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GNSS
POSITION
NAVIGATION
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Research Roundup

Point-Process Modeling Reveals Polynesian Rituals

LIDAR LIFT
BOOST MAPPING PROFIT, ACCURACY

Antenna Designs Improve Efficiency

Next-Gen PNT Satellite Coming

Smart Parking: New Map Method

A NORTH COAST MEDIA PUBLICATION

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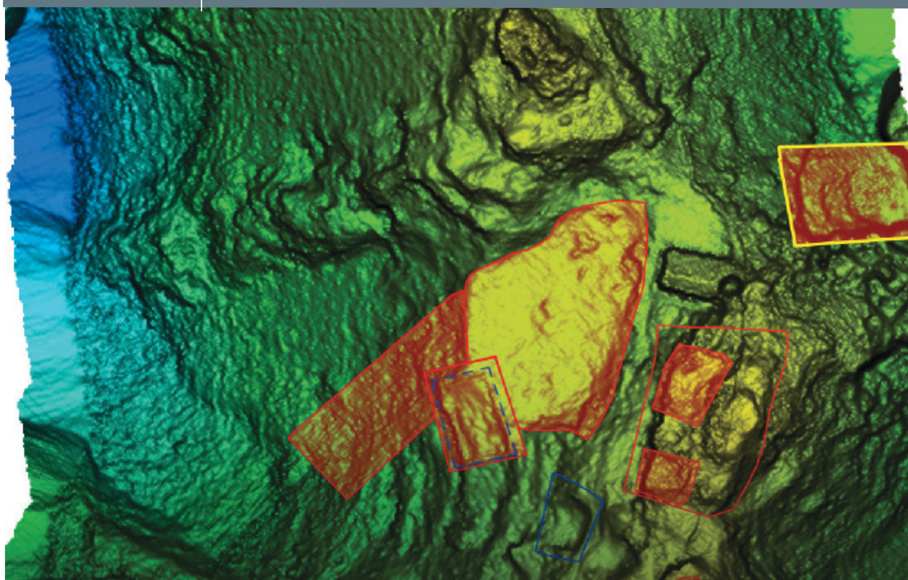

Photo: Lidar USA

ADDED DEPTH

Photo: GeoNumerics

Steven Sullivan/Shutterstock.com

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OPINIONS AND DEPARTMENTS

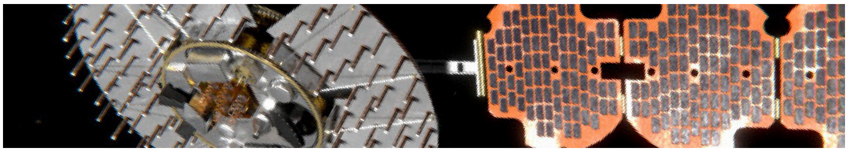

Illustration: Lt. Jacob Lutz, AFRL Space Vehicles Directorate

LAUNCHPAD

MARKET WATCH

ONLINE NOW

NEWSLETTER EXCERPTS

Augmenting Reality with Geospatial Information

BY William Tewelow
CONTRIBUTING EDITOR, GEOSPATIAL INTELLIGENCE

Geographical information systems (GIS) and augmented reality (AR) have become a part of our daily lives, so much so that we hardly notice them. The world is filled with data. Using AR, that data can be draped in front of us in a tapestry based upon our individual needs and interests…

MIT graduate student Ivan Southerland invened a graphical user interface (GUI) on a TX-2 computer for his doctoral thesis, thereby revolutionizing computer graphics, computer-generated imagery and computer-aided design. Southerland soon found himself heading the government's Advanced Research Projects Agency (ARPA) to further develop the GUI. His innovations greatly advanced programs such as NPIC, allowing photo-interpreters to work directly with imagery displayed on a computer screen.

A visionary, Southerland saw computer-generated synthetic worlds merging man and computer; he created what became known as the Sword of Damocles, the first AR headset. It was so heavy it had to be suspended from the ceiling on cables in a big swindling contraption, hence its name. The Sword of Damocles evolved into the helmet-mounted display that military pilots use today, and became the foundation for development of Google Glass, Oculus Rift, Microsoft's HoloLens and Meta.

Photo: MIT archives

Several years later, Southerland went to Harvard as an associate professor, continuing his work with computer graphics. During his tenure, a student working in Southerland's computer graphics and spatial analysis lab saw the potential of combining CGI and CAD with his own knowledge of environmental science and landscape architecture. That student was Jack Dangermond, who created Esri in 1969.

Thanks to Dangermond and Southerland, GIS and AR are a part of our daily lives, so much so, we hardly notice them. They have changed how we watch sports — football shows a red scrimmage line on every play and the first down line in blue… Advertisements appear only to television viewers… Museums consider AR the next frontier…

Read the full column at **www.geospatial-solutions.com**.

NSGIC Releases Report on Progress toward Geo-Enabled Elections

Includes first draft of best practices for implementing GIS

The National States Geographic Information Council (NSGIC) has released the first-year report of phase one of its Geo-Enabled Elections project, highlighting the project's accomplishments in the first 12 months. These include completing a baseline assessment of how far states have come, to date, in terms of integrating geographic information systems (GIS) with electoral systems, as well as assembling a team of leaders and experts to help guide the project.

The project team has also facilitated conversations with a wide range of stakeholder groups to raise awareness of the importance of GIS in elections.

Photo: iStock.com/YinYang

Phase one of the Geo-Enabled Elections project runs from Oct. 1, 2017, to Sept. 30, 2019, with the aim to help strengthen electoral systems by supporting states in the adoption of GIS. Tthis means encouraging state governments to replace non-spatial "address file" systems with election precinct and voter data in a GIS format, leveraging that format's inherent visual and analytical advantages…

NSGIC released the first draft of its best practices for how states may go about enhancing election accuracy using GIS. The five identified best practices are:

- Convene a team of specialists.
- Collect and sustain a statewide voting unit GIS layer.
- Adopt and implement a statewide geocoding strategy.
- Assemble and provide best available contextual GIS layers.
- Define and implement data validation processes.

Keep up-to-date with geospatial news at **www.geospatial-solutions.com**, and subscribe to *Geospatial Solutiond Monthly* at **www.gpsworld.com/subscribe**.

A Galaxy of Constellations

BY ALAN CAMERON
EDITOR-IN-CHIEF

Just last month we celebrated the kickoff of the GPS III campaign, reporting on the launch of the first space vehicle of that generation in the closing days of 2018. A new era had begun, heralded by a rocket's blazing path, bearing aloft a new "lighthouse in the sky serving all humankind."

Turn around and — whoa! Where did all these other new PNT satellites come from?

We attempt to chronicle them all in this issue, though I'm not sure we haven't still missed some.

For years we've been talking about the Iridium constellation, a low-Earth orbit telecommunication network that can also deliver timing services to improve accuracy, and signal acquisition in urban environments. Were it not for the fact that 10 more of its satellites just launched in January, bringing the total of its second-generation NEXT constellation to 75, this would practically qualify as old news.

But let's move on to the real new news. Turn the page and read about NTS-3, the new kid on the block most closely related to the GPS family. In fact, integrally a part of it. This third Navigation Technology Satellite will go even beyond GPS III — whose capabilities, mark you, are not yet online — to investigate new experimental antennas, flexible and secure signals, increased automation and use of commercial ground assets.

Look across the gutter (magazine term) to learn about 72 nanosatellites of the Spire constellation piggybacking on Galileo signals to offer GNSS radio occultation products for the weather community. This may not be exactly direct-to-user PNT, but it's a derivative.

Turn one more page to absorb the latest on Hawkeye 360 formation-flying Pathfinders, designed to detect and geolocate radio frequency (RF) signals, and use the data in search-and-rescue as well as commercial maritime operations.

Don't stop there! Scan further down to Planet, the breadloaf satellites, current population 300 with more coming, beaming down 1.2 million high-resolution Earthly images per day, useful for agriculture, defense, mapping and GIS, and a few other industries.

If a group of satellites is a constellation, what do you call a group of constellations? If we are to follow astronomy's lead, I've just learned that the proper technical term is an *asterism*. However, I think *galaxy* will be easier to handle.

Illustration: Lt. Jacob Lutz, AFRL Space Vehicles Directorate

THE PROGRESSION OF NAVIGATION TECHNOLOGY SATELLITES: **Left, NTS-1, launched in 1974 as a precursor to GPS; Center, NTS-2, launched in 1977 as the first NAVSTAR GPS Phase I satellite; right, NTS-3, scheduled for a 2022 launch to investigate new PNT technologies and capabilities.**

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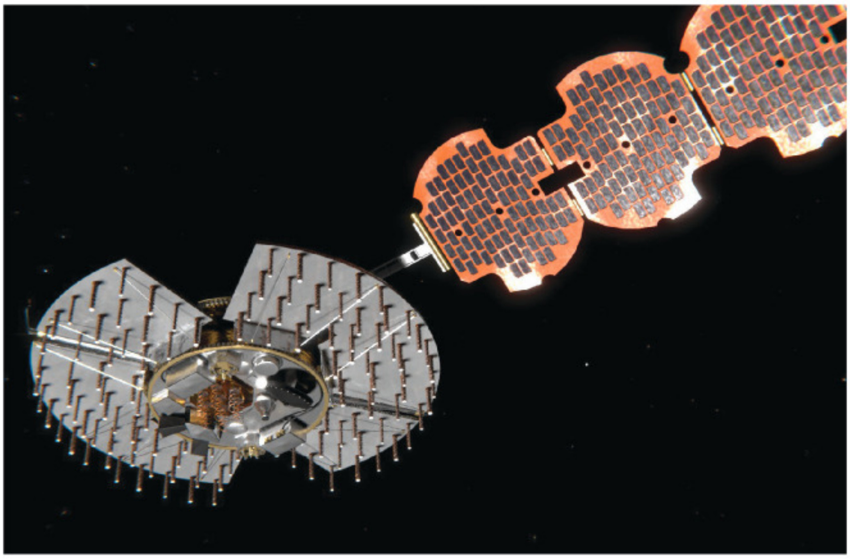

Illustration: Lt. Jacob Lutz, AFRL Space Vehicles Directorate

Beyond GPS III
NTS-3: The Next Chapter

The U.S. Air Force Research Laboratory and the Space and Missile Systems Center selected Harris Corporation as the prime contractor to build Navigation Technology Satellite-3 (NTS-3), the next-generation experimental positioning, navigation and timing (PNT) spacecraft. The satellite is expected to launch in 2022, with one year of experimental operations.

Geosynchronous Testbed. NTS-3 will integrate several advanced technologies to test and demonstrate resiliency and new concepts of operation to include experimental antennas, flexible and secure signals, increased automation and use of commercial ground assets. It will operate geosynchronously, hovering above approximately the same spot on Earth throughout its lifetime.

Technologies matured and knowledge gained from NTS-3 are expected to transition to future generations of GPS and augmentation layers for national PNT capabilities.

Agile Waveform Platform. In support of NTS-3, Harris plans to develop the Agile Waveform Platform, a digital signal generator that can be reprogrammed on orbit, enabling operators to quickly develop and deploy new signals to meet rapidly evolving needs on the battlefield.

Additionally, Harris' electronically steerable phase-array antenna will support simultaneous broadcast of multiple waveforms in both Earth-coverage and spot-beam configurations.

NTS-3 will use Northrop Grumman Innovation System's ESPAStar bus, building on AFRL's EAGLE spacecraft that launched in April 2018.

NTS-3 was selected as the Space Vehicle Directorate's next major integrated space experiment in 2015, and it represents AFRL's first PNT flight experiment to prototype a more resilient PNT multi-layer architecture in accordance with the Space Enterprise Vision (SEV) and the Space Warfighting Construct (SWC).

Heritage. NTS-3 builds on a history of Department of Defense (DoD) satellite navigation (SATNAV) programs that began in the 1970s with the predecessors of the modern GPS constellation. NTS-1 was developed by the Naval Research Laboratory (NRL) and launched in 1974 with two rubidium-vapor frequency standards that advanced the timing and navigation precision demonstrated by the earlier TIMATION satellites.

NTS-2 launched in 1977 as the first NAVSTAR GPS Phase I satellite, and demonstrated cesium frequency standards and a worldwide network for data acquisition. There has been no major DoD SATNAV developmental program since then, until NTS-3.

In 2017, AFRL restructured NTS-3 to emphasize mission objectives to demonstrate disaggregated, resilient PNT in a multi-layer space architecture, as outlined by the SEV and the SWC. NTS-3 will provide space qualification for core technologies such as on-orbit digital signal reprogrammability and solid-state amplifiers. In addition to new signals, onboard experiments include improvements to timing accuracy and integrity, including ensembling to improve long- and short-term stability. NTS-3 will demonstrate key tactics, techniques and procedures (TTPs) for multi-layer PNT through all three segments of the SATNAV system: space, control and user.

Ground Control. Braxton Technologies was selected to handle NTS-3 SATNAV ground control.

Collaborators. AFRL/RV is seeking collaboration from industry, government agencies and universities in developing experimental concepts and participating in the flight experiment.

Galileo Now Predicts the Weather

BY Tracy Cozzens
MANAGING EDITOR

Spire Global, a space-to-cloud analytics company, is now using Galileo to offer GNSS radio occultation (GNSS-RO) products for the weather community. Radio occultation is the process of using satellites to measure how GNSS signals are refracted by the Earth's atmosphere.

Two of Spire's nanosatellites are the first to use Galileo signals to measure GNSS-RO profiles, a service now available to Spire's global user base as a new tier of data for advanced weather prediction. The satellites launched on Nov. 29, 2018, from Sriharikota, India.

The satellites are part of the collaborative European Space Agency ARTES Pioneer Space-as-a-Service program, which aims to prove the value of using nanosatellites for space-based GNSS-RO.

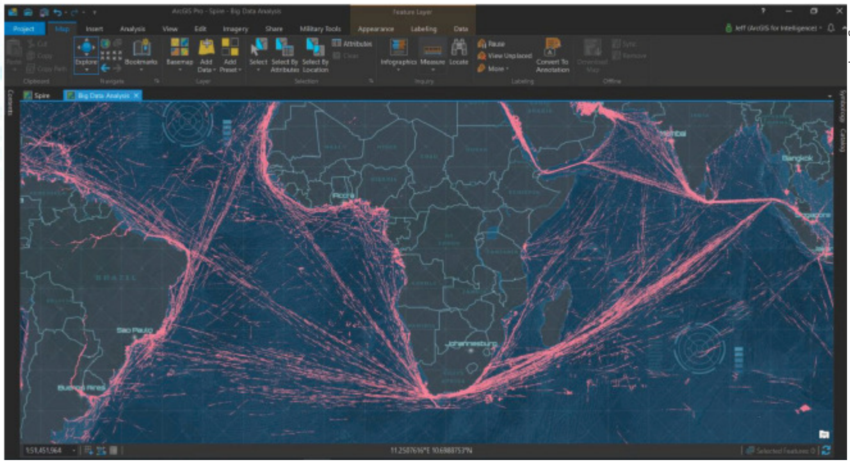

Image: Spire

With Galileo, Spire's weather observation satellites can harvest approximately 25 percent of the total GNSS-RO profiles available from the existing GNSS satellite constellations in orbit today.

Spire operates 72 nanosatellites — also known as "cubesats" — and more than 30 ground stations throughout the world. The nanosatellites are developed, assembled and tested at Spire's production facility in Glasgow, Scotland. 🌐

RF LOCATION

MicroSat Constellation Geolocates RF Signals

Space Flight Laboratory (SFL) has launched three formation-flying HawkEye 360 Pathfinder 15-kilogram, 20 x 27 x 44-centimeter microsatellites designed to detect and geolocate radio frequency (RF) signals.

The target signals emanate from VHF radios, maritime radar systems, automatic identification system (AIS) beacons, very small aperture terminal (VSAT) communication systems and emergency beacons. HawkEye 360 applies advanced RF analytics to the data to assess suspicious vessel activity, survey communication frequency interference and direct search-and-rescue.

Precise formation flying is critical, as the relative position of each satellite must be known to accurately geolocate transmission sources. The satellites carry space-qualified GPS receivers and high-performance attitude control systems to keep them stable in orbit.

Flying in formation, two or all three satellites may receive the same transmission when it originates from their common footprint. The signal's different times of arrival at each satellite and their different apparent center frequencies (Doppler) will enable onboard comparison of time-of-arrival and frequency-of-arrival measurements to then calculate the transmitter's position. The onboard GPS receivers provide precise estimates for the position and velocity of the receivers, information required for multilateration. The satellites further synchronize their clocks using GPS receivers, which also stabilize the phase-locked loops governing the tuning frequency in the RF tuners.

The satellites were built by Deep Space Industries of San Jose, California, and University of Toronto, Institute for Aerospace Studies/Space Flight Laboratory (UTIAS/SFL). They were launched in December 2018 into low-Earth orbit.

Image: UTIAS Space Flight Laboratory

HAWKEYE 360 Pathfinder satellite trio flies in formation, seeking RF signals from Earth.

SATELLITE IMAGERY

Breadloaf Satellites Capture Earth Surface

Planet has put about 300 satellites into space, charged with photographing the entire land mass of the Earth every day.

