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APRIL 2019 | Vol 30 | No 4


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Cover Photo: Collins Aerospace

COVER STORY

Photo: U.S. Air Force / Staff Sgt. Scott H. Spitzer

30 ROLLING OUT THE BIG M

New military code nearly ready to board 700+ platforms

BY MIKE JONES

Much development has been necessary to enable the new M-code capability on more than 700 weapon systems that require it. This story overviews M-code, the updates to antenna and receiver technology to make these varied platforms M-code ready, and perspectives from key stakeholders in the M-code community.

Photo: Harris Corporation

DESIGN & INTEGRATION TRENDS

38 GOING BEYOND THE NEWEST GENERATION OF GPS

The third Navigation Technology Satellite will go beyond GPS III — whose capabilities are not yet online — to investigate new experimental antennas, flexible and secure signals, increased automation and use of commercial ground assets.

BY JOE ROLLI

Image: National Trust of Scotland/GeoGeo

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ONLINE NOW

Year-Long Ocean Cruise Finds GNSS Interference...Everywhere

A year-long project aboard a commercial cargo ship collected tens of thousands of snapshots of radio-frequency interference in the GNSS band on a passage from Spain to Korea and back. Most interference was detected in busy port areas, less interference while transiting along coasts, and while least frequent, interference was still found in the open ocean.

Researchers at the German Aerospace Center (DLR) are still analyzing the vast amount of GNSS disruption data collected during the year-long project. Two papers have already been published about this project, and more are on the way, according to principle researcher Emilio Pérez Marcos.

In a paper presented at the Institute of Navigation in 2018, Marcos and his co-authors outlined the results... Detection equipment was mounted on a large Hapag-Lloyd container ship. The antenna was mounted about 50 meters above the water line and provided a line-of-sight of 25 km or more. The L1/E1 and L5/E5a frequency bands were continuously monitored. In addition to a "Snapshot" recording device used to save raw data samples (time snapshots), a more resilient DLR multi-antenna receiver was used to assess the impact of


Image: Emilio Pérez Marcos

interferences in beamforming array GNSS receivers (semi-resilient)…

Of the 39,045 snapshots recorded, 6,632 contained radio frequency interference at 1 dB or higher. Separate tests have shown that many single-antenna GNSS receivers begin to perform poorly with interference signals greater than 1 dB. The other 32,413 snapshots could represent interference signals that may have come from weaker transmitters, sources more distant from the ship, been the result of adjacent band transmissions, or other phenomena.

Three particularly strong and persistent interference incidents were noted: Suez Canal northbound; entering the port of Dubai, UAE; and entering the Malacca Straits…

Read the full article at **gpsworld.com**, and see related story in **The System**, **page 14**.


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GPS as Metaphor

BY ALAN CAMERON
EDITOR-IN-CHIEF

One day in perhaps the year 2000, I rushed into the office of this magazine's founding editor and thrust the morning paper under his nose.

"Did you see this?"

"Yup." He smiled his farmboy smile and allowed as how "We're part of the popular culture now."

We stood in a moment's admiration for the comic strip that had worked the term GPS into its humorous routine. I don't remember the cartoon, but I do remember the validation felt. Something I was involved in, hitherto thought abstruse or esoteric, had begun its entry into common parlance.

Nowadays of course the word GPS can be found everywhere, commonly denoting things that have nothing to do with satellites or radio frequency, but deriving their connection from a notion of position or navigation, or even just a general direction in life. "God's GPS," seen on church marquees. "Surgeon's GPS," a robotic tool for minimally invasive brain surgery. And so on.

Lately use of the term has veered perpendicularly in a new direction, into the realm of — abstruse, again — natural science. Technical papers in neurophysiology and paleobiology bring this to the forefront.

RATS. In 2005, researchers discovered that some brain grid cells appear to function like a map. These cells, adjacent to the hippocampus in the medial entorhinal cortex, organize themselves in hexagonal patterns serving as coordinates for animals navigating their surroundings. Cerebral GPS.

Studies now in *Science* magazine say researchers determined that rats' mentals maps formed by such grid cells, once thought fairly rigid, may change as the animals learn and remember where they can locate new food rewards. Stanford University neurobiologist Lisa Giocomo and University of Oslo researcher Charlotte Boccara are responsible for these findings.

My own brain struggles to connect this metaphor back to geodesy and global positioning. Could the Earth's surface be malleable as well? Hmm. Well, we do have magnetic North on the move, and that is causing some kind of havoc. Maybe that's not the same thing.

