier test near Seville, Spain, concluded that these corrections could support pass-to-pass accuracies in the order of 20 centimeters in a consistent manner and with a high degree of repeatability.

To assess EDAS performance validity for agriculture applications, two additional tests were done in Lisbon, Portugal, and York, UK. These locations provide diversity with respect to the Seville test, especially in terms of distance from the farm to the selected EGNOS reference station (≈320 km in York and 40 km in Lisbon, versus the 110 km baseline of the test in Seville) and also geographically. In all tests, a real-time kinematic solution operated in parallel to the EDAS DGPS solution to provide the required reference for the post-processing of the recorded data. Nine different runs with a total of 78 passes were performed in these two campaigns.

SEE EDAS Ntrip, PAGE 48. >>


Article photos and figures: Topcon




**PASS-TO-PASS (P2P) accuracy concept.**

## EUROPEAN SATELLITE SERVICES PROVIDER (ESSP)

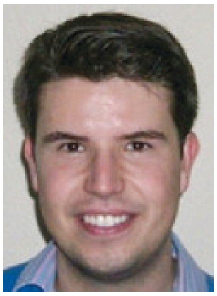
**Juan Vazquez**
Team Leader, EDAS Service Provision

Pass-to-pass accuracy is the key performance indicator to assess the precision of guidance systems, characterizing the short-term dynamic performance determined from off-track errors along the straight segment passes (error with respect to the desired path in the direction perpendicular to the tractor trajectory).

The results of the tests reported in this article, jointly performed by Topcon Agriculture and ESSP, confirm that EDAS DGPS corrections can support a wide range of precision agriculture applications and represent a real alternative for cereal farms, when located in the vicinity (at least up to 260 km away) of an EGNOS reference station, complementing the benefits that the EGNOS signal-in-space is already providing to a large number of agriculture users in Europe.

More info on EDAS is available at **egnos-helpdesk@essp-sas.eu**.

## TOPCON AGRICULTURE



**Julian Rioja**
Channel Development and Business Intelligence Manager

All tests were performed using Topcon receivers, vehicles and auto-steering systems. Two different Topcon guidance systems on board tractors ran simultaneously to assess the EDAS DGPS positioning performance with respect to the reference provided by a real-time kinematic (RTK) system. Hence, two independent positioning outputs were continuously available (the receivers were placed along the same longitudinal axis on the roof of the tractor):

- **RTK position:** provided by the AGI-4 receiver fed by Topcon's Hiper V RTK base.
- **DGPS position:** provided by the AGI-4 receiver fed by the EDAS Ntrip service.

On board the tractor, two Topcon X35 consoles were each connected to one of the receivers. A Topcon AES-25 electric steering system was installed on the tractor so that the selected navigation input (RTK or EDAS DGPS) could be used to automatically guide the tractor along the defined reference pattern.

## EFFIGIS GEO-SOLUTIONS

**Nicos Keable-Vézina**
Director of Precision Agriculture

Thanks to artificial intelligence, variable-rate application of nitrogen has made great strides in recent years. Science has demonstrated that effective nitrogen management requires an array of technologies, including massive databases. Data is geospatial (positioning signal and satellite imagery enabling the identification of changes in nitrogen requirements), agronomic (mainly soil texture and seasonal weather), and economic (grain and nitrogen price).

To automate extraction and analysis of such data, combining very low-cost positioning technologies, satellite imagery and artificial intelligence is paramount. A democratized access to technology has led to the development of scientifically proven nitrogen prescribing platforms, among them FieldApex, that calculate the most profitable nitrogen rates and generate prescriptions in seconds without soil sampling. Further technological and platform integrations are likely to bolster such innovation.

## Hemisphere GNSS

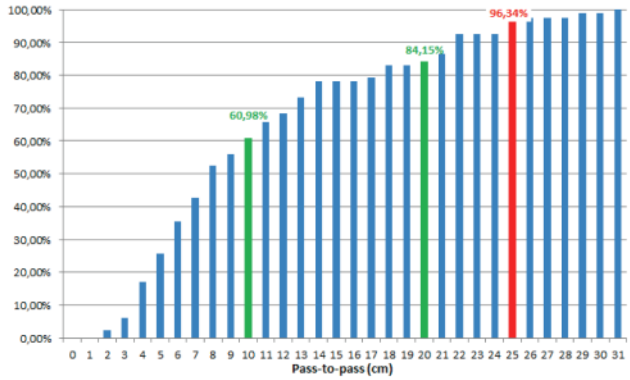
**John McClure**
Engineering Manager, Precision Agriculture

Precision agriculture is expanding the use of ISOBUS for CAN communication between a common terminal and implements, to reduce clutter in the cab. These virtual terminals now act as display and user entry for multiple applications including GNSS receivers and factory or after-market steering systems.

INS-aided GNSS solutions, typically using RTK or satellite-based correctors such as Atlas, provide time/position data for rate and section control and auto-steering. CAN-based NMEA 2000 is the commonly used receiver protocol for position data, replacing serial NMEA 0183.