The satellites weigh 5 kg (12 pounds) and measure 20 x 20 x 44 centimeters, about the size of a loaf of bread. They are packed with commercial-off-the-shelf electronics and are built in downtown San Francisco. Mission control consists of a single engineer for dozens of satellites.

Aptly named "doves," the birds circle the Earth in 90 minutes, their cameras continuously rolling. "It gives you a perspective of the planet as a dynamic and evolving thing that we need to take care of," said company co-founder Will Marshall.

Each day the satellites transmit 1.2 million images at a spatial resolution of 3–5 meters, far more than enough to fully occupy all the analysts at the National Geospatial Intelligence Agency (NGA), one of Planet's more than 200 customers. Historically, the NGA has relied on 3 or 4 very large, very expensive — and to global adversaries, very predictable — spy satellites. The agency has found Planet's approach intriguing and challenging.

Planet has devised computer algorithms to look for new features day to day, such as roads or buildings that may signal activity of a significant or nefarious sort. Other customer uses are more mundane, such as agricultural companies monitoring crop health.

Image: Planet Labs Inc.

PARIS, capable of going to 3–5m resolution.

PNT Q+A

Are drones (UAVs) a disruptive or constructive technology for high-precision mapping that yields practical, actionable results for the end user/customer?

"More constructive than disruptive. Drone mapping is opening new markets that, to a large extent, were not serviceable by conventional manned flights. On the other hand, the profound changes — and crisis — in the mapping business were not produced by drones."

"Drones have dramatically reshaped the surveying and mapping industry. Combined with reliable positioning and recent advancements in high-resolution cameras, photogrammetry and computer vision, drones now enable high-accuracy mapping faster and at much lower cost than conventional mapping techniques."

"Drones can be constructive augmentations to high-precision map products because of their ready access to diverse locations. Drone imagery can document real-time physical changes that affect mapping applications during natural disasters or other events — but images alone aren't maps without a geo-referenced grid such as the U.S. National Grid."

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1. DEAD-RECKONING MODULE

FOR INDUSTRIAL AND AUTOMOTIVE

The L26-DR dead-reckoning GNSS module is a multi-GNSS receiver embedded with a dead-reckoning solution to greatly improve positioning accuracy and speed while simplifying customer designs. The dead-reckoning capability ensures the module delivers the highest performance positioning solution available, even when GNSS signals are absent or compromised. Equipped with six-axis sensor MEMs and a powerful GNSS core, the module provides high sensitivity, fast GNSS signal acquisition and tracking with low system integration effort. The L26-DR can acquire and track any mix of GPS, GLONASS, BeiDou, Galileo and QZSS signals.

Quectel Wireless Solutions, quectel.com

2. TRACKER

OFFERS A LONG BATTERY LIFE

The Arvento Treyki Mini is a compact people and asset tracking device with 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 and can be used as an emergency beacon. It 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. It uses the u-blox ZOE-M8Q concurrent multi-GNSS module, which is able to receive 72 channels simultaneously.

u-blox, www.ublox.com;
Arvento Mobile Systems, www.arvento.com

3. SMALL DEVICE ANTENNA

PINPOINTS LOCATION TO WITHIN CENTIMETERS

The new Antenova Raptor achieves high accuracy using the L2 1200-MHz GNSS bands. The L2 band combines multi-band satellite signal reception and GNSS correction data, helping to mitigate position errors. The antenna is the latest addition to Antenova's lamiiANT range of rigid FR4 antennas designed for easy insertion onto a printed circuit board (PCB). It is a GPS single-feed antenna in surface mount (SMD) form, measuring 16.0 x 8.0 x 1.6 millimeters, suitable for small PCBs within all kinds of small electronic devices. Raptor is supplied in tape and reel for ease in high-volume manufacturing applications.

Antenova, www.antenova.com

4. GNSS RECEIVER

MINIATURIZED ANTI-SPOOFING MODULE

The Regulus Pyramid is a fully functional GNSS receiver fortified with spoofing detection capability. The receiver contains patented technology that enables it to differentiate between real GNSS signals and fake ones generated by an attacker. It is availble both as a fortified GNSS receiver (v1), capable of detecting spoofing attacks, and at the chip level (v2), allowing mobile phones, cars and internet of things (IoT) devices to receive GNSS spoofing protection. A Pyramid GNSS Add-On can be integrated with another satellite receiver to enable spoofing detection capabilities for any GNSS board.

Regulus Cyber, www.regulus.com

5. GNSS ANTENNAS

FOR HIGH-PRECISION POSITIONING

The AGR6302 and AGR6303 GNSS patch antennas are designed for precision dual-frequency positioning. The AGR6302 is capable of receiving L1/L2 bands, and the AGR6303 is capable of receiving L1/L5 bands. They are designed for UAVs, precision agriculture, autonomous vehicles and other applications where precision matters. The AGR6302/AGR6303 active antenna is designed to cover GPS, BDS, Galileo, GLONASS, IRNSS and the QZSS system. It employs a stack four-feeds architecture with hybrid to achieve the multi-band operation, lower axial ratio, wider half-power beamwidth and excellent right-hand circular polarization. It is housed in a compact, industrial-grade waterproof and magnet mount enclosure.

Allystar Technology, www.allystar.com

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1. MULTI-ROTOR DRONE

LIFTS 20-LB PAYLOAD 12–15 MINUTES

The Alta 8 Pro multi-rotor drone includes waypoint technology to allow preprogrammed movements and autopilot functionality. The Alta Pro flight controller runs open PX4 flight stack for quick and powerful interfacing. The Alta 8 Pro fuses readings from accelerometers, barometer, and GPS to create high-bandwidth height control flight mode. By fusing GPS data with an IMU and barometer, the drone is able to hold position even in difficult weather conditions.

FreeFly, FreeFly.com

2. POST-PROCESSING

THIRD-PARTY GNSS USE ENABLED

The DJI Phantom 4 Pro RTK (P4R) drone is now integrated into the AirGon Sensor Processing Suite (ASPSuite). ASPSuite is a post-processing solution for GeoCue's Loki direct geopositioning system for DJI and other drones. The 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 PPK workflow. It includes support for engineering-grade survey options such as vertical transforms, creation of and transformation between collection datums and local coordinate systems, application of antenna static and dynamic lever-arm corrections, and full support for Loki direct geopositioning systems.

GeoCue Group, geocue.com

3. 360-DEGREE UAV CAMERA

11K EIGHT-LENS VR CINEMA CAMERA

The Insta360 Titan is an eight-lens cinematic virtual reality (VR) camera that captures 360-degree photos and video at up to 11K resolution. The Titan uses eight micro four thirds (MFT) sensors, the largest sensors available in any Insta360 standalone VR camera. It has a GPS signal antenna and a Wi-Fi signal antenna. The sensors maximize image quality, dynamic range, low-light performance and color depth, increasing realism in high-end professional VR capture.

Insta360, www.insta360.com

SURVEY & MAPPING

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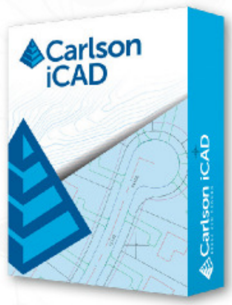

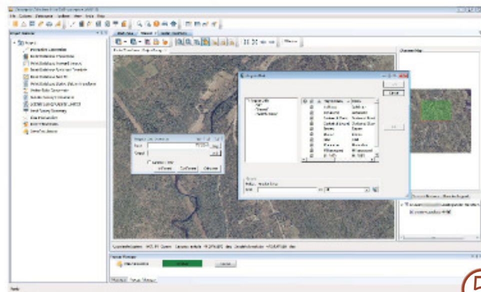

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1. INTEGRATED RECEIVER

FOR DIVERSE RTK APPLICATIONS

The GRX3 is designed to provide a smaller, lighter and fully integrated GNSS solution to Sokkia's GNSS receiver line. Its compact and lightweight housing has been tested to meet IP67 certification for protection against harsh weather. The receiver features Sokkia Tilt technology, which includes a nine-axis inertial measurement unit (IMU) and compact eCompass designed to compensate for misleveled field measurements by as much as 15 degrees. UTC technology automatically tracks signals from all available and planned constellations, including GPS, GLONASS, Galileo, Beidou, IRNSS, QZSS and SBAS.
Sokkia, www.sokkia.com

2. AIRBORNE 3D SCANNING

DESIGNED TO GATHER LARGE AREA DATA

The Faro–Stormbee airborne solution includes the Faro Focus laser scanner, the Stormbee S series UAV and the Beeflex software suite. It enables wide-area scanning missions such as highways, train infrastructure and buildings. It allows users to capture complex environments traditionally inaccessible to ground-based scanning. It has no need for control points. Users can create centimeter-level accurate point clouds directly from the in-flight data.
Faro, faro.com; Stormbee, stormbee.com

3. DOCUMENTARY SERIES

EXPERTS DISCUSS VALUE OF AUTOMATION AND NEW TECHNOLOGY

The new *Infrastructure and Technology* series of documentary videos is designed to foster awareness of growing global infrastructure demands and the technology that can help meet them. Experts interviewed include representatives from Intel, SAP, Industry Consultants, Constructech, Solar City and Topcon. They discuss how, by adopting technology, the construction and agriculture industries can increase productivity and help address infrastructure needs now and in the future. The series was filmed globally in the U.S., the Netherlands, the United Kingdom and Germany.
Topcon Positioning Group, topconpositioning.com

4. PROJECT SOFTWARE

UPDATED TO LATEST INTELLICAD TECHNOLOGY CONSORTIUM RELEASE

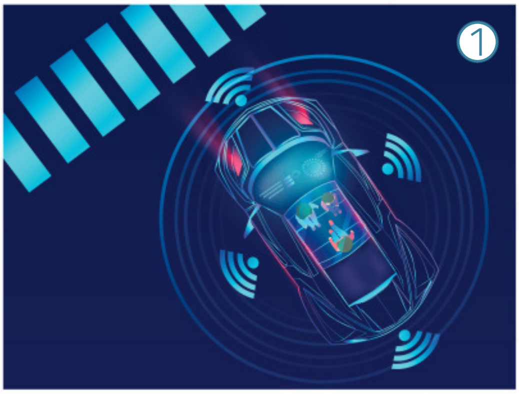
The specialized drafting package Carlson iCAD 2019 allows technicians to supplement the finished product in their project deliverables. New additions and functions to the iCAD 2019 release are new tool palettes, new 3D solid commands, additional DGN support, and new express tools. iCAD features Google Earth import and export KML/KMZ, standard CAD entities and the drawing inspector tool.

Carlson iCAD 2019 has been built with and updated to the IntelliCAD 9.0 engine from the previous IntelliCAD Technology Consortium 8.3 release. IntelliCAD 9.0 supports direct read of DGN files, allowing users to make edits without converting drawing formats, and features a CUI interface for custom workspaces, toolbars and ribbons.
Carlson Software, www.carlsonsw.com; IntelliCAD Technology Consortium, www.intellicad.org

5. GEOGRAPHIC CALCULATOR

INCLUDES GEOCALC GEODETIC REGISTRY

The 2019 Geographic Calculator features a universal copy and paste function, a new angular unit conversion tool, support for NADCON 5.0 and updated seismic survey conversion functionality. The foundation of the calculator's geodetic data-processing functionality is the embedded GeoCalc datasource, which is continually revised and improved with updates through the online GeoCalc Geodetic Registry. The datasource included in the 2019 release mirrors the most current EPSG database definitions. The calculator's copy and paste function can be used to quickly capture data for use in a third-party application or to insert new coordinate values in an existing job.
Blue Marble Geographics, www.bluemarblegeo.com



1. POSITIONING SOFTWARE

FOR AUTONOMOUS VEHICLES

The InvenSense Coursa Drive software is an inertial-aided positioning solution for autonomous vehicle platform developers. It is a high-performance extension of the InvenSense Positioning Library (IPL), which has provided sensor-aided positioning to more than 50 million devices worldwide. Coursa Drive enhances inertial-only vehicle positioning to <0.2 percent of distance traveled, accuracy critical to maintaining decimeter lane-level vehicle positioning in challenging GNSS/perception system environments. Coursa Drive's inertial navigation system (INS) calibrates using absolute position inputs from either high-accuracy GNSS receivers or from perception-based systems (camera, radar, lidar) with high-definition (HD) maps. In real time, Coursa Drive provides high-rate, 100-Hz delta positions and orientation to the autonomous vehicle system, complementing the lower rate position references from GNSS and perception systems. For non-real-time applications such as HD map creation and maintenance, Coursa Drive's offline mode reprocesses INS data at two to three times higher accuracy than real-time mode, providing HD map companies alternative position references to verify HD map accuracy, even without GNSS, for up to 60 seconds.

TDK Corporation, www.invensense.com

2. VIDEO SURVEILLANCE

MOBILE NETWORK VIDEO RECORDER (NVR)

The mobile NVR408M with GPS navigation is designed for use in moving vehicles, remote locations or rugged environments. The rugged compact design works in harsh and demanding conditions to deliver quality video surveillance. Typical applications are in law enforcement or public transportation, using vehicles such as trains, buses, trucks, cars, airplanes and ships. NVR408M is an EN50155-certified product, able to withstand severe vibration and shock and making it suitable for railway applications.

Lilin, www.meritlilin.com

3. CAR2X/V2X INTERFACE

ACCESSES IEEE 802.11 AND CAN NETWORKS

The VN4610 is a powerful interface for accessing IEEE 802.11p and CAN (FD) networks for Car2X/V2X communication using a USB PC connection. The VN4610 provides precise position, time and speed information that can be used by the application as test stimulus or for documentation. The absolute GNSS timestamps can be used to synchronize recordings of distributed measurements for subsequent analysis. The u-blox NEO-M8U supports GPS, GLONASS, Beidou and Galileo — up to three systems simultaneously. The IEEE 802.11p-based dedicated short-range communication (DSRC) communicates in the 5.9-GHz range. The VN4610 supports the unfiltered receiving and sending of IEEE 802.11p frames used for the implementation of Car2X/V2X applications. The received IEEE 802.11p radio-signal-based frames are transferred to the application synchronously to the CAN (FD) messages.

Vector, www.vector.com

4. FAA-CERTIFIED AVIONICS

WITH ENHANCED ADS-B, SBAS AND GEOREFERENCED CHARTS

The Pro Line Fusion avionics upgrade for Pro Line 4-equipped Bombardier Challenger 604 series aircraft has been certified by the U.S. Federal Aviation Administration (FAA). The all-in-one upgrade complies with pending mandates while modernizing the flight experience for pilots. The upgrade includes ADS-B mandate compliance, SBAS-capable GNSS, localizer performance with vertical guidance (LPV) approaches, radius-to-fix (RF) legs, geo-referenced electronic navigation charts, widescreen LCD screens and synthetic vision.

Collins Aerospace, www.collinsaerospace.com

Photo: Bailie McRae

UAV LIDAR GIVES MAPS A POP

ASPECTS AND ADVANTAGES TO LASER USE

WHY ABANDON WELL-WORN MAPPING METHODS IN CURRENT USE?

It has to be for one or more forms of gain: time, money or staffpower. UAV-borne lidar can save a lot of field time, eliminate the need for site revisits, capture more data than previously possible, and provide a better product using more automated extraction tools.

BY JEFF FAGERMAN

Surveyors and other mappers must frequently develop a reliable surface model of an area about to undergo major construction. If it is new construction over native soil, then the area is often covered with vegetation ranging from short grass to very tall trees. By far the majority of these areas are surveyed using GPS, total stations, levels or some combination thereof, depending on the project. In any case, at least one trained individual, more often two or even three individuals, must walk the area collecting the necessary data with some form of survey equipment.

This is the tried-and-true methodology. It is easy to schedule, easy to estimate, and barring any field or office mistakes, absolutely reliable. Manually visiting a point in the field on return visits should yield similar, though not exact, results, at least within the tolerances of the equipment. It doesn't matter if the temperatures are near freezing or over 100 degrees. It doesn't matter if it is raining or sunny. It doesn't matter if the grass is cut or if the leaves are on and in full glory. This is a very reliable method in all respects, assuming the proper tools and techniques are used.

How can this type of field survey be improved upon? First, is the product sufficient? Does the field crew reliably capture all the pertinent features? Did they get the location of the trees, buildings, poles and so on?

How many site visits are usually required to complete the average project?

What about the elevation data? Did they capture the drainage and breaklines sufficiently?

All GNSS civilian signals

TRIUMPH 3

Based on TRIUMPH chip with 864 channels

• Spread Spectrum • Bluetooth • UHF • 4G/LTE Cellular • Wi-Fi • Integrated GNSS antenna

see back page >

J-Mate Overview

6 pages inside >

J-Mate Test Volunteer

We have delayed the introduction of the new J-Mate to enable us to add new features like replacing liquid vials with a highly accurate internal inclinometer to monitor and continuously compensate for level offsets.

We now are ready to send J-Mates to **20 volunteers in the United States**, who would like to test the J-Mate with their TRIUMPH-LS and give us feedback over a period of up to two months.