> "Cerebral GPS. Fossil GPS. Where will the figures of speech end?"

At any rate, now there are barnacles to consider.

YES, BARNACLES. Oxygen isotope ratios in barnacle shells change with ocean conditions and enable scientists to chart the migration of the host whales upon which said barnacles hitch their rides. Barnacles retain this data even as they detach, sink to the ocean floor and become fossils. Brought to the surface, into the lab and under the electronic microscope, they furnish records of whale migrations as far back as the Pleistocene Era.

As such, they may help scientists better understand climate change over the last 3 to 5 million years.

Fossil GPS. Don't believe me? Check out a paper by Berkeley researchers Larry Taylor and Seth Finnegan in the current issue of *Proceedings of the National Academy of Sciences.*

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Published monthly

Did the Chicken You're Eating Live a Happy Life?

BY Tracy Cozzens
MANAGING EDITOR

In 2011, the first-ever episode of a TV comedy called "Portlandia" debuted. In one sketch, concerned diners played by series stars Fred Armisen and Carrie Brownstein question their waitress about the origins of their chicken dinner.

The waitress shows the couple the chicken's papers and photo — Colin the Chicken lived a free-range life on a four-acre woodland farm only 30 miles away, dining on sheep's milk, soy and hazelnuts, in the company of his chicken friends. Unconvinced even by these details, the couple decides to drive to the farm to see it for themselves.

In a case of comedy becoming reality, Chinese insurance company ZhongAn Online has outfitted more than a 100,000 chickens with GPS trackers. People who buy a chicken with a tracker strapped to its leg will know every step that that chicken has taken. Using a smartphone app called GoGo Chicken, customers can monitor the animal's diet, exercise and environment.

The company says its technology will be on 2,500 farms in China by next year. It is also working on facial-recognition

Screenshot: IFC

PORTLANDIA PREDICTION: **Fred Armisen and Carrie Brownstein have a few questions about their chicken dinner.**

technology so that consumers can make sure the organic chicken they saw on the farm is the same one that ends up on their plate.

While this all sounds a bit much for many of us who grew up on Chicken McNuggets, there is a practical side. The company hopes GPS tracking will help prevent food safety problems, such as a 2014 crisis in China in which a supplier was caught selling rotting and expired meats to fast-food chains. In the event an issue does arise, the data tracked by the devices could help find the source of the problem.

EDITORIAL ADVISORY BOARD

What is a primary challenge for implementing the new M-code across 700+ MGUE platforms?

“The biggest challenge is access to MGUE for testing. Changing from legacy to M-code receivers can affect power, interfaces or antenna integration within individual platforms. While impacts may be minimal they are unknown without access to MGUE test items.” — Alison Brown

“Putting into practice in the DoD a modular open-system multi-Service integration approach with non-proprietary PVT interface standards. This will enable tailored use of non-GPS PNT complements along with GPS M-Code and reduce integration costs for resilient PNT in all DoD systems.” — Jules McNeff

“DoD must fund and implement an urgent program for full production prototypes for high-priority users. “Manufacturing-ready” articles to receive all GNSS signals plus regional integrity signals. Software and hooks should allow third party narrow-beam digital antennas and deep integration with inertial components. USAF has already partially implemented this.” — Bradford W. Parkinson

SatGen Signal Simulation Software

SatGen

GPS: L1, L2C, L5

GLONASS: L1, L2

GALILEO: E1, E5, E6

BeiDou: B1, B2

SatGen signal simulation

We are proud to announce that **SatGen** signal simulation software can now be used with **LabSat Wideband** to simulate all major constellations and signals.

If you need to record, replay or simulate multi-frequency, multi-constellation signals, then we have an easy to use, and cost-effective solution.

For more details, please visit labsat.co.uk/signals

Russia Practices Widespread Spoofing

Analysis of Satellite Data Exposes Threats to Civil Aviation

The Russian Federation is growing and actively nurturing a comparative advantage in the targeted use and development of GNSS spoofing capabilities to achieve tactical and strategic objectives at home and abroad.

A new report titled "Above Us Only Stars: Exposing GPS Spoofing in Russia and Syria," presents findings from a year-long investigation ending in November 2018 on an emerging subset of electronic warfare (EW) activity: the ability to mimic, or spoof, legitimate GNSS signals to manipulate PNT data. Using publicly available data and commercial technologies, the authors detect and analyze patterns of GNSS spoofing in the Russian Federation, Crimea and Syria. They profile different use cases of current Russian state activity to trace the activity back to basing locations and systems in use.