All major tractor, agricultural equipment, and GNSS manufacturers attend regular "Plugfest" meetings, organized by the Agriculture Industry Electronics Foundation, to test interoperability of products and set common standards.

Smart CAN dongles are being developed to read sensors and control systems, supplying positioned data via telematics as the Big Data for real-time and post analysis.


**CUMULATIVE DISTRIBUTION of P2P accuracy, in centimeters.**

## EDAS Ntrip

« *Continued from page 46.*

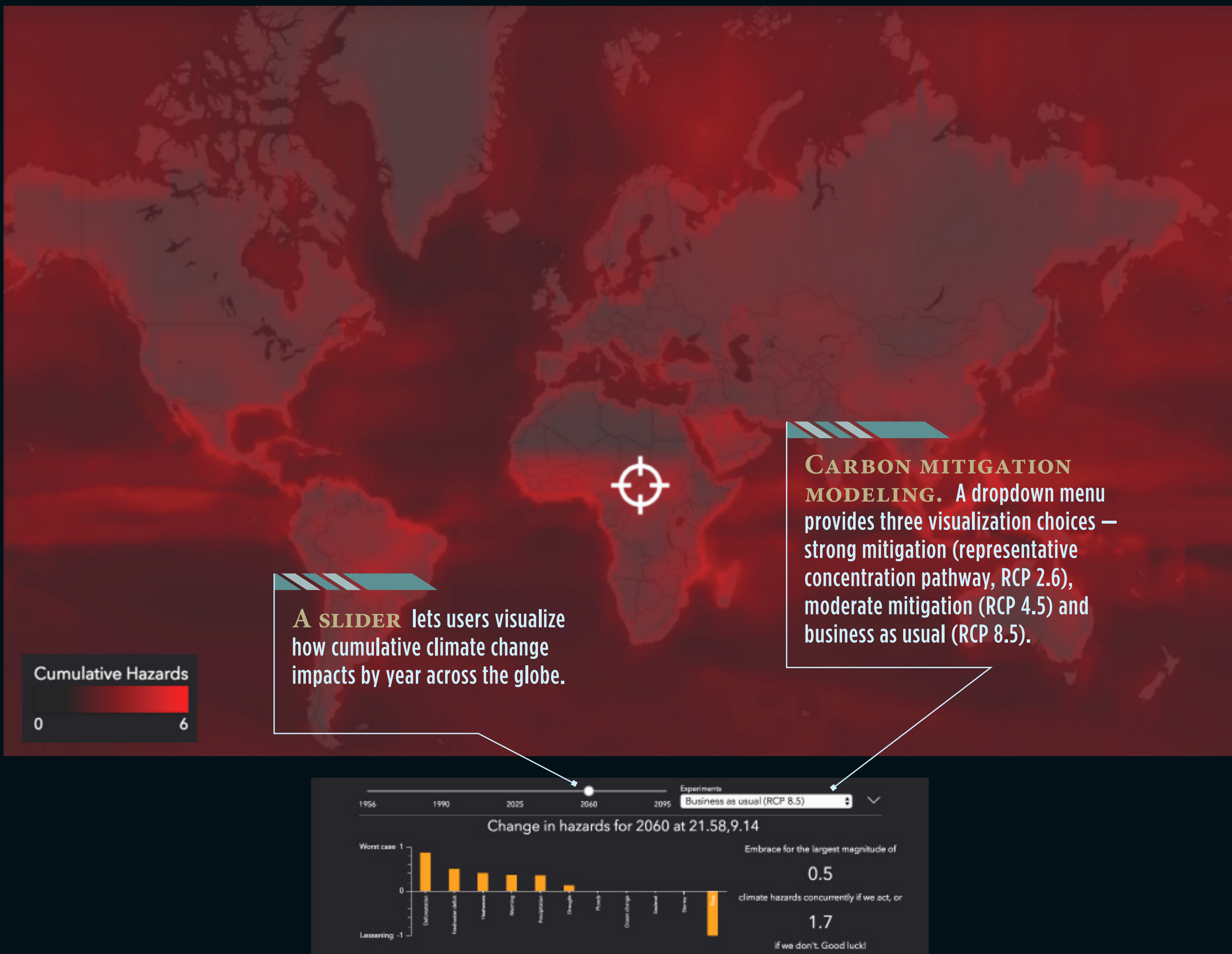
Considering the results from the three tests, the pass-to-pass accuracy supported by EDAS DGPS corrections was below 10 cm for more than 60% of passes and below 20 cm for more than 85% of the passes. These figures exceed the earlier results and confirm that EDAS DGPS corrections can deliver pass-to-pass accuracies in the order of 10 to 20 cm in a consistent manner.