As a reward for each volunteer's efforts, we will offer a **50% discount on the J-Mate** if they decide to buy it.

Please go to **www.javad.com**, to submit your volunteer application at "J-Mate Test Volunteer".

JAVAD

J-Mate Quick Overview and Update to Videos

First let's set the record straight: J-Mate is not a total-station. J-Mate and TRIUMPH-LS **together** are a **"Total Solution"** which is a combination of GNSS, encoder and laser range measurements that **together** does a lot more than a total station. At long distances you use GNSS and at short distances (maximum of 100 meters) you use the J-Mate along with the TRIUMPH-LS. Together they provide RTK level accuracy (few centimeters) in ranges **from zero to infinity**. Although the sensors are specified to work up to 100 meters, usage is quicker and more convenient for distances of up to 50 meters.

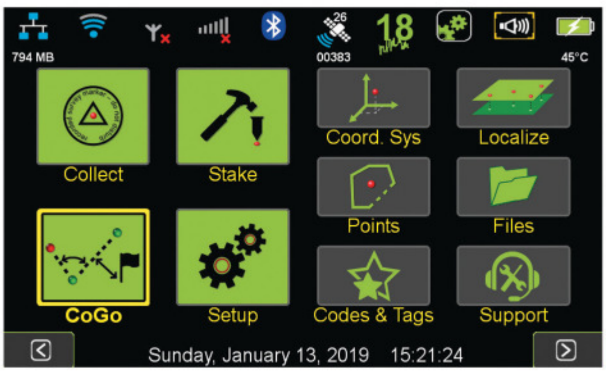
One burden that we leave you with is to focus the camera manually when you need it. If you are always more than 15 meters away from the target, you keep the focus button on maximum and leave it there. We will replace the focus button to make it easier to access if needed.

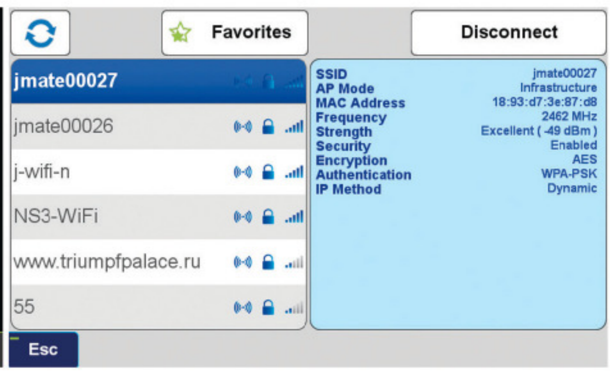
As with the TRIUMPH-LS, with the J-Mate we also provide software improvement updates regularly and free of charge. Download the J-Mate update in your TRIUMPH-LS and then inject it to the J-Mate. When you connect the TRIUMPH-LS to the J-Mate, the injection will be done automatically; but with your consent.

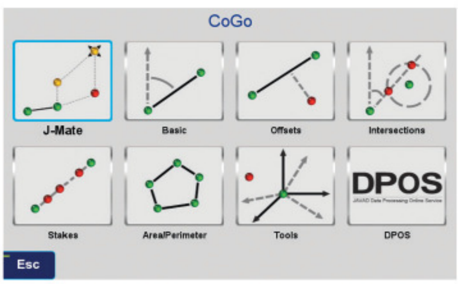
There are many new features in the J-Mate. We try to explain them in a few steps. Please also view the J-Mate videos on our website.

Connecting J-Mate to TRIUMPH-LS:

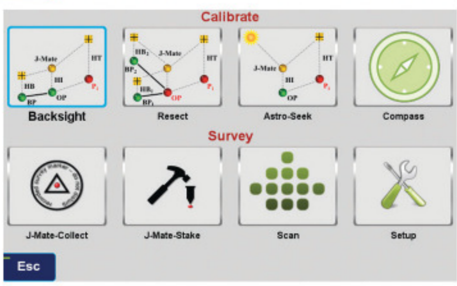
TRIUMPH-LS communicates with the J-Mate through Wi-Fi. Turn on both the TRIUMPH-LS and the J-Mate. Click the Wi-Fi icon of the TRIUMPH-LS Home screen to connect to the J-Mate, much the same way as you connect TRIUMPH-LS to your Wi-Fi access point. J-Mate has ID of the form JMatexxx.

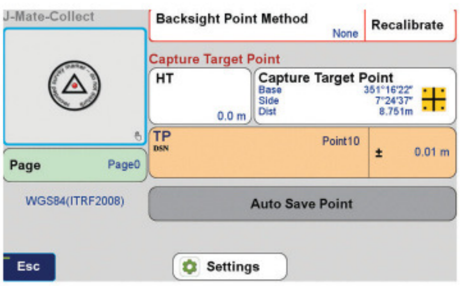






After connection, try to get acquainted with the **Main Navigation Screen**: On the TRIUMPH-LS Home screen, click CoGo/J-Mate/J-Mate Collect/Capture Target points.





Finding the target automatically:

There are three ways to search and find the target automatically:

1) One is by laser to scan and snap to a point when range changes by the specific amount. This is particularly valuable to snap to cables, poles and edges of buildings.

2) Second is search for the object of the specific flat size and focus on its center.

3) Third is with the camera to search for the QR target that we supply. We will discuss these later.

Switching between the two cameras:

You can view the scenes by the wide-angle camera of TRIUMPH-LS, while sitting on top of J-Mate; or by the narrow angle precise camera on the Side of J-Mate. Click Button **"4"** of Figure 1 to switch between the two.

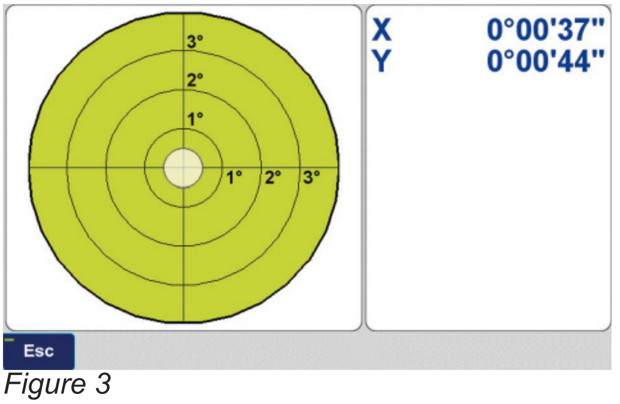


Figure 3

Viewing the embedded Inclinometer:

If you hold button **"4" of Figure 1**, you will see the embedded 0.001-degree electronic inclinometer of the J-Mate as shown in Figure 3. It updates 10 times per second.

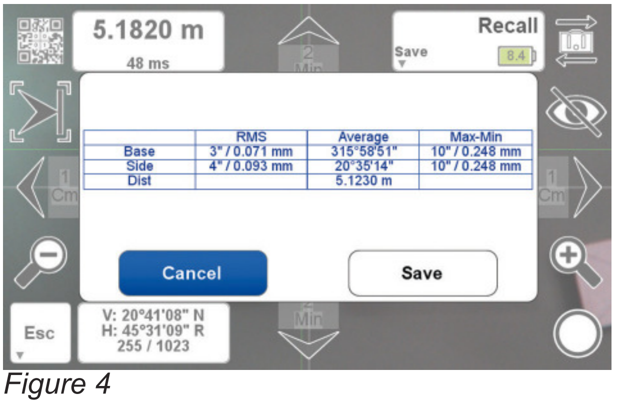


Figure 4

Taking a Point:

When you focus on your target manually or automatically, you can click the "Take" button (**"5"** in the Figure 1). The Encoders will be measured 10 times, the average, RMS and spread will be shown and you can decide to accept or reject (Figure 4). The accepted points will be treated like RTK points but labelled as "JM" points.

You can access and treat them like any other points in the TRIUMPH-LS.

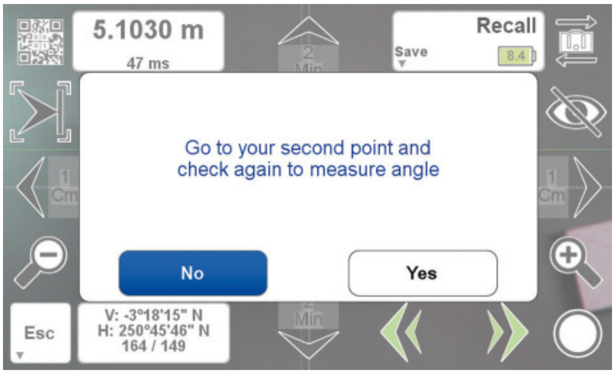
Figure 5

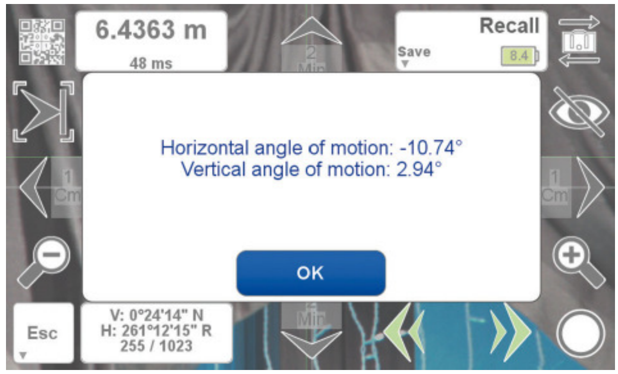
Viewing the Measured Points:

Clicking button **"6"** in Figure 1 will remove some of the items from the screen (Figure 5). Hold it long and you will see live view of the points taken by J-Mate.

Measuring angles quickly:

Aim at the first point and click button **"7"** of Figure 1. Then Aim to the second point and click this button again. You will see the horizontal angles between the two points.





Saving and Recalling Orientations:

Aim at a point and hold long the button **"8"** of the Figure 1 to save the horizontal, vertical, or both of that orientation (Figure 7). Click this button to rotate to that saved orientation.

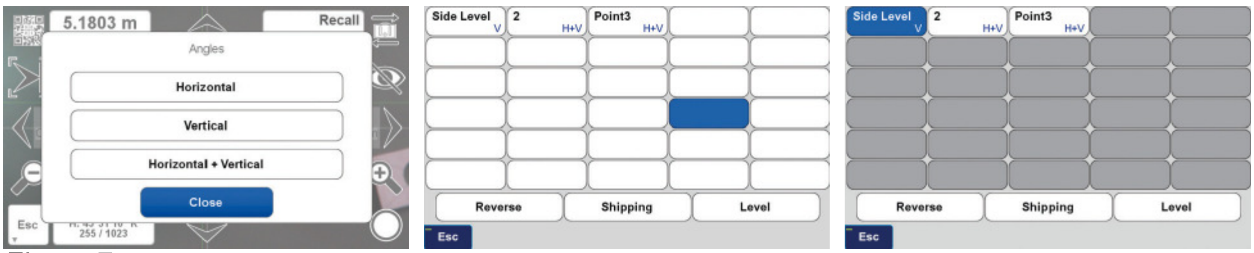
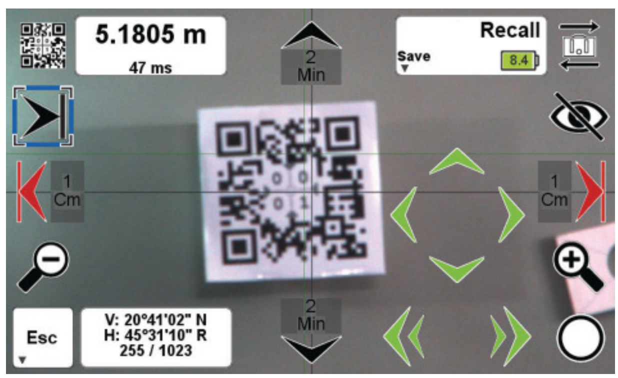


Figure 7

Scanning and Snapping to an object:

Click button **"9"** of Figure 1 and the left and right motion buttons (**"3"** on Figure 1) change to red which means when you click them scanning to snap will start. Hold long button 9 to get to the screen that sets the parameters for the Scan and Snap operation.

In this screen you can define the scan range and ask the scan to stop when range changes by the specified value. Then you can select the point that was measured before the stop or after the stop. By selecting a very large number you can scan the ranges that you have specified and record the 3D image. When you click button 9 to stop change the scanning back to normal motion, you will be asked if you want to save the scanned file. You can view the 3D image of the scanned file in the "File" icon of the Home screen of the TRIUMPH-LS.



Connecting and Re-connecting J-Mate to TRIUMPH-LS

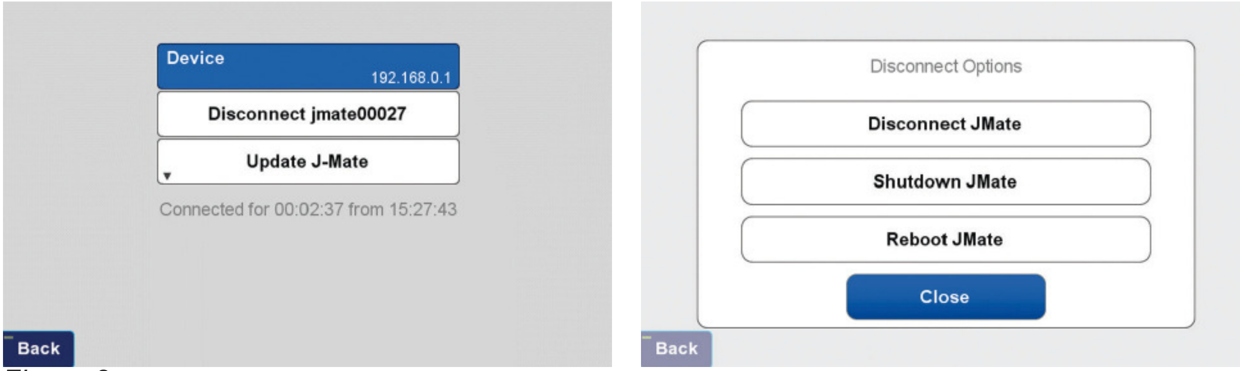


Figure 8

Holding the **"ESC"** button (**"10"** in Figure 1) will take you to Figure 8 which lets you disconnect J-Mate, Reboot, or turn off. Like all Wi-Fi connections, you may lose connection and need to use this screen to disconnect, re-connect, or re-boot J-Mate and in some occasions reboot TRIUMPH-LS too, especially when connection between the camera of the J-Mate and TRIUMPH-LS is lost.

View Range measurements

Box **"12"** of the Figure 1 shows the range measurements. It reads up to 20 times per second.

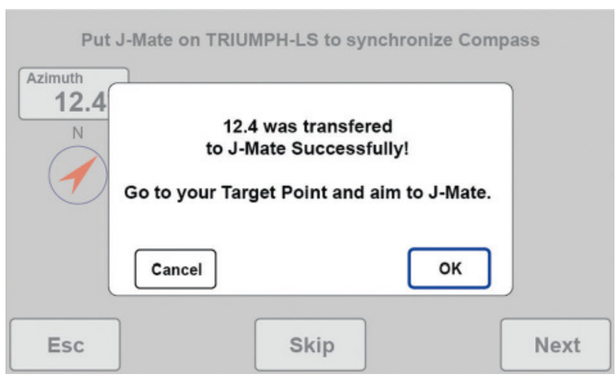
Automatic Finding of the Target:

Click the QR icon (**"11"** of the Figure 1). You will be guided through the following steps to aim at your target point. :

1. Put the TRIUMPH-LS on top of J-Mate (or slightly above it, but at the same orientation as the J-Mate, to be far from the motor magnets of the J-Mate) and click Next.

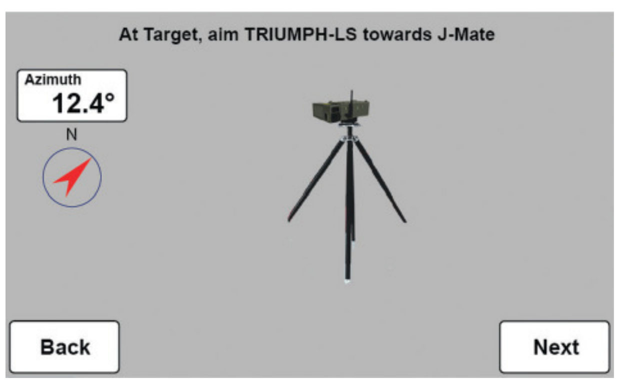
This step will transfer the compass reading of the TRIUMPH-LS to the J-Mate encoders.

You can skip this and the next step if you are in an area that the compass readings are not valid or you can aim manually in the next steps. .



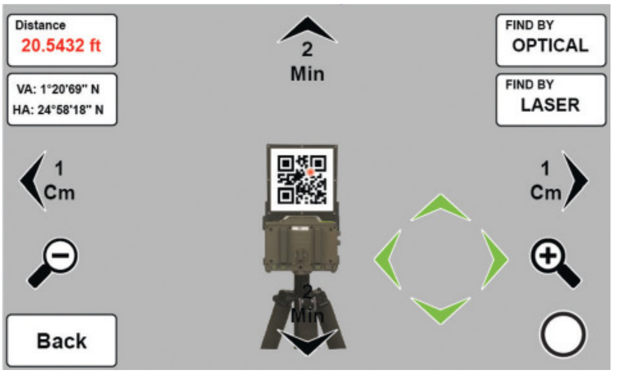
2. Go to your target, Put the QR accessory on top of the TRIUMPH-LS and aim the TRIUMPH-LS towards the J-Mate (with the help of the TRIUMPH-LS camera) and click Next.