The report is issued by C4ADS, a Washington, D.C.-based nonprofit organization dedicated to providing data-driven analysis and evidence-based reporting on global conflict and transnational security issues. Its website, **c4ads.org**, lists transnational organized crime, proliferation networks (rogue nations and non-state actors), threat finance and supply-chain security as areas of focus.

Todd Humphreys, a University of Texas at Austin associate professor and head of the university's Radionavigation Laboratory, collaborated on the research underpinning the report.

Humphreys stated that, as far as he knew, the study constitutes the first characterization of GNSS interference from space, and cited "some interesting findings:

"Using Automatic Identification System (AIS) data captured by overhead satellites, we monitored spoofing in the Black Sea, around St. Petersburg, Archangelsk, etc., and built a picture of interference activity that spans two years. All such activities occur near Russian coastal waters.

"Correlating this activity with the travel schedule of the Russian head of state, we have strong evidence that the spoofing is a protective measure used to thwart drone attacks on Vladimir Putin.

"By exploiting a software-defined GNSS receiver my lab is operating on the International Space Station, we were able to pinpoint a powerful source of interference, which we found to be coming from the northwest quadrant of a Russian-operated airbase in Syria. This explains the many reports of GNSS interference in the eastern Mediterranean during the past year."

Global Threat. The tools and methodologies for perpetrating GNSS interference are proliferating at a rapid rate, and the frequency of such incidents around the world increases steadily. GNSS attacks, and GPS attacks specifically, now constitute an active, present, disruptive strategic threat in every theater of operation.

The C4ADS website, in announcing the report, states that "The Russian Federation has a comparative advantage in the targeted use and development of GNSS spoofing capabilities. However, the low cost, commercial availability and ease of deployment of these technologies will empower not only states, but also insurgents, terrorists and criminals in a wide range of destabilizing state-sponsored and non-state illicit networks. GNSS spoofing activities endanger everything from global navigational safety to civilian finance, logistics and communication systems."

Examining GNSS spoofing events across the entire Russian Federation, its occupied territories and overseas military facilities, the report identifies 9,883 suspected instances across 10 locations that affected 1,311 civilian vessel navigation systems since February 2016. It demonstrates that these activities are much larger in scope, more diverse in geography, and longer in duration than any public reporting suggests to date.

C4ADS believes the Russian Federal Protective Service (FSO) operates mobile systems to support this activity. It chronicles the use of GPS spoofing in active Russian combat zones, particularly Syria, for airspace-denial purposes. This capability is scarcely reported in the public domain. C4ADS identified ongoing activity that poses significant threats to civilian airline GPS systems in the region.

The 66-page PDF report can be downloaded at **www.c4reports.org/aboveusonlystars.**

INERTIAL

World's Largest Technical Professional Group Focuses on Inertial

Inertial 2019, the sixth annual Institute of Electrical and Electronics Engineers (IEEE) International Symposium on Inertial Sensors and Systems, took place in Florida earlier this month. Events of particular note included two keynote talks from experts at the U.S. Defense Advance Research Projects Agency (DARPA) and the Air Force Institute of Technology (AFIT), and a technical paper on the "Design and Performance of Wheel-mounted MEMS Inertial Measurement Uniti (IMU) for Vehicular Navigation."

Miniature Sensors. Ronald Polcawich from DARPA addressed "Miniature Navigation Grade Inertial Sensors: Status and Outlook." The agency's Precise Robust Inertial Guidance for Munitions (PRIGM) program has focused for more than three years on developing inertial sensor technologies to enable PNT in GPS-denied environments. PRIGM has developed a navigation-grade inertial measurement unit (NGIMU) based on micro-electromechanical systems (MEMS) platforms. The device has a mechanical/electronic interface compatible with drop-in replacement for existing tactical-grade IMUs on legacy U.S. Department of Defense (DoD) platforms.

PRIGM's second main area of interest is advanced inertial micro sensor (AIMS) technologies for future gun-hard, high-bandwidth, high-dynamic-range, GPS-free navigation. It explores alternative technologies and modalities for inertial sensing, including photonic and MEMS-photonic integration, as well as novel architectures and materials systems.

Map-Matching. Aaron Canciani from AFIT educated the many computer scientists, software developers, information technology professionals, physicists and electrical and electronics engineering attendees on "The Importance of INS Accuracy for Map-Matching Navigation."