The stability of the results and the very good pass-to-pass accuracy levels observed in the York scenario, where baselines larger than 300 km were tested, deserve highlighting. For grain and dry soil cultivation, at least 1 meter (95th percentile) of absolute horizontal accuracy is required. It can be assumed that, within the area where EDAS DGPS supports sub-meter horizontal accuracies (up to 260 km from the selected EGNOS station, according to previous studies), EDAS DGPS corrections can also support pass-to-pass accuracies in the order of 10-20 cm.

Such performance levels are considered to be appropriate for most grain farm operations. In particular, the observed performance is sufficient to support the following precision agriculture applications:

- Spraying/spreading of any crop type.
- Tilling of grain.
- Harvesting of grain.

## ADVERTISER INDEX: COMPANIES FEATURED IN THIS ISSUE




# Interactive App Illuminates Climate Change Around the Globe

A new interactive app by Esri models the cumulative number of climate hazards likely to occur under different emissions scenarios for any place on Earth through 2100. The app visualizes the index of 11 hazards, including warming, drought, heatwaves, fires, precipitation, floods, storms, water scarcity, sea-level rise and changes in natural land cover and ocean chemistry. Users can see how severely locations around the world will be affected by these cumulative hazards under different global mitigation scenarios.

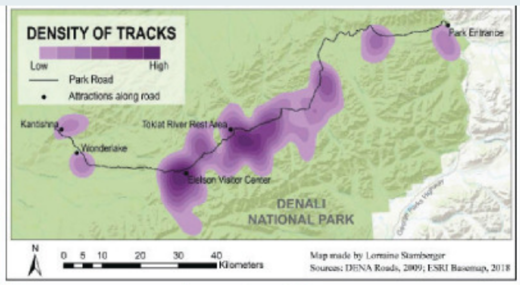
Esri created the app in partnership with Camilo Mora of the University of Hawaii, lead author of a study in *Nature Climate Change* that provides a comprehensive assessment of the simultaneous occurrence of multiple climate hazards strengthened by increasing greenhouse gas emissions and their effect on humanity. Mora's analysis of thousands of peer reviewed scientific papers reveals 467 ways in which human health, food, water, economy, infrastructure and security have been impacted by multiple climatic changes.

By clearly visualizing the threats that our world's ecosystem faces at every level, the maps and data hammer home how location intelligence can help with understanding what is at stake in making decisions, even at a global scale. Visualize the data at https://maps.esri.com/MoraLab/CumulativeChange/.

# SEEN & HEARD

## BACKPACKER TRACKING

A recent study by Lorraine Stamberger used GPS units to understand where backpackers travel in the wilds of Denali National Park, where there are few trails. Researchers distributed Canmore GT-740 FL GPS units to backpackers; the devices recorded waypoints every 15 seconds, creating detailed spatial data. Results showed backpackers were concentrated in specific hotspots, which surprised researchers and park managers. *(Via ScienceDirect)*




## BACK TO BIKE BASICS

Since the beginning of 2017 Chinese cities have been provided with 23 million GPS-equipped bicycles, part of a bike share program that has been credited with changing traffic patterns across the country and reviving a mode of transportation that was fading fast. On one day last year, the system logged 70 million riders — three to four rides per bike. The bike-share program is credited with reducing gridlock and smog. *(Via CBC)*

## NYPD GOES HIGH-TECH

In December, the New York City Police Department added a fleet of drones to its force. The 14 DJI drones will be used by licensed NYPD officers for search and rescue, event monitoring, crime scene documentation, HAZMAT incidents and hostage situations. Eleven of the drones are small quadcopters that will be used for tactical operations. Two are larger, weather resistant quadcopters with a zoom camera and thermal imaging capabilities. Another quadcopter will be used for training and testing.

## KEEPING BESSIE FIT

Australia's national science agency (CSIRO) and agtech startup Ceres Tag have completed successful trials of a new fitness tracker for cows. The smart ear tag will enable farmers to track the location of their cattle through the use of GPS, and by using accelerometers, it will also be able to inform the farmers of any unusual activity.

PHOTO CREDITS: Denali map/LorraineStamberger; Drones/NYPD; Bike rental in China/iStock.com/yurouguan; cow/CSIRO.

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record • replay • simulate


# LabSat 3 WIDEBAND

**The most powerful LabSat yet, the new LabSat 3 WIDEBAND captures and replays more GNSS signals at a much higher resolution than before.**

Small, battery powered and with a removable solid state disk, **LabSat 3 WIDEBAND** allows you to quickly gather detailed, real world satellite data and replay these signals on your bench.

With three channels, a bandwidth of up to 56MHz and 6 bit sampling, **LabSat 3 WIDEBAND** can handle almost any combination of constellation and signal that exists today, with plenty of spare capacity for future planned signals.

**LabSat 3 WIDEBAND** can record and replay the following signals:

- GPS: L1 / L2 / L5
- GLONASS: L1 / L2 / L3
- BeiDou: B1 / B2 / B3
- QZSS: L1 / L2 / L5
- Galileo: E1 / E1a / E5a / E5b / E6
- SBAS: WAAS, EGNOS , GAGAN, MSAS, SDCM
- IRNSS

www.labsat.co.uk