This will help the J-Mate to know the general direction to the target and limit its search range. You can go back to previous step to fine tune view of the J-Mate. Or you can skip these two steps.



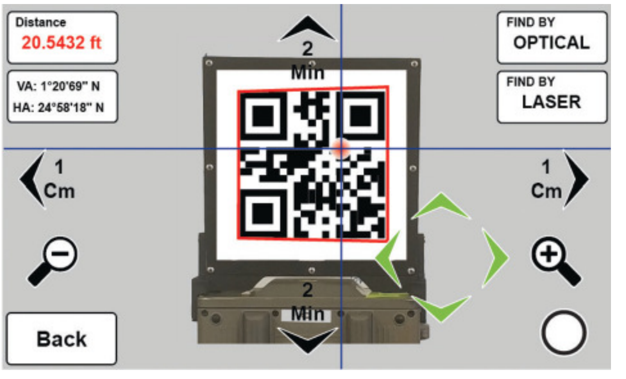
3. You will see the J-Mate camera view on the TRIUMPH-LS screen. You can fine tune the J-Mate view by the navigation buttons to make recognition faster. You can skip these steps if you don't want to make the search faster.

In here you can also manually aim at the center of the QR panel and take your shot.



4. Click "Find by Optical" if you want the QR panel to be scanned and centered automatically.

When J-Mate focuses on the center of the QR, you can click the "Take" button. You will be asked if you want too record the point.



5. If you also want to find the center of the QR by Laser scanning, you can click the "Find by Laser". If Laser scan is successful, you can click the "Take" button to replace the previous measurement with the current measurement done by laser scanning.

The center of the QR is vertically collocated with the GNSS antenna and you don't need to be exactly perpendicular to the J-Mate path. For safeguard, we measure the four sides of the QR and determine the angular offset, if we need it.

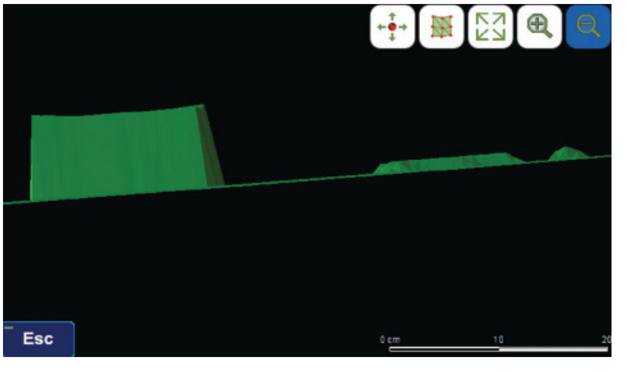
If light condition is such that camera cannot find the QR, chances are better that laser scanner can find it.

Finding the center of QR by laser and by the camera is a tool to calibrate these two sensors together.

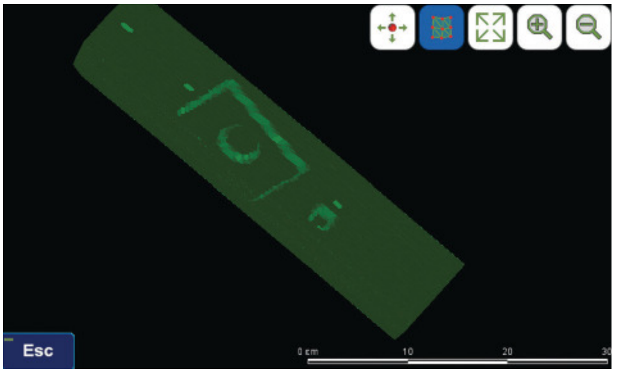
You can run this feature periodically to re-calibrate their axis if you need to. This calibration is small portion of the factory calibration.

You see the 3 views of the 3D scanning

The first scan image is scan of a 1 cm thick and a 6 cm thick objects. 1 cm step resolution.



The last one is scan of a 12.5 x 8 cm object of 1 cm thickness.



This overview as also an update to videos at www.javad.com.

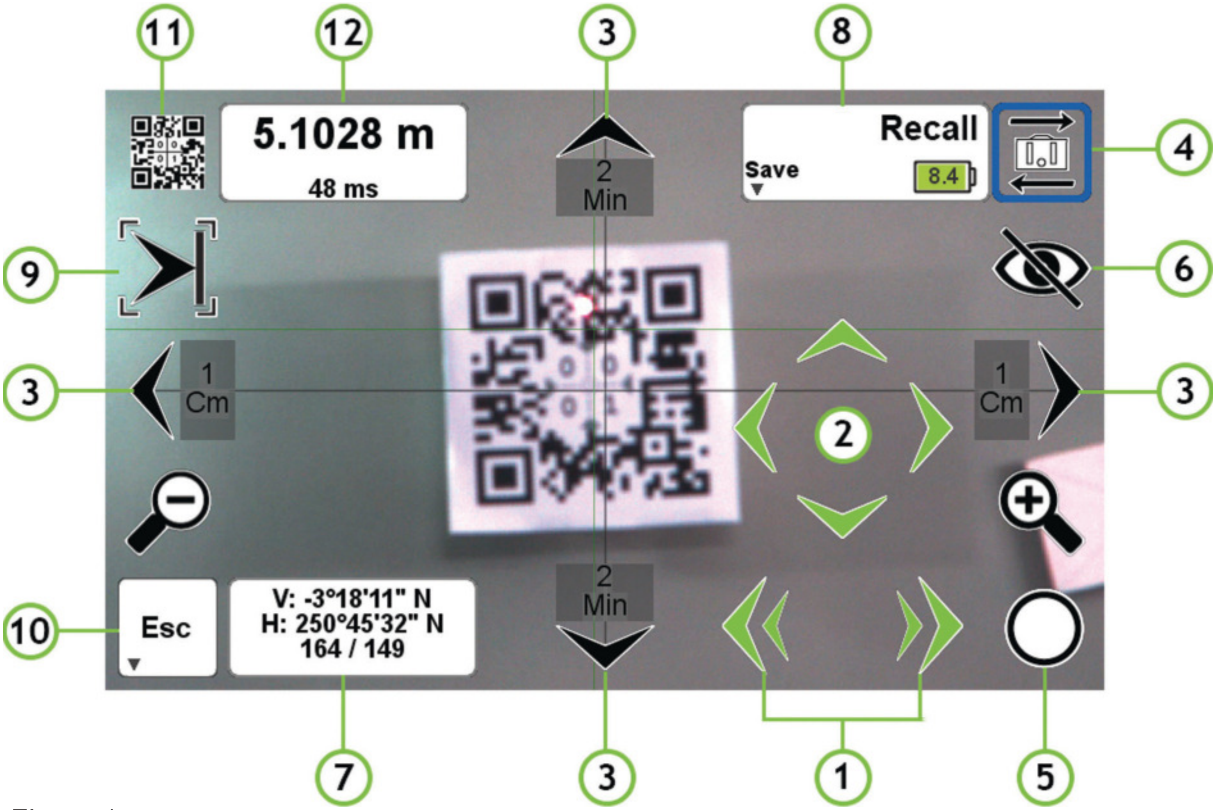


Figure 1

This is the **Main Navigation Screen**

Finding the Target:

You can find targets manually or automatically.

There are five ways that you can manually rotate the J-Mate towards your target:

1. On the bottom right of the Main View screen, there are left and right "Fast Motion" buttons. While you hold them the J-Mate rotates about 30 degrees per second. (**"1"** on the Figure 1)

2. Above them, there are slow Left/Right/UP/Down "Slow Motion" buttons. While you hold them, the J-Made rotates about 5 degrees per second. (**"2"** on the Figure 1)

3. Then there are Left/Right/Up/Down buttons around the screen. Each click moves the J-Mate according to the value that users assign to them. Hold these buttons to assign angular or linear values to them (**"3"** on the Figure 1). The Value Assignment Screen is shown in Figure 2.

4. Touching points on the cameras and by gestures.

5. You can also rotate the J-Mate manually while it is not moving automatically, but limit that to the small rotations in the area of motor free motion, not to apply backpressure to motor as much as you can. Motor manufacturer does not prohibit manual motion, but we think it is better to avoid that as much as possible.

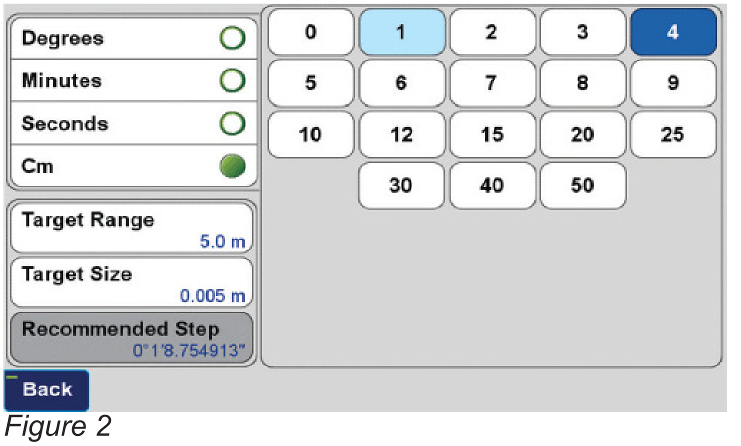


Figure 2

TRIUMPH-3

The new TRIUMPH-3 receiver inherits the best features of our famous TRIUMPH-1M.

Based on our new third generation a TRIUMPH chip enclosed in a rugged magnesium alloy housing.

The TRIUMPH-3 receiver can operate as a portable base station for Real-time Kinematic (RTK) applications or as a receiver for post-processing, as a Continuously Operating Reference Station (CORS), and as a scientific station collecting information for individual studies, such as ionosphere monitoring and the like.

It includes options for all of the software and hardware features required to perform a wide variety of tasks.

- UHF/Spread Spectrum Radio
- 4G/LTE module
- Wi-Fi 5 GHz and 2.4GHz (802.11 a, b, g, n, d, e, i)
- Dual-mode Bluetooth and Bluetooth LE
- Full-duplex 10BASE-T/100Base-TX Ethernet port
- High Speed USB 2.0 Host (480 Mbps)
- High Speed USB 2.0 Device (480 Mbps)
- High Capacity microSD Card (microSDHC) up to 128GB Class 10;
- “Lift & Tilt”
- J-Mobile interface

Ideal as a base station

As always, the driving question is: Why change? Why abandon well-worn methods in current use?

It has to be for one or more forms of gain: time, money or manpower — which often equates to one or both of the first two terms.

When surveying with conventional equipment such as total stations, levels, and even GPS equipment, the likelihood of failure of a tried and true system is not very great. Comparatively, when using a UAV lidar system, not only are the stakes higher (as the equipment costs more), but the likelihood of an all-out failure is more likely and is definitely more devastating. There is no quick fix if your UAV crashes. It is more likely that the UAV will crash (usually due to operator error) than the lidar system itself will fail.

Facing these concerns, does one embrace a UAV lidar solution or hold to the tried and true?

If it is important to get a heavily wooded 40- to 100-acre job collected and delivered as a surface at 1-foot contour accuracy (or maybe even 0.5 foot) in a single day, then UAV lidar is the tool for the job. UAV lidar can save a lot of field time, eliminate the need for site revisits, capture more data than previously possible, and allow for a better product using more automated extraction tools.

Accuracy. Often the client wants a 3D point cloud, or digital elevation model (DEM), which is not necessarily derived from lidar. If the site has no vegetation present, then an image-based solution should be sufficient. However, most sites are initially covered with vegetation. In that cae, an image solution from some sort of aerial camera will only provide a surface on the top of the vegetation — not what the client wants. While lidar may not be perfect, it can get to within 0.1 to 0.2 feet of the ground surface, in spite of grass or trees. For most initial design surveys, this is all that is required.

Money. Cost is perhaps the topic of greatest persuasion against lidar and in favor of an image-only solution. A lidar system is more expensive than most camera systems, but again the camera system simply cannot collect viable ground data in vegetated areas.

Time. Another factor is the time required to become profitable with the system, and the longevity of the system. In a good economy, it doesn't take many 40-acre topo jobs to completely pay for a UAV lidar system. Once more, it is about time.

As to product longevity, any new UAV product released today should be just as functional in five years. You may have to upgrade your UAV, but the lidar system will still be good for the jobs we're discussing.

Lidar collects XYZ and intensity. It does not collect RGB values. This is a strike against lidar. While lidar data can be colorized with imagery captured from a camera on the same system as the lidar, or separately, this is generally discounted as being imprecise (not well aligned). Lidar does not inherently or directly capture color. However, imagery is 2D in nature and does not capture XYZ data.

Imagery can align with the lidar nearly perfectly; it is a matter of a good boresight.

UAV photogrammetry, or image-only solutions are amazing. They provide a wealth of information. They are complementary to and synergistic with UAV lidar.

The advantages of including a UAV lidar solution along with a UAV photogrammetry solution include:

- the ability to measure at any time, day or night, in bright light or no light;
- rapid surface generation (not instant, but fast);
- flat surfaces, vertical walls, overhead structures — everything is collected without difficulty;
- power lines, guy wires and so on are all collected directly,
- bare-earth collection (multi-echoes and direct collection to ground, not just top of vegetation) is possible;
- generally a much wider collection width and fewer flight lines.

Further, lidar can often penetrate dust, fog and mists.

SENSORS AND THEIR ISSUES

Lidar does require an inertial navigation system (INS) and all of the controlling software. This generally makes the system more expensive. It also makes it able to more rapidly generate the final product.

Inertial Use with Lidar. An INS combines a GNSS receiver with an inertial measurement unit (IMU) and a lot of software and specialized filtering algorithms. It is essentially the central nervous system of a lidar system. The GNSS receiver provides universal timing such that every instrument including the IMU, scanner, cameras and others are all precisely time-stamped. This is key to proper data fusion. The GNSS receiver also provides positioning. The IMU is essential for determining proper orientation (roll, pitch, heading) as well as positioning at an extremely high data rate (2000 Hz) between the recorded GNSS epochs. If a GNSS event is missed (which shouldn't happen on a UAV) the IMU bridges the gap between epochs. Large gaps can lead to positional drift, but shouldn't happen on a UAV.

The real-time software maintains satellite lock (coupling with the IMU as necessary), while the post-processing software, using a post-process kinematic (PPK) process, provides the best possible solution of the trajectory. It solves the trajectory forward, backward and over and over with different parameters until it reaches an optimum solution. So it's not just the hardware that makes the system more expensive, it's also the software.

Double Duty? There is some confusion as to the INS on

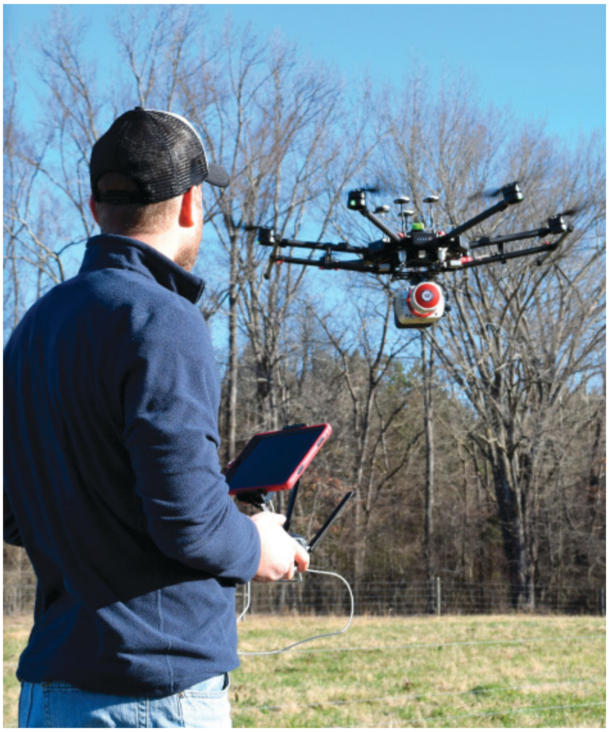


Photo: Bailie McRae

PILOTING a lidar-equipped drone.

a UAV. Can the INS used to navigate the drone be used for the lidar system as well, to save money? Yes, and no. Yes it can, with the proper integration — however, the INS to navigate the drone is usually far, far inferior to that required by a lidar system. So, No. Also, the lidar system really should be portable from the UAV to a car to maximize use. So the systems need to remain separate, for the most part.

Height and Width. Another UAV sensor issue concerning lidar is often very confusing. Some sensors are only good for 40- to 60-meter flying heights; some are useful to 200 or more meters. Depending upon where you work, this may be of no concern. In the U.S., we are limited to 120 meters above ground level (AGL) in any case. In most areas, being able to fly at 80 to 100 meters AGL is sufficient as long as accuracy and point density are not compromised.