Image: Jussi Collin

INERTIAL WHEEL SENSOR **mounted on wheel rim.**

The GPS-alternative technique matches measurements from a sensor to a map to provide navigation information. With repeatable measurements, almost any map may be used to navigate. Common maps used for navigation include terrain height, gravity, magnetic fields, Wi-Fi RSS and more. The inertial navigation system often plays a critical role in the accuracy of these methods, and increased INS accuracy plays a synergistic role in an overall map-matching navigation system.

WHEEL-MOUNTED IMUS

In today's automobiles, MEMS gyroscopes and accelerometers provide essential measurements for enhancing stability and control. Both types of sensors have significant noise at low frequencies, limiting the measurement accuracy, particularly in low-dynamic conditions. Further, uncompensated accelerometer tilt causes large bias to acceleration estimates. For gyroscopes, physical rotation of the sensor can remove the constant part of the gyro errors and reduce low-frequency noise. In ground vehicles, such rotation occurs conveniently in wheels.

When inertial sensors are attached to the wheel, both types of sensors provide information on the rotation, gyroscopes naturally and accelerometers via specific force measurement. As a result of carouseling, accurate wheel heading, roll and pitch estimation can be estimated with high resolution, and the result is nearly bias-free. Combining the wheel orientation to distance traveled via known radius enables classic dead-reckoning mechanization (assuming zero slip) and other vehicle dynamics monitoring systems (considering wheel slip as unknown to be solved).

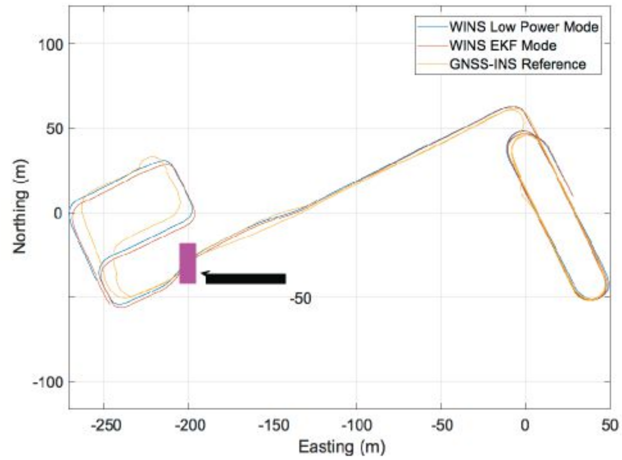
Authors Jussi Collin of JC Inertial Oy,

Finland, and Oleg Mezentsev, Pacific Inertial Systems Inc., Canada, provided details of wheel-mounted inertial system hardware and algorithms and showed test results for several system configurations and applications. They discussed future system improvements — in particular, system miniaturization and an energy-harvesting development progress for next-generation inertial systems.

They have designed a wheel-mountable sensor system that contains MEMS sensors, battery, Bluetooth module and electronics to run computations and navigation algorithms on board. It operates in several programmable modes:

- Computes navigation parameters real time and sends them via Bluetooth to an onboard computer (can be any other integrated system, data logger or a tablet).
- Sends real-time raw data to an onboard computer.
- Records high-rate raw sensor data (up to 2 kHz) to an embedded micro-SD card.

The onboard computer is a MEMS-array IMU with 48 gyro and accelerometer channels, with a BT receiving and sync controller, data storage and Wi-Fi interface. They can connect up to four such units to one onboard computer and have all their data in sync with the in-cabin inertial data. All of this data can be used for navigation, wheel dynamics measurements or road quality monitoring applications.



Graphic: Collin/Mezentzev

POSITION ESTIMATION of the researchers' PI-WINS device in two modes versus in-car GNSS/inertial system.

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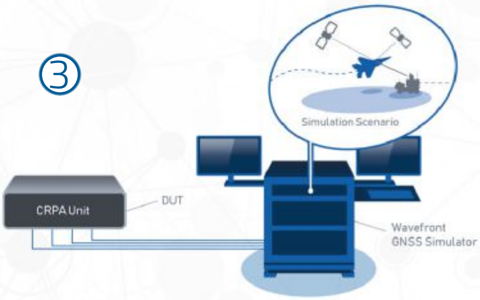

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1. GNSS RECEIVER

WITH EMBEDDED 9-DOF IMU

The Argonaut GNSS receiver is able to provide geo-location with real-time accuracy of 2 meters and off-line accuracy better than 0.4 meters using Argonaut PaaS. This is possible because GNSS raw measurements, together with inertial measurement unit (IMU) nine-degrees-of-freedom (9-DOF) measurements, are stored for offline GNSS processing (PPK, RTK, DGNSS). Argonaut will also register external events such as camera triggers within microsecond resolution and decimetric geo-location accuracy. The embedded IMU allows for an increased rate of navigation fixes as well as robust solutions in scenarios with impaired GNSS availability.