Scan width varies a lot as well. The scan width of the shorter range systems is typically no more than 150 meters of usable area, whereas others can scan 500 meters wide. Consider that most surveys are 40 acres, maybe up to 100 acres, and we find that one flight is all that is necessary even with the least-expensive system. Do you need 500 meters wide? The answer depends upon your business model. If you are doing miles and miles of transmission corridor work, you probably need the greater width.

Ground Accuracy. What matters here is not so much positioning accuracy but point-cloud thickness. This can be difficult to understand and is a worthy subject by itself. The question is whether you can deliver the product you most often are required to deliver with the system. If you deliver 1-foot contour projects, can you achieve this with a 6-centimeter system or do you have to have a much more costly 1-centimeter system? Clearly the 1-centimeter system is much better, but what do you need to deliver?

Intensity is another concern. Most of the less expensive systems don't do a very good job delivering a "b+w image-like" point cloud; that is, their intensity falls off dramatically with distance. Others do an amazing job. Is this important? Can it be overcome with colorization? If you were doing your work conventionally, would you be delivering an image-like surface? I doubt it. Certainly the intensity is nice to have and the information can be very useful in automated processing, but is it worth the price difference?

ULTIMATE TEST: THE JUNGLE

Recently we undertook an adventure with some explorers in South America, near the city of Jaen, Peru. A crew filming a new TV show for the Travel Channel sought to understand more about the ancient civilization of Chachapoyas, Warriors of the Clouds. Little is known about this race of people because they were conquered by the Incas in the 16th century and shortly thereafter by the Spanish conquistadores.

Our team was to help identify structures in an area called Leymebamba, about four hours' drive from Jaen, hidden beneath the deep Amazon cloud forests — definitely not a typical North American forest. These forests are not only very dense with vegetation but with cloud cover that is generally at the level of the canopy.

Many centuries after the Chachapoyas have vanished, structural remains are concealed not only by the clouds and the canopy, but buried beneath several feet of dirt and a lot of living and long-since-dead organic matter. Only the most pronounced features can be found by the naked eye or a traditional survey.

Lidar brings a huge advantage in that it can get a much better approximation of the ground as well as any other hard surface such as walls, fences, trails, buildings and towers. By blanketing an area with dozens if not hundreds of points per square meter, post-processing software can "peel" the living vegetation away from the ground surface. This ground-classified data can then be analyzed by a trained scientist to determine if there are in fact any revelations to be had.

In our case, we were using an A-series high-definition lidar system, best flown at 40 to 60 meters and, in extremely dense vegetation, at 5 to 6 meters/second. Collecting 700,000 points per second enables us to potentially capture

Photo: Forrest Briggs

UAV AND LIDAR, bound for the cloud forest.

more than 400 points per square meter in a single pass. The area we were to scan varied considerably in terrain and had very little to offer that was flat and open. In fact, to get to the site, we had to pack several mountain horses with the UAV, several sets of batteries, and the scanner as they traveled down very steep terrain about 900 feet to the base of the hill to be scanned.

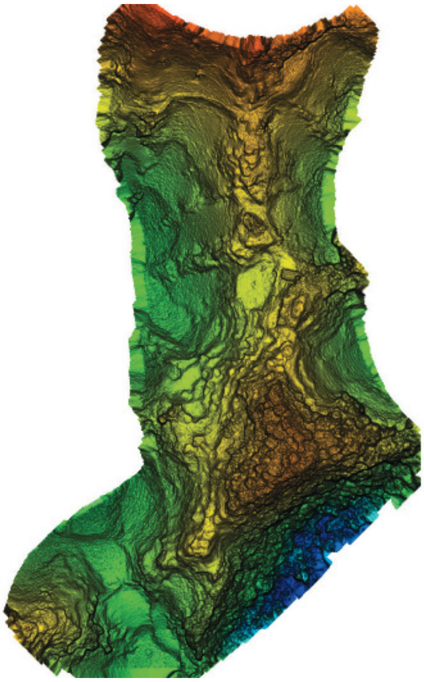
We've said we can scan from nearly anything moving, but we've never done it from a horse. Well, we weren't actually scanning, but it was pretty close.

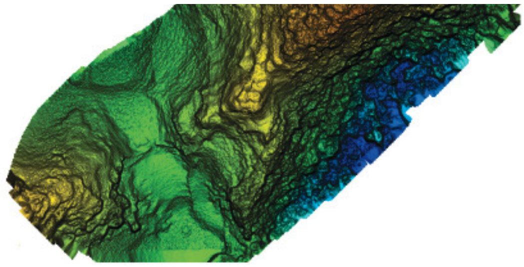
Finding a suitable take-off and landing area posed a challenge. Due to vegetation and terrain, only small areas could be scanned in a single flight, as the vehicle would quickly leave line-of-sight (LOS). While LOS may not be an issue legally in this area, it remains a real concern: we always want our equipment to come home at the end of the mission.

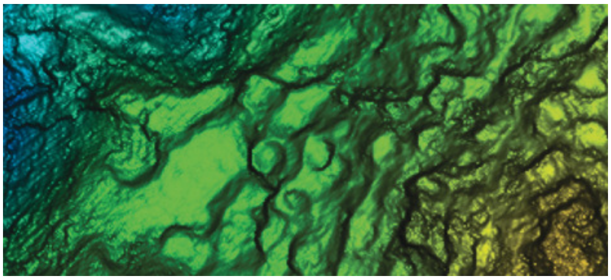
We learned something we hadn't anticipated along this journey regarding weather. The day would start out around 80° F; around 2 p.m. it would rain, and the rest of the day would close out much cooler. Does this matter? Yes, if you are now wet and cold with several hours ahead of you. It seems there is always some new surprise.

As the area was remote, with no internet access, the existing map data for mission planning had to be downloaded prior to visiting the site. Each lidar mission was preceded by a scout flight using a small UAV to help ensure safety and appropriate flying height per flight line.

Situating the Base. Projects like this always pose







All figures Lidar USA

FIGURES 1, 2, AND 3 **Left, broad overflight area of the cloud forest. Top, bare earth classified surface of small site. Bottom, closer site inspection — notice non-natural occurring mounds.**

dilemmas. Finding a good place for a GPS base station in a cloud forest is no small task. Normally we would put the base station on a known reference point so we can easily join the data with other projects. In this case we didn't have any such concern. We simply needed an area with a clear view of the sky; usually this means no obstructions 12 degrees above the horizon. However, in a forest and in the mountains, you take what you can get. In our case, we found a rock outcropping and placed the unit on it with no tripod. It didn't give us the best solution, but it worked.

Ideally we leave the base running for hours to get a good solution. Since we had multiple sites to scan, this wasn't a problem. All sites were within walking distance of the base, so there was no concern about being too far away and adding more problems to the project. In PPK mode we can easily be 10 or 20 kilometers from the base with no concern.

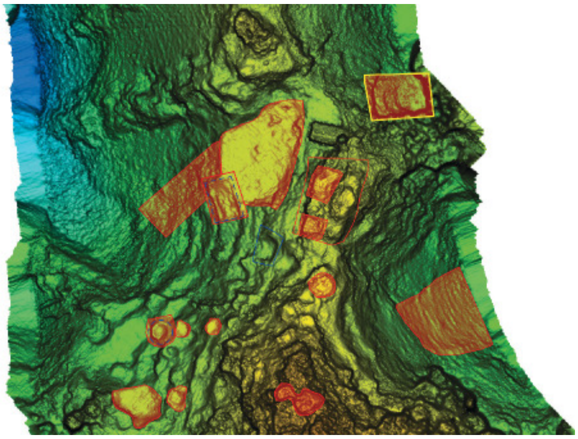


FIGURE 4 **Areas of interest to archeologist — lots of them.**

Other Forest Challenges. In-field processing, far from internet or electrical supply, requires very judicious battery and especially laptop usage. The lack of many things we take for granted can quickly be a show-stopper if necessary (maybe even a phone call). Even back at the hotel where power was available — don't count on it. While the film crew and archeologists are eager to see results, everybody has to wait. No power. Supposedly this is common and only lasts an hour. Three hours pass and everybody goes to bed but the lidar crew.

Finding the ground should be easy, but a new version of software has been installed. There's a kink in our plans. Finally after some internet help (a call back home), the right settings are found and the software begins peeling away the vegetation to reveal the ground. The top of each hill (several were scanned) looked like a primitive fortress with 20 to 30 cylindrical structures clearly spread over the top of each site. On one site we identified a tower at least 3 meters in height.

While areas like this could be scanned with a conventional aerial system, collecting much larger areas, the UAV lidar solution offers several distinct advantages. One of these is just a quick recon of the area. Physically being on the ground at the site makes the team much more aware of what is going on. Secondly is the far, far greater density of points and the ability to collect much more off-nadir, allowing for more of the vertical structure to be captured.

In the end, our mission was successful. The UAVs were ported by horseback up and down precarious trails. The lidar worked great. None of the batteries failed. The drones didn't crash. The archeologists were thrilled with the results, having found several new structures and a tower unknown to them. Once again, UAV lidar proved to be the best tool for the job. Indiana Jones out!

MANUFACTURERS

As both INS sensors and lidar scanners continue to change, this allows us to make quite a variety of configurable systems. For this particular project, we used our Snoopy INS (OEM) with a **Quanergy** M8 Ultra scanner. The Snoopy INS uses a **NovAtel** OEM719 GNSS receiver to ensure best performance with GNSS collection. Other options for the INS include the NovAtel STIM300 (**Sensonor** IMU), **VectorNav** VN-300 and **Trimble Applanix** AP family. For scanners we support all **Velodyne** scanners including the latest AlphaPuck, Quanergy, **Riegl** and several more. Of course, for cameras there are the ever-popular **FLIR, Sentera, PhaseOne** and **DJI**. GPS base stations are not all equal, but most will work as long as they log at least L1/L2 GPS at 1Hz.

EQUIPMENT **Left to right, from top down: GPS antenna, laser head (Quanergy M8), detachable mount (car & UAV), computer and INS (GNSS receiver + IMU), interface plate, battery.**

JEFF FAGERMAN is a a professional surveyor and certified photogrammetrist. He has a master's degree in photogrammetry from Purdue University and worked as a photogrammetric software developer at Intergraph before starting Fagerman Technologies. Now known as Lidar USA, the company focuses on mobile lidar aboard UAVs.

OEM

Allystar Launches Multi-GNSS Chipsets

Allystar Technology Co. Ltd. has launched two new multi-band, multi-GNSS chipsets.

Portable Devices. The HD8040 series is designed to help portable devices save size and weight. Offered in wafer-level chip-scale packaging (WLCSP), it fully supports all civil signals on the L5 band (Galileo, BeiDou, the Indian NavIC system and Japanese QZSS).

Besides the L1 band, HD8040D supports L5/B2a/E5a signals, which are expected to have lower noise and be better in multipath mitigation mainly due to the higher chipping rate of L5 signals relative to L1 C/A code.

HD8041D supports NavIC, which makes it suitable for navigation in urban areas in India and the Middle East, where seven NavIC satellites have a higher elevation than both GPS and Galileo satellites.

With its features of small size (3 x 3 millimeters) and low power consumption, the HD8040 series is suitable for smartphones, tablets and other portable devices. Besides basic peripheral interfaces UART, I2C, SPI and GPIO, it supports the CAN interface for automotive applications, too.

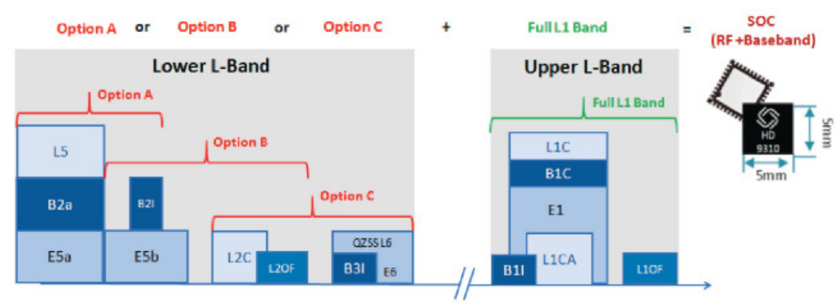


Chart: Allystar

THE HD9310 SUPPORTS three options of RF setting (A, B, C) for product developers.

High Precision. Based on the Cynosure III architecture integrating multi-band multi-system GNSS RF and baseband, the HD9310 supports BeiDou-3 and is capable of tracking all global civil navigation systems in all bands (L1, L2, L5, L6).

With small size, low power consumption (<50 mA), and ease of integration and mass production, the HD9310 is suitable for high-precision applications such as vehicle management, driverless, wearable devices, GIS data collection, precision agriculture, smart logistics, survey and other fields.

It measures 5 x 5 millimeters and supports CAN interface and can be used in vehicle management, car navigation, GIS data collection, precision agriculture, smart logistics, driverless, engineering survey and other fields.

The quad-flat no-leads package allows customers to reduce printed circuit board and bill of materials costs while reducing the number of peripheral devices.

The HD9310 comes with built-in support for standard RTCM protocol, supporting multi-band multi-system high-precision raw data output, including pseudorange, phase range, Doppler, SNR for any kind of third-party integration and application.

Module. Allystar Technology also has launched a multi-band multi-GNSS module, TAU1302, which integrates the HD9310 chipset and measures 12 × 16 × 2.3 millimeters.

FAA Chooses NovAtel for Safety of Life

The U.S. Federal Aviation Administration (FAA) has contracted NovAtel to design, produce and deliver 40 next-generation Ground Uplink Station (GUS) signal generators to support the FAA's safety-of-life WAAS navigation service.

The service provides safety-critical infrastructure for the North American aviation navigation network. The contract includes ongoing engineering support services for NovAtel's portfolio of satellite-based augmentation system (SBAS) products deployed by the FAA, including the WAAS G-III reference receiver platform. The FAA has relied on NovAtel's safety-critical SBAS technology for more than 20 years, starting with NovAtel's first-generation WAAS reference receiver, created in the 1990s. Developed by the FAA, the WAAS network is a safety-critical navigation aid that allows aircraft to use GPS for all phases of flight.

Every time an aircraft takes off or lands within the WAAS coverage area, NovAtel technology is generating and processing data that allows aviators to make precision approaches to any airport.

OEM NEWSBRIEFS

TAOGLAS ACQUIRES THINKWIRELESS

Taoglas, a provider of internet of things (IoT) and automotive antenna and RF solutions, has completed its acquisition of ThinkWireless Inc., an antenna provider that specializes in the design, development and production of combination antenna systems for the commercial vehicle market. The ThinkWireless brand will become ThinkWireless, a Taoglas company.

ADVANCED LTE MODULE PROVIDES LOCATION

Quectel Wireless Solutions has introduced the EM20, an LTE Advanced Category 20 module with location. It offers the maximum LTE throughput of 2.0-Gbps downlink and is optimized specially for laptop, PC and high-speed industrial internet of things (IoT) applications. The EM20 features Qualcomm IZat location technology Gen8C Lite (GPS, GLONASS, BeiDou, Galileo and QZSS). The integrated GNSS greatly simplifies product design, and provides quicker, more accurate and more dependable positioning capability.

INVENSENSE PROVIDES AUTO MOTION SENSORS

Invensense (TDK Corporation) has introduced a line of automotive high-accuracy devices: the IAM-20680, IAM-20680HP, IAM-20380 and IAM-20381. They are designed to enhance the absolute position of a vehicle in GNSS- and GPS-denied environments. The IAM-20680 is a 6-axis qualified sensor that features 16-bit accelerometers and 16-bit gyroscopes. The IAM-20680HP is a high-performance version of the IAM-20680 that features high gyroscope and offset thermal stability. The IAM-20380 gyroscope is compatible with a 3-axis automotive accelerometer and an automotive-qualified 6-axis device. The IAM-20381 is a 3-axis accelerometer compatible with a 3-axis automotive gyroscope and an automotive-qualified 6-axis device. The IAM-20680HP and IAM-20680 can be used to improve estimates of position, direction and speed when GNSS is denied, as well as improve quality of the position estimation when the satellite signal is strong. Customers can design with the IAM-20680 and can use the IAM-20680HP when navigating in high temperature environments or for systems where cooling is weak or unavailable.

TRANSPORTATION

Racelogic Takes Auto Testing Indoors

Racelogic is launching a new indoor positioning solution for accurate position and velocity in the absence of any GNSS signals, such as inside parking garages.

The new VBOX Indoor Positioning System will consist of a network of fixed beacons communicating with a small receiver mounted on the roof of the vehicle, which is connected to an existing VBOX. The receiver computes its position 100 times a second to around 5 centimeters real-mean-squared (rms) accuracy.


Images: Racelogic

THE BEACON (left) and example placement.

The system can be used on its own or with an internal inertial measurement unit (IMU) to improve the velocity accuracy.

VBOX data-acquisition systems are used for measuring the speed and position of a moving vehicle. Based on a range of high-performance GPS receivers, VBOX dataloggers can record high-accuracy GPS speed measurements, distance, acceleration, braking distance, heading, slip angle, lap times, position, cornering forces and more.

Racelogic engineers are working closely with VBOX customers to develop the solution, which allows the same test equipment and software that has traditionally been limited to outdoor use to be used anywhere that satellites coverage is limited or completely unavailable, such as in a parking garage.

The VBOX seamlessly switches between outdoors and indoors, allowing testing to continue whatever the environment and VBOX users to make use of their original hardware and software applications.

Tesla Granted US Patent for Positioning Tech

Tesla has developed a technology aimed at providing more accurate positioning for autonomous cars by sharing data between vehicles, according to a U.S. patent application. The patent, "Technologies for vehicle positioning," was filed in 2017 and made public in December 2018.

Solutions include cameras detecting matching locations and using other vehicles in its fleet as "cooperative reference stations" to share raw GNSS data and make positioning corrections.

Tesla describes in the patent, "The inventions increase such positioning accuracy via determining and applying offsets (corrections) in various ways, or via sharing of raw positioning data between a plurality of devices, where at least one knows its location sufficiently accurately, for use in differential algorithms."

Techniques include:

- a reference station sharing a positional offset with an automobile,
- a reference station calculating and sharing a set of parameters (offsets and corrections) for various error components including atmospheric, orbital and clock,
- a reference station sharing its raw GNSS data so that vehicles can remove errors through differencing or other calculations.

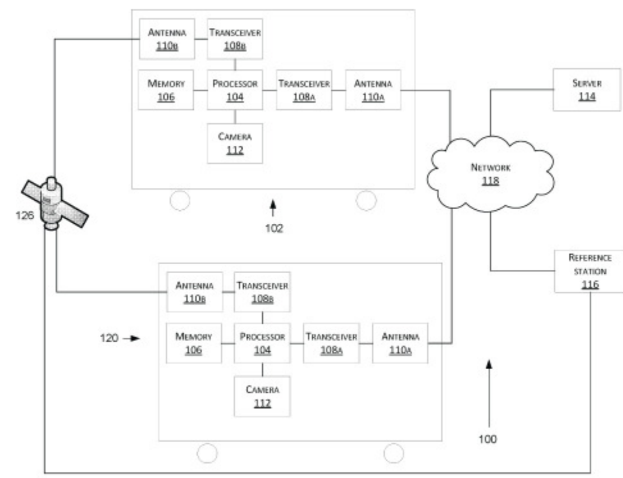


Diagram: U.S. Patent Office

SCHEMATIC OF TESLA'S SYSTEM **shows two vehicles (102, 120) feeding data to a network, a server and a reference station.**

Tesla also would correct GPS data by matching camera data with vision maps to detect the exact location of a vehicle. With this vision-map matching localization approach, "a location estimate is varied until the location estimate makes a camera-reported lane boundary coincide with a map-reported lane boundaries," the patent reads.

UAV

Photo: Bell Helicopter

Bell Helicopter Unveils Full-Scale Air Taxi at CES

Bell Helicopter unveiled a full-scale vertical-takeoff-and-landing (VTOL) air taxi at CES 2019, held in Las Vegas. The Bell Nexus air taxi is powered by a hybrid-electric propulsion system and features Bell's signature powered lift concept incorporating six tilting ducted fans designed to safely and efficiently carry passengers.

A team of companies is collaborating on the Nexus. Bell is leading the design, development and production of the VTOL systems; Garmin is integrating the avionics and the vehicle management computer (VMC); Thales is providing the flight-control computer (FCC) hardware and software; Safran is providing the hybrid propulsion and drive systems; EPS is providing the energy storage systems; and Moog is developing the flight-control actuation systems.

Drones Survey for Geothermal Energy in British Columbia

Global UAV Technologies Ltd. has completed a drone-based geothermal energy exploration survey for Borealis GeoPower Inc. The survey used UAV-mounted geophysical and thermal imaging sensors over an area in northern British Columbia, Canada.

Global UAV subsidiary Pioneer Aerial Surveys collaborated with Hummingbird Drones to collect and analyze high-resolution magnetometer and thermal data over the 2,200-hectare survey area. The survey was conducted using both day and night flight operations to maximize efficiency and data quality. The survey produced high-resolution deliverables on the geological and geothermal features of the survey area.

The work was conducted at the Terrace, BC, geothermal project, near the location of one of the world's largest hot springs. Borealis is refining its reservoir model in advance of drilling in 2019.

DEFENSE

UK Tests Tracking UGVs

In December 2018 near Salisbury, England, four Milrem Robotics' and QinetiQ TITAN unmanned ground vehicles (UGVs) were put through three weeks of rigorous tests by British troops during the Army Warfighting Experiment 2018 (AWE18). The goal was to determine how new unmanned technologies can enhance soldier's survivability and effectiveness on the modern battlefield.

The test was conducted in three phases: conduct combat operations without the benefit of new technologies; conduct combat operations using new technologies but without changing tactics; and, lastly, conduct combat operations using new technologies and adapting tactics according to the capability that the new technology provides. The UGVs were used in a number of different roles with missions conducted in urban, open and forested terrain.

In remote-control mode, a command-and-control station allows the operator to receive real-time sensor data from the UGV and to transmit command data to the vehicle through a tactical data link. Various third-party sensor packages can be installed.


Photo: Milrem Robotics

THE MODULAR BASE can be adapted for various missions, includinng casualty retrieval.

Of the four Milrem UGVs, two were deployed by Milrem Robotics and two by QinetiQ. The Milrem-fielded systems included one configured as a casualty evacuation and logistical support unit and a second unit equipped with a tethered multi-rotor drone pod provided by Threod Systems.

One of the four UGVs was TITAN Strike, a prototype system carrying a Kongsberg remote weapon station, fully controlled by a remote operator and using QinetiQ's Pointer system as a means of integrating the capability with dismounted infantry. The second system, TITAN Sentry, also enabled with Pointer, featured a Hensoldt-provided sensor suite including electro-optical and thermal-imaging cameras and a battlefield radar.

SPIRENT FEDERAL'S SIMMNSA GRANTED DIRECTORATE SECURITY APPROVAL


Photo: Spirent

Spirent Federal Systems' new M-code solution, SimMNSA, has been granted security approval by the GPS Directorate. Spirent Federal is the first company to provide such a solution for simulating classified GPS signals, and is currently taking orders. In 2017, Spirent Federal partnered with Rockwell Collins to develop software that will use the Modernized Navstar Security Algorithm (MNSA). This new approach to M-code simulation adds to Spirent Federal's portfolio of classified signal simulation solutions, and will be available to authorized users of its GSS9000 series simulators.

MOBILE

Photo: Forward X Robotics

Luggage that Follows You

Chinese company Forward X Robotics showed off its Ovis luggage at the 2019 Consumer Electronics Show.

Ovis uses cameras for facial recognition and a movement tracking algorithm to lock in on its owner and stick with her or him at a speed of six miles per hour. Ovis is able to avoid collisions as it makes its way through crowds, according to its maker, which is now producting the suitcase after an IndieGoGo campaign.

The Ovis suitcase comes with a smart wristband that sounds and vibrates if the case gets more than six feet away. Its embedded GPS provides real-time monitoring and tracking via smartphone; the location tracker is in an uncuttable luggage tag.

Similar following suitcases include 90Fun's Puppy 1, which uses remote control to follow, and the Travelmate, which provides a removable GPS chip to enable tracking of the bag or anything else of value. 🌐

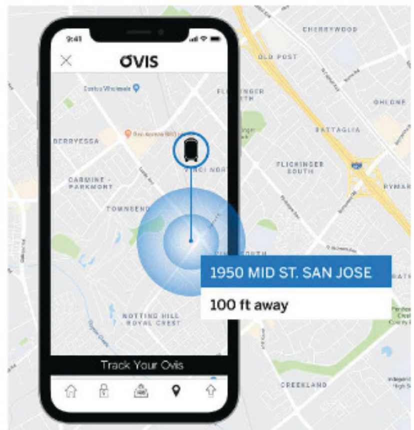


Image: Forward X Robotics

MACHINE CONTROL

AMW Offers New Construction and Ag Products

AMW Machine Control Solutions, a subsidiary of CHC Navigation, has introduced four new solutions for the survey, construction and agriculture markets, all of whih run on Android and CHC Navigation GNSS tablet hardware.

GRADE I and II Products. GRADE I runs on a CHC Navigation industrial tablet and utilizes an internal meter-accurate GNSS receiver for field workers and supervisors to view layered maps including design files, topo or Google Maps for locating elevations and topographical features.

GRADE II adds centimeter elevation and positioning accuracy with an external CHC Navigation RTK-capable GNSS receiver that wirelessly communicates with the tablet. GRADE II collects topographic data on the jobsite by walking or driving the area, eliminating surveyor stakes and providing accurate data for earth-moving operations. The density of elevation points can be adjusted. The GRADE II "Smart Base" allows a user to establish RTK control points.

DIRT I and II Products. DIRT combines GRADE II mapping functionality with automatic blade control for skid steer, scraper, grader or dozer applications for rough and fine land-shaping activities on large or compact equipment. DIRT is available as DIRT I or DIRT II versions depending on the type of blade control needed. Utilizing additional sensors, DIRT II adds the ability to manage cross slopes.

DIRT includes an RTK GNSS, inclinometers, tablet computer,

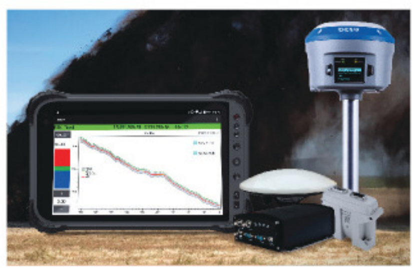


Photo: AMW Machine Control Solutions

CANBUS controller and DIRT software running on a CHC Navigation tablet. The tablet wirelessly connects to the RTK receiver and other sensors, making the system easily portable so it can be reinstalled on other equipment.

For agriculture applications, AMW Solutions' proprietary algorithm within the DIRT solution results in accurately graded surfaces within the limits of the equipment. 🌐

SURVEY

Eos Supports GEOID Height Models in Arrow

Orthometric height support enables Arrow GNSS receivers to collect high-accuracy, survey-grade vertical data.

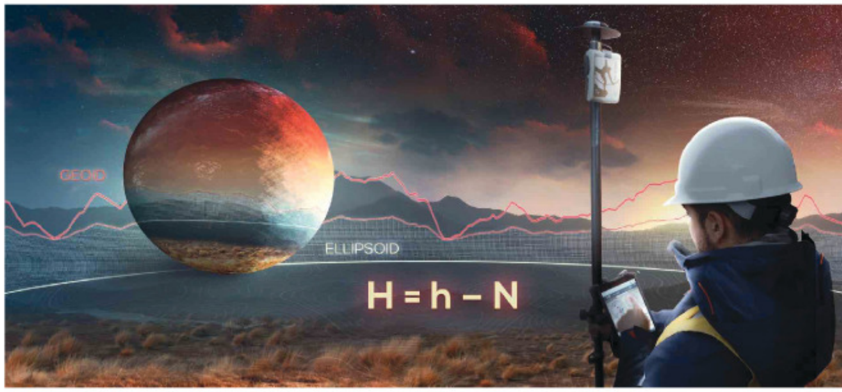


Image: Eos Positioning

Eos Positioning Systems Inc. has announced support for GEOID height models within its Arrow Series GNSS receivers. Eos manufactures high-accuracy GNSS receivers for any app running on iOS/Android/Windows devices and using the Eos Arrow Series.

With support for GEOID models, Arrow receivers automatically output survey-grade elevations to all iOS and Android data collection software. Support will also soon be available for Windows devices.

The Arrow receivers now support the entire United States to provide survey-grade elevation in NAVD88 orthometric heights through the GEOID12B (U.S.) model. The Arrow receivers also support the Canadian CGG2013a and HTv2.0 GEOID models for the CGVD2013 and CGVD28 vertical datums, respectively. Additional GEOID models for other countries are planned.

Eos has designed the new feature so that users will easily be able to update to new GEOID models as they become available. Field technicians in pipeline, construction, engineering, architecture, water, and other industries are finally able to enjoy GNSS location with survey-grade vertical accuracy on their iOS and Android devices, with the data-collection app of their choice and their Eos Arrow receivers. 🌐

Tersus GeoCaster Provides NTRIP Corrections

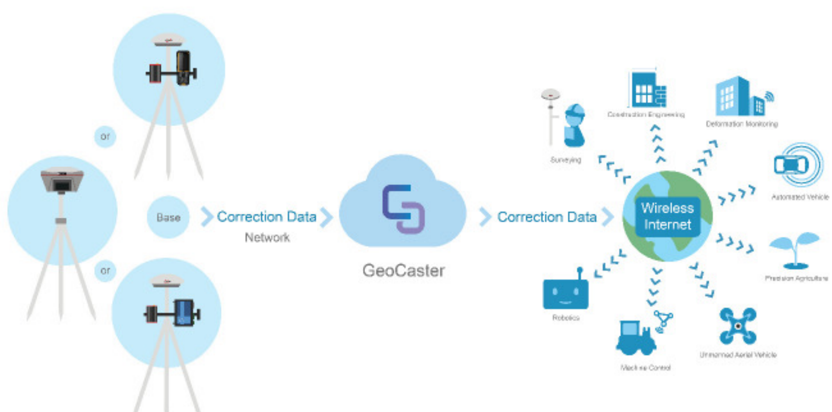


Image: Tersus GNSS

Tersus GNSS Inc. has released the Tersus GeoCaster, an NTRIP caster software. The software expands the company's product line and provides users with better and more comprehensive services.

The Tersus NTRIP (Networked Transport of RTCM via Internet Protocol) caster software is designed to allow GNSS correction data such as RTCM corrections to be repeated and sent to different end users via the internet.

GeoCaster has a user-friendly interface, and it supports multiple bases online simultaneously as well as multiple rovers for one base. It gives users a real-time review of detailed statistics. User-defined permissions can be modified manually.

Tersus GeoCaster supports configurable bases online simultaneously and configurable rovers for one base. GeoCaster supports NTRIP protocol and operates continuously.

The software is designed for end users involved in applications such as surveying, construction engineering, deformation monitoring, automated vehicle, precision agriculture, unmanned aerial vehicles, machine control and robotics.

This is the first release of GeoCaster. Version 2.0, targeted at the first quarter of 2019, is expected to offer higher accuracy and longer baseline applications. 🌐

MAPPING

DURHAM PUBLIC WORKS USES NEARMAP TO MANAGE MASSIVE CITY GROWTH

Location content provider Nearmap has partnered with the fast-growing city of Durham, North Carolina, helping it manage infrastructure projects. The city's Public Works Department uses Nearmap's high-resolution imagery to aid in managing all infrastructure data for the city, including the city's $16 million a year Stormwater Utility Fund.

"Having access to imagery back to 2014, we're able to go back in time during the thrust of development and monitor it forward," said Edward Cherry, Durham's GIS administrator. "With Nearmap, we've been able to update development processes and policies to support the revitalization of the downtown district as well as rapid city growth."

After using satellite imagery systems with low resolution and infrequent captures, Cherry and his staff of 14 GIS professionals determined the city needed superior mapping imagery. Captured every six months at a 2.8-inch ground sample distance (GSD), Nearmap supplies Durham with clear images that are up-to-date and accessible through web-based cloud servers.

The result is better monitoring of pavement conditions; time savings and documentation of road repairs; more detailed maps of city riparian zones; and accurate and detailed customer billing.

Image: Nearmap

NEARMAP HIGH-RESOLUTION aerial image of Durham, North Carolina, photographed Jan. 15.

Fugro's New RAMMS Acquires Dense Data

Fugro has completed a data acquisition campaign over the Turks and Caicos Islands, marking the first commercial success of its new Rapid Airborne Multibeam Mapping System (RAMMS).

Working under contract to the United Kingdom Hydrographic Office (UKHO), the company acquired more than 7,400 square kilometers of integrated, high-resolution bathymetric, topographic and image data. The resulting deliverables will support updated nautical charts and coastal zone management activities in the region.

Launched in August 2018, RAMMS is an efficient, next-generation airborne bathymetric mapping system that uses multibeam laser technology to deliver depth penetration and point densities. It combines bathymetry, topography and imagery for navigation and coastal applications.

The compact sensor is deployed from small aircraft and can be integrated with other remote sensing technologies for simultaneous collection of multiple complementary datasets. Fugro plans to operate the unmanned aerial vehicle (UAV)-proven system autonomously in 2019, increasing access to remote project areas.

Photo: Agile LeVin, Visit Turks and Caicos Islands, via Fugro

FUGRO DEPLOYED its new RAMMS airborne mapping system to acquire over 7,400 square kilometers of integrated, high-resolution data in the Turks and Caicos Islands.

The Key to Accuracy for High-Precision Applications

New developments in antenna technology empower the final positioning solution with better accuracy and reliability. Leading experts discuss the technology advances producing greater user benefits.

The increasing prevalence of both intentional and inadvertent jamming, new wider bandwidths, and the significance of antenna phase-center variation all bring changes to the dynamic and evolving antenna sector.

JAVAD GNSS

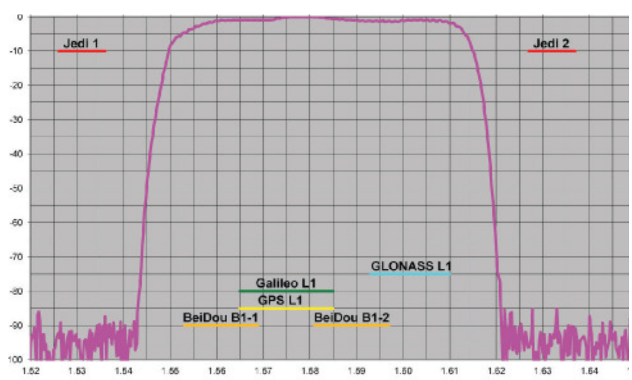
Javad Ashjaee
President & CEO

Advanced filtering techniques enable our antennas to defend against jammers and spoofers and to inform users with the details of these intrusive actions when they are detected.

Near-Band Interference. The J-Shield is a robust filter in our antennas that blocks out-of-band interference, in particular such signals that are near the GNSS bands like the LightSquared/Ligado signals. The graph below shows the protection characteristics of the J-Shield filters. It has a sharp 10-dB/KHz skirt that provides up to 100 dB of protection. It makes the precious near-band spectrums available for other usages and protects GNSS bands now and in the future.

In-Band Interference. Our in-band protection digital filter protects against in-band interference like harmonics of TV and radio stations when you get close to them, or against illegitimate in-band transmissions. Our in-band interference protection is based on the 16 adaptive 80th-order filters. Advanced interference mitigation (AIM) filters can be combined in pairs for complex signal processing. This filter can simultaneously suppress several interference signals.

The 16 finite impulse response (FIR) AIM filters can be combined in any number in chain. Each filter is a 255-order FIR filter. It can be used to suppress the stationary interference signal in programmable area (compare with adaptive AIM-filter) or for spectrum shaping. To have more suppressing areas or more aggressive suppressing, one can combine FIR AIM serial.



Graph: JAVAD GNSS

NovAtel

Neil Gerein
Director, Product Management

At NovAtel we often say, "accuracy is addictive," and to meet increasingly demanding accuracy and reliability requirements it is vital to concentrate on the antenna. After all, the antenna is the first in a long chain of key technologies that the GNSS signals must pass through to create a position, navigation and timing solution.

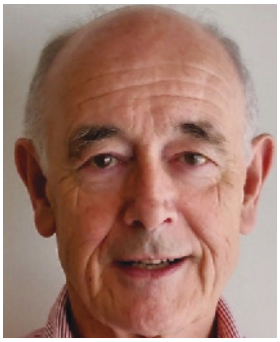
All modern GNSS transmit on multiple frequencies, with wide bandwidth signals, requiring antenna elements and integrated low noise amplifiers (LNAs) that operate across these frequencies. The challenge is to design the antenna element and LNAs for symmetric radiation patterns across all frequencies while minimizing multipath, phase center offset (PCO) and phase center variation (PCV). The result is better carrier-phase measurements, and therefore more accurate solutions in real-time kinematic (RTK) and PPP applications.

Since 2016 the Radio Equipment Directive (RED) has been in effect, and all GNSS receiver systems sold into the European Union must be compliant to the standard, including adjacent-band compatibility and spurious emissions testing. RED compliance is an end-to-end system test, where the filtering within the antenna must be analyzed in concert with the filtering capabilities of the connected GNSS receiver to meet the requirements. The antenna performance therefore becomes critical to any GNSS receiver system that is intended to be sold within the EU.

Photo: NovAtel

Tallysman

Gyles Panther
President and Chief Technical Officer



A fact often not appreciated is that the performance of a GNSS antenna is commonly the limiting factor in system accuracy. Digital signal algorithms in the receiver are helpful, but if the signal delivered by an antenna is less than optimum, the receiver cannot compensate.

Precision GNSS systems typically rely upon resolved wavelength ambiguity measurements, combined with ephemeris and clock corrections to determine signal time of flight. In real-time kinematic (RTK) and precise point positioning (PPP) receivers, the basis for this measurement is phase locked tracking of received satellite signals. Thus an over-arching measure of antenna performance in the specific application conditions is the proportion of the time that phase lock is maintained by the receiver.

All this provides for an unprecedented level of accuracy, with precision antennas now more akin to the ends of a tape measure than providing a simple GNSS "fix." To this end, key parameters include a best possible G/T ratio, high multipath rejection, excellent axial ratio, high front-back ratio and minimal phase-center variation (PCV), all with high uniformity in the azimuth — altogether a very demanding design task.

Combining these parameters to provide exquisite accuracy, the Tallysman VC6100 choke ring antenna has less than 1 millimeter PCV when combined with absolute calibrated corrections data, whilst the lower cost VP6000, with its less complex installation, can be used without corrections data and still be within a millimeter or two of the truth compared to its more precise cousin.

Photo: Tallysman

RESEARCH Roundup

Images: Robert DiNapoli and co-authors

POINT-PROCESS MAPPING LINKS EASTER ISLAND STATUARY TO FRESHWATER SOURCES

BY ROBERT DINAPOLI, *UNIVERSITY OF OREGON;* CARL LIPO, *BINGHAMPTON UNIVERSITY;* TANYA BROSNAN AND MATTHEW BECKER, *CALIFORNIA STATE UNIVERSITY, LONG BEACH;* TERRY HUNT, *UNIVERSITY OF ARIZONA;* SEAN HIXON, *PENNSYLVANIA STATE UNIVERSITY;* ALEX E. MORRISON, *UNIVERSITY OF AUCKLAND.*

Rapa Nui (Easter Island, Chile) is famous for its elaborate ritual architecture: more than 300 monumental platforms (ahu) and nearly 1,000 monumental, multi-ton anthropomorphic statues (moai). To date, however, we lack explicit modeling to explain spatial and temporal aspects of monument construction.

In a span of only about 500 years, from the 13th century A.D. to European contact in A.D. 1722 and into historic times, the Rapanui islanders sculpted and erected these famous megalithic statues. Why? And why were they placed where they stand? For many years, scholars thought that the island must have supported a larger and more complex society under more prosperous environmental conditions that then collapsed following a self-imposed "ecocide." In recent years, nearly every major component of this narrative has been shown to lack empirical sufficiency.

In this paper, we use spatially explicit point-process modeling to explore the potential relations between ahu construction locations and subsistence resources, namely rock-mulch agricultural gardens, marine resources and freshwater sources — the three most critical resources on Rapa Nui. Through these analyses, we demonstrate the central importance of coastal freshwater seeps. Our results suggest that ahu locations are most parsimoniously explained by distance from freshwater sources, in particular coastal seeps, with important implications for community formation and inter-community competition in precontact times.

The island's marginal ecology limited the food options available to the inhabitants. These environmental constraints could be a key factor in the emergence of monuments on Rapa Nui, such as their role as adaptive responses to environmental uncertainty or as territorial signals of control over limited resources.

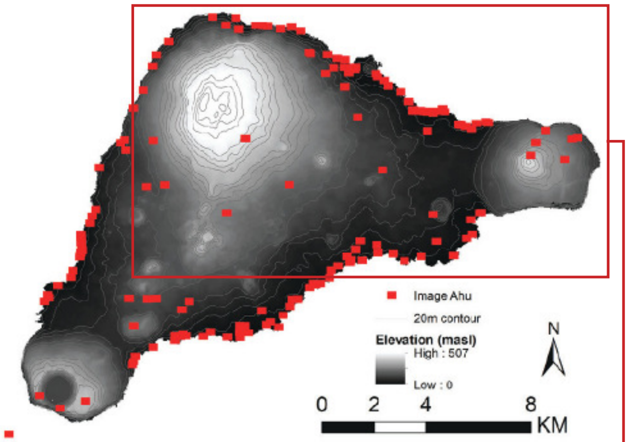


FIGURE 1 **Locations of image-ahu on Rapa Nui (Easter Island).**

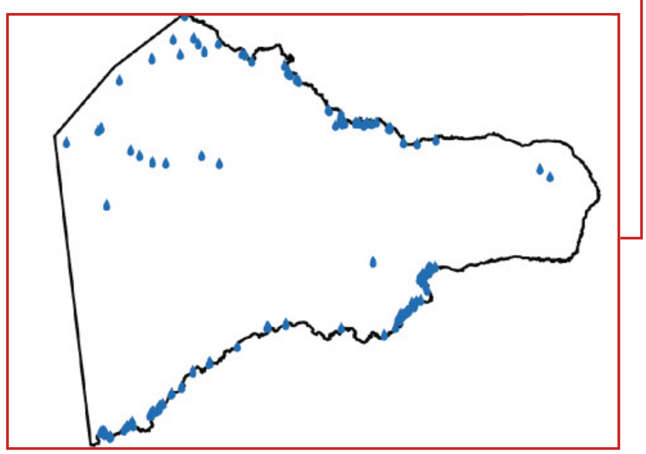


FIGURE 2 **Locations of freshwater sources.**

We quantitatively modeled how the spatial distribution of ahu is explained by different resources thought to be the focus of competition.

Point-process models (PPM) are a wide class of spatially explicit models that facilitate formal analysis of the relationship

SEE **Easter Island**, *PAGE 45.* >>

MODELING AND UNDERSTANDING LIDAR DATA FOR ABSOLUTE AND RELATIVE POSITIONING

BY DANIELA E. SÁNCHEZ, HARVEY C. GÓMEZ AND THOMAS PANY, *INSTITUTE OF SPACE TECHNOLOGY AND SPACE APPLICATIONS (ISTA)*

This paper presents how our system, consisting of a GNSS receiver antenna, an inertial measurement unit (IMU) and a lidar, is used in order to obtain high-precision maps through the georeferencing of lidar point clouds. An accuracy assessment of the system is conducted, which also gives us insights on the quality of lidar range measurements for autonomous driving applications.

The assessment is done by georeferencing the obtained point clouds of extracted buildings and comparing them against a supporting measuring system like a total station. The building extraction is done by performing an approximation of the mathematical model of a plane to the facades that composes the building in both, the lidar and the supporting measurement system data.

The paper also indicates the proposed pose determination method of a mobile agent using lidar data. Thanks to the advantages of active, 3D sensors, diverse objects in the environment can be detected as individual point sets, or clusters. Each of the segmented objects can be used as a landmark to figure how the agent is located with respect to those structural elements. The algorithm is capable of detecting the clusters in one point cloud, and finding the most alike point set on a subsequent scan. This is achieved by comparing global descriptors for point cloud data.

The Ensemble of Shape Functions (ESF) is selected as the cluster descriptor. The cluster matching is performed by comparing the clusters one-to-one, calculating the minimum Chi-squared distance among their descriptors. The smaller this distance, the greater the probability of being the same cluster in distinct epochs.

Images | ISTA

FIGURE 1 **Rendering of three georeferenced lidar point clouds on Google Earth.**

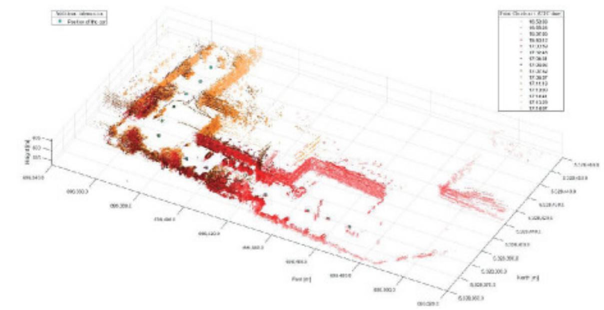


FIGURE 2 **Direct geo-referencing of lidar data at different times.**

The resultant cluster correspondences for the whole point cloud allow finding the rigid transformation between the point clouds. An initial coarse alignment among the clouds based on the centroids of each matched cluster was performed, followed by a fine alignment in order to reduce errors by the use of the Iterative Closest Point (ICP) algorithm. This approach is valid for urban environments, or for those where many objects can be segmented as clusters.

Finally, a practical case is described in order to show how we plan to use the outcome of the highly precise georeferenced point clouds and the pose estimation method using lidar.

More info at **www.ion.org/publications/ browse.cfm**.

<< **Easter Island**,

CONTINUED FROM PAGE 46.

between point-patterns and a range of spatial covariates. PPM works by fitting a spatial intensity function to the intensity of an empirical point pattern and finding the values of the predictor variables (i.e., parameters) that best fit the data. The technique is similar to geographically weighted regression or maximum entropy modeling but has a number of strengths, such as its ability to simultaneously model both first-order and second-order properties in the underlying point-pattern and how these properties may be dependent upon a set of underlying spatial covariates.

Our full paper in the January 2019 issue of *PLOS One*, an open-access scientific journal published by the Public Library of Science, presents a series of formal models that indicate that if Rapa Nui's monuments did indeed serve a territorial display function (in addition to their well-known ritual roles), then their patterns are best explained by the availability of the island's limited freshwater.

More info at **https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0210409**.

3D AT CENTIMETER LEVEL

KINEMATIC GROUND CONTROL POINT FOR UAV PHOTOGRAMMETRY

A DYNAMIC DUO of UAV and mobile van combine to deliver the accuracy of conventional methods with only 2+2 ground control points at the ends of the corridor.

BY ISMAEL COLOMINA, PERE MOLINA AND ROBERTO DA SILVA RUY

A Brazilian and a Spanish company, ENGEMAP and GeoNumerics respectively, have finalized the accuracy evaluation of a mission conducted with the latter's mapKITE technology on a Brazilian motorway last year. The goal of the evaluation was to confirm the advantages of the mapKITE method and its kinematic ground control point (KGCP) concept over conventional corridor mapping methods. The mapKITE and the conventional method delivered comparable accuracy results — the difference being that the latter requires a dense set of surveyed ground control points (GCPs) while mapKITE does the job with almost no GCPs.

For this purpose, a 4-kilometer segment of the Rodovia Raposo Tavares in São Paulo state was populated with a set of 37 evenly distributed, signalized, accurately surveyed ground points. The set was divided into two subsets of 23 GCPs and 14 ground check points (GChPs) — the ground truth — respectively. The 4-km road segment was also covered by 189 drone images and their corresponding 189 KGCPs. The image set was processed as a conventional aerial corridor block:

- with the integrated sensor orientation (ISO) method in a 23 GCP + 14 GChP configuration, and
- as a mapKITE aerial corridor block in a 4 GCP + 14 GChP + 189 KGCP configuration.

The two processes produced similar accuracy results: mean (μ), empirical standard deviation (σ) and root mean square (rms) error of the photogrammetric determination of the horizontal ($_{EN}$) and vertical ($_{h}$) coordinates of the GChPs against the ground truth. (All units are stated in millimeters.)

The conventional method delivered: $\mu_{EN} = 17$, $\mu_h = 26$, $\sigma_{EN} = 26$, $\sigma_h = 44$ and $RMS_{EN} = 32$, $RMS_h = 51$.

The mapKITE method delivered: $\mu_{EN} = 26$, $\mu_h = -20$, $\sigma_{EN} = 22$, $\sigma_h = 48$ and $RMS_{EN} = 34$, $RMS_h = 52$.

The mapKITE configuration uses only four GCPs (two at each end of the road segment) in contrast to the 23 GCPs of the conventional method. Nominal flying height of the drone was 120 meters above ground, producing

All photos: GeoNumerics

an average ground sampling distance (GSD) of 2.3 cm. Forward image overlap was 80% resulting in a base-to-height ratio of 0.157.

MapKITE is a GeoNumerics patented method for 3-dimensional corridor mapping that combines the two latest geodata acquisition methods, terrestrial mobile mapping and aerial drone-based mapping. MapKITE is a tandem terrestrial-aerial mapping method and system composed of:

- a terrestrial mobile mapping system (land vehicle and sensors) carrying
  - an optical metric target on its roof;
  - a drone aerial mapping system and
  - a real-time virtual tether and post-mission software.

In a mapKITE mission, the drone follows the land vehicle, and thus the vehicle target becomes a kinematic ground control point visible and measurable on each image. It is a high-accuracy, high-resolution Earth observation method. MapKITE combines the advantages of mobile land-based encompassing images and 3D point clouds. MapKITE combines the advantages of mobile land-based (manned) and aerial drone (unmanned) mapping systems.

GeoNumerics (Castelldefels, Spain) is a research and development company specializing in geomatics and accurate navigation.

ENGEMAP (Assis, Sao Paolo, Brazil) is one of the largest and oldest mapping companies in Brazil. It has more than 100 employees, three aircraft, two mapping land vehicles, a number of rotary- and fixed-wing drones and a record of accomplished mapping and cadastral projects. ENGEMAP is officially authorized by the Brazilian Ministry of Defence (MD) and the Brazilian Department of Airspace Control (DECEA) to conduct mapKITE commercial flights in Brazil.

MANUFACTURERS

The mapKite campaign was conducted with a **Sensormap** SMM terrestrial mobile mapping system and a **UAVision** UX Spyro drone equipped with a **NovAtel OEM2** GNSS dual-frequency receiver with a Maxtena antenna and a **Sony** α7R camera with a 25-mm camera constant lens. The INS/GNSS system in the Terrestrial Vehicle was a Span-CPT (Novatel) including dual-frequency antenna and DMI wheel sensor.

ISMAEL COLOMINA is chief executive and chief scientist at GeoNumerics. He has a Ph.D. in mathematics from the University of Barcelona. **PERE MOLINA** is advanced applications program manager at GeoNumerics. He holds a master's degree in mathematics from the University of Barcelona and a master's in photogrammetry and remote sensing from the Institute of Geomatics, Catalonia. **ROBERTO DA SILVA RUY** is technical manager at ENGEMAP. He has a Ph.D. from the Universidade Estadual Paulista.

Photo: Norbert Schnidler

NEW MAP METHOD OPENS UP PARKING

CONTINUOUS ENVIRONMENT MAPPING FOR ENHANCED LOW-COST URBAN NAVIGATION

COLLECTIVELY RECORDED CONTEXT DATA BY MANY IDENTICAL PLATFORMS gather similar sensor readings when operating in a given area. Further processing integrates the data with a map and feeds the summarized results to a user.

BY IVAN SMOLYAKOV, EVGENY KLOCHIKHIN AND RICHARD B. LANGLEY

Complex, dynamic urban environments comprise millions of devices with localization capabilities. While GNSS remains a primary positioning tool, its performance is subject to significant degradation from blocked signals, multipath and non-line-of-sight (NLOS) signal reception. In aided navigation, a positioning filter with GNSS measurements integrates data from various sensors and correction streams to compensate for these disadvantages.

Low-cost platforms are limited with the variety and quality of sensors on board, as well as by processor performance and battery capacity. Positioning routines must be computationally light, energy efficient and make the most productive use of available data.

One new research area covers use of crowd-sourced GNSS data. Many vehicles now include some type of native wireless connection capability, which could be complemented by a designated third-party device.

The growth in connectivity brings an opportunity to access a stream of sensor data produced by a high number of devices operating in a localized urban area. Here, we explore the idea of creating a GNSS signal-strength map using the connected vehicle GNSS data stream and then use the map as statistical information for Kalman filter parameters tuning. This approach improves filter reaction to the environment and produces a positioning accuracy improvement.

SYSTEM ARCHITECTURE

C/N_0 levels of reflected and diffracted signals are more likely to be lower than that of the LOS signals. We propose that the C/N_0 level averaged during a given period among all satellites tracked in a given area would correlate with a higher probability of multipath-contaminated and NLOS signal reception.

A sufficient number of C/N_0 readings associated with a given space-time cube should be collected to compute the statistics populating the signal-strength map. However, the city environment does not remain static: new construction occurs, traffic congestion shifts, and so on. Therefore, the C/N_0 space-time statistics must be continuously updated in real time to reflect these changes. Additionally, the solution must be highly scalable as the market of connected vehicles

All figures supplied by the authors.

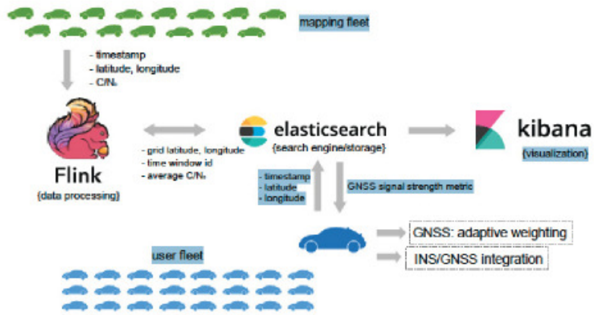


FIGURE 1 Continuous GNSS signal strength environment mapping architecture.

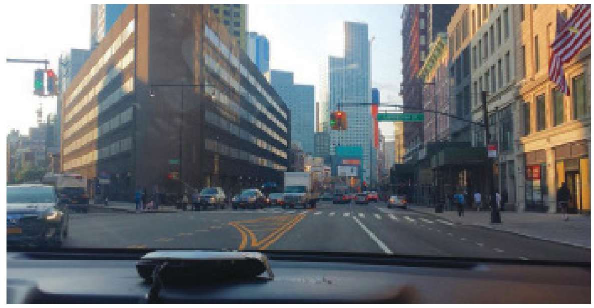


FIGURE 2 Mapping setup: Parkofon board is installed on the dashboard of a vehicle.

is growing and so is the volume of the streamed data.

A recent advance in cloud-based data-stream processing, a data flow model treats an input data stream as something that will never become complete. A derivative of that model is Flink, an open-source framework capable of both unbounded data (stream) and bounded data (batch) processing, while treating bounded data as a special case of the streaming applications. We use Flink as a core library for the environment mapping architecture as it fits the needs of event-time processing while being a highly scalable solution. The processing enables calculating necessary statistics based on a moment of time a reading occurred rather than based on a moment of time the reading arrived at the cluster. The proposed system architecture is presented in **FIGURE 1**.

The connected vehicle mapping fleet transmits packets of the GNSS receiver readings via cellular Internet connection to the server at 1 Hz. Each packet contains a timestamp in the UTC time system, the geographic coordinates determined by the proprietary positioning algorithms of a connected vehicle, and the C/N_0 measurements per each tracked satellite. The geospatial processing block calculates the average C/N_0 metric among the readings of a given space-time cube. Computed statistics are sent to Elasticsearch, updating the map in real-time. Elasticsearch is an open-source, distributed search and analytics engine integrated with Kibana, an open-source data visualization tool. User platforms request the average C/N_0 metric from the search engine with their UTC timestamp and coordinates and apply it in the processing filter.

PILOT PROJECT

The system is currently in prototype. Collection of the data populating the map was performed with two positioning boards designed by Parkofon Inc. and installed on the dashboard of a vehicle (**FIGURE 2**).

Lack of a high number of vehicles for the data collection campaign was compensated with an extensive piloting time (17 hours 43 minutes) in a limited area, driving the same roads repeatedly. Two areas of New York City were the subject of extensive mapping.

Tests concentrated on two sectors with different GNSS signal strengths: sector A, a relatively open-sky area; and sector B exhibiting deep urban canyon conditions. The mapped average C/N_0 is denoted as $\overline{m}_{C/N_0}$.

The $\overline{m}_{C/N_0}$ of the less obstructed sector A = 39.3 dB-Hz, while that of the more obstructed sector B is lower: 18.1 dB-Hz. This tendency is repeatable throughout the surveyed area and allows for further GNSS signal-strength map integration into the algorithms at the user side.

MAP-AIDED WEIGHTING FUNCTION

It is a challenge to find an optimal set of urban navigation filter parameters, as the signal obstruction environment changes significantly with the moving positioning platform. Our approach adjusts parameters of the GNSS observation weighting function with respect to the $\overline{m}_{C/N_0}$ retrieved from the map. The algorithm scheme appears in **FIGURE 3**.

When the first position fix is obtained, the algorithm sends a request to the server with the timestamp and the coordinates determined at the previous epoch. If one is available in the current user area, the server response includes the $\overline{m}_{C/N_0}$ metric retrieved from the GNSS signal-strength map. Next, the GNSS observation weighting function is adjusted according to equations given in the full technical paper (see **Acknowledgment** section).

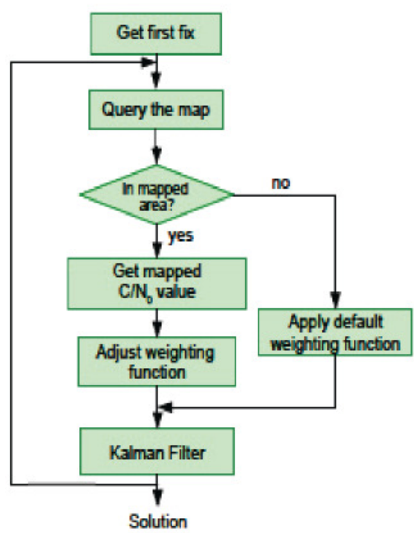


FIGURE 3 Map-aided automatic weighting adjustment algorithm.

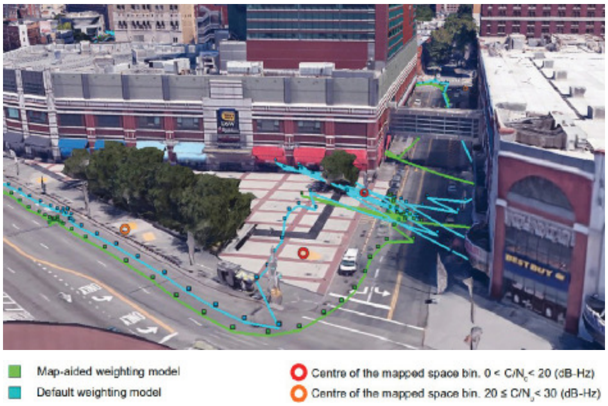


Image: Google Maps

FIGURE 4 **Example of faster map-aided solution re-convergence.**

PRACTICAL RESULTS

Algorithm performance was evaluated by analysis of the distances between the coordinates calculated with our engine and the centerline of the road in two downtown and two residential areas. For an estimated 86% of the track, our proposed map-aided weighting performed better than when the default weighting function was applied during the whole track. The map-aided weighting of the observations brings approximately 25% and 35% accuracy improvement in the dense urban area and in the intermediate residential environment respectively. Additionally, there were instances of faster solution re-convergence when fix was lost due to insufficient number of the satellites tracked in narrow streets or under obstructions (see **FIGURE 4**).

FUTURE WORK

For the mapped average C/N_0 levels to be unbiased, normalization procedures must be implemented. This would soften or eliminate hardware constraints on the mapping fleet and facilitate its growth. With more data available, the temporal discretization of the map needs to be implemented as satellite geometry and multipath environment change throughout the day. Optimal dimensions of the mapped space-time cube remain an open question: more real-world data needs to be collected to provide better mathematically-derived estimations. We plan to investigate the benefits of a variable-dimension space-time cube with respect to the area and the mapping fleet density. We also plan to extend the environment map-aided filter tuning to a multi-constellation GNSS approach integrated with inertial navigation systems and other sensors.

The technique is commercially implemented in Parkofon, a fully automated parking payment and guidance system that helps people find cheaper, safer and easier parking. The platform includes a mobile app and device placed in the car to guide drivers to open parking spaces in real time and charge them only for actual time parked in designated garages. Parkofon also offers real-time on-street space availability.

ACKNOWLDEDGMENTS

This article draws on a paper presented at ION GNSS+ 2018. For the full paper, see **www.ion.org/publications/ browse.cfm**. Research is supported by the Natural Sciences and Engineering Research Council of Canada.

MANUFACTURERS

Experimental datasets were collected with a **Septentrio** AsteRx-m2 receiver and **Maxtena** M1227HCT-A2-SMA antenna. Parkofon boards carry a **u-blox** M8N receiver module and a **Taoglas** CGGBP.25.4.A.02 patch antenna.

IVAN SMOLYAKOV is a Ph.D. student in the Department of Geodesy and Geomatics Engineering at the University of New Brunswick (UNB). **EVGENY KLOCHIKHIN** is CEO of Parkofon Inc., a smart mobility company utilizing the Internet of Things to guide drivers to open parking. He holds a Ph.D. in Public Policy and Management from the Manchester Business School, UK. **RICHARD B. LANGLEY** is a professor in the Department of Geodesy and Geomatics Engineering at UNB.

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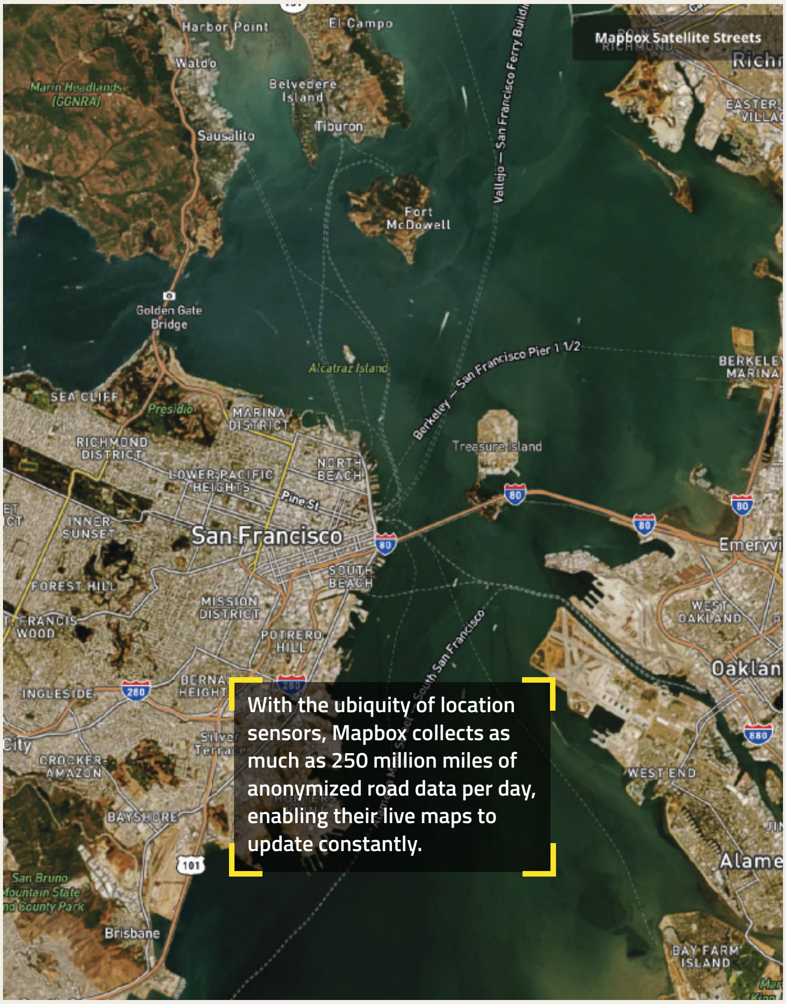
Peering Behind the Curtain



Images: Mapbox

Augmented Reality view from the Mapbox Vision SDK.

Location intelligence powers applications with data and "live maps" updated continuously

According to Forbes, 70% of telecommunications companies consider location intelligence critical to their success. The intelligence data is provided by specialists such as Google, Esri, Here and PlaceIQ.

In January, Sprint and location intelligence startup Mapbox launched precision mapping technology with the Curiosity IoT network. The 5G network's extreme bandwidth and low latency will allow Mapbox to collect higher volumes of richer data to create "live maps." A live map is built not from traditional data surveys months or years before, but from data collected from hundreds of millions of location-enabled sensors that feed back information about the world in real time, including high-resolution video.

Mapbox uses artificial intelligence (AI) to turn the massive data flows into a picture of real time transit paths that can be used for precise, up-to-date routing.

According to Mapbox CEO Eric Gundersen, maps that constantly update are essential to the internet of things (IoT). "As maps guide new smart machines on IoT networks, you remove the human in the middle that used to compensate for differences between the map and the real world," he said. "Precision mapping services need to reflect the world as it is, at that precise moment so that those smart machines can travel safely and efficiently."

According to Mapbox, smart machines such as drones and autonomous delivery carts will be able to make fast location and routing decisions using its detailed, updated maps.

Other companies that use Mapbox's location services include IBM, Lonely Planet, Square, Tableau and The Weather Channel.

SEEN & HEARD

ROBOT VS. ROBOT CAR = ROBOT LOSES

A self-driving Tesla Model S hit and destroyed an autonomous Promobot, the robot model v4, on Jan. 6 in Las Vegas. The incident took place at 3000 Paradise Road during preparations for the annual Consumer Electronics Show. Heading to the exhibit hall in a line, one Promobot missed its way and drove to the roadway, where it was hit by a self-driving Tesla car. The passenger in the car explains that he decided to try the self-driving mode and chose an area with litte traffic for the test. The robot missed the exhibition.

SETTING TIME BY THE STARS

ESA's technical center in the Netherlands (ESTEC) has begun running a pulsar-based clock. The PulChron system measures the passage of time using millisecond-frequency radio pulses from multiple fast-spinning neutron stars, relying on observations from radio telescopes across Europe. PulChron aims to demonstrate the effectiveness of a pulsar-based timescale for the generation and monitoring of satellite navigation timing in general, and Galileo System Time in particular. While less stable than atomic clocks, a pulsar-based clock would provide timing over decades, beyond the working life of any individual atomic clock.

TREKKING SOLO ACROSS ANTARCTICA

American adventurer Colin O'Brady became the first person to cross Antarctica on a solo, unsupported mission. He provided Instragram updates and a live-tracking map using a GPS tracker programmed with waypoints to lead him across the frozen desert. After skiing 932 miles, he reached the finish line on the Ross Ice Shelf on Dec. 26, ahead of competitor Louis Rudd, a British army captain.

HEY, KIDS! BIG BROTHER IS WATCHING YOU

More than 10 schools in Southwest China have adopted GNSS-equipped "intelligent uniforms" to monitor students' attendance and whereabouts. School authorities receive timing of students' entry and exit and automatically send the data to parents and teachers. A voice alarm activates if students wearing intelligent uniforms walk out of school without permission. While the uniforms provoke privacy concerns (the system can locate students during non-school hours), authorities say student location isn't checked after school hours.

PHOTO CREDITS: Promobot crash/screenshot from video by Kevin Jenkinson; Lovell Telescope at Jodrell Bank/Mike Peel via ESA; Antarctic trek/Colin O'Brady; uniform/Guanyun Technology.

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