Rokubun, rokubun.cat

2. GALILEO ALTBOC ADDITION

PLUS ATMOSPHERIC CORRECTIONS

SDX GNSS simulator update version 19.1 adds Galileo AltBOC signal generation, new atmospheric errors, SBAS improvements and SV antenna patterns. SDX users licensed with the Galileo E5 signal will be able to generate 8 Phase Shift Keying (8-PSK) constant envelope AltBOC after upgrading to SDX 19.1. Version 19.1 also adds a new error type to all SDX users: atmospheric delays. These errors can be compensated for with the SBAS option installed.

Skydel Solutions, skydelsolutions.com

3. WAVEFRONT SIMULATOR

ADDED TO SOFTWARE-DEFINED PLATFORM

The BroadSim Wavefront Simulator is a new addition to Skydel's software-defined platform. The BroadSim Wavefront further extends the capabilities achieved by BroadSim Anechoic, incorporating support for controlled radiation pattern antenna (CRPA) and multi-element receiver testing. Powered by Skydel SDX, the simulator's features include phase-coherent simulation, real-time automated phase calibration, scalability from 4 to 16 elements, and advanced jamming and spoofing scenarios.

Skydel, www.skydelsolutions.com

4. GNSS ANTENNA

FOR HIGH-PRECISION AND AUTONOMOUS APPLICATIONS

The M7HCT-A-SMA is a high-accuracy, multi-frequency active quadrifilar helix GNSS antenna designed for high-precision and autonomous multi-frequency applications. The design offers concurrent GNSS reception on L1 (GPS, GLONASS, Galileo, Beidou) and L2 (GPS L2C, Galileo E5B and GLONASS L3OC) in a rugged, compact and ultra lightweight form factor. The antenna is designed for GIS, RTK and other high-accuracy GNSS applications such as the drone and automotive markets. Helicore technology provides exceptional pattern control, polarization purity and high efficiency in a 25-gram form factor. The antenna offers up to 30-dB gain for GNSS applications in one radome housing with a single SMA connector.

Maxtena, maxtena.com

5. PORTABLE SIMULATION

SOLUTION FOR FIELD-TEST REQUIREMENTS

The CAST-1000 duplicates GPS RF signals and uses dual-frequency signal generation technology. This allows for duplicate testing in the laboratory or the field and real-time or configured control. The CAST-1000 is mobile and portable, which makes it the ideal solution for field test requirements. Producing GPS and GLONASS signals with up to 12 satellites in view, the CAST-1000 simulates signals for satellites of P code on L1 and L2 and C/A code on L1. The GPS RF signal is dual-frequency and has a 12-channel configuration for any combination of visible space vehicles. The system is highly programmable — operators can choose from an array of vehicle types and replicate dynamic motion for all kinds of vehicles, from terrestrial to aquatic, airborne to space-based. By utilizing 6-DOF dynamic profile data collected in the field and through profile configuration, a trajectory can be created. The CAST-1000 also features a performance evaluation module, allowing for comparisons between raw and filtered data.

CAST Navigation, www.castnav.com

All GNSS civilian signals

TRIUMPH 3

Based on the TRIUMPH 3 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 >

After adding the high precision built-in inclinometer, now we added

motorized auto focus for the J-Mate high precision camera

NEW

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**.

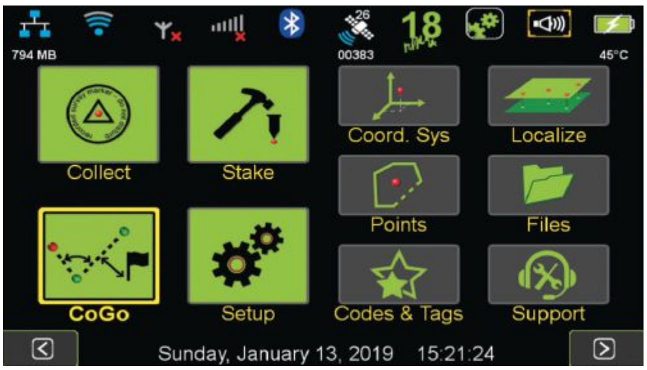
One major improvement that we did recently is to add motorized control of the camera focus feature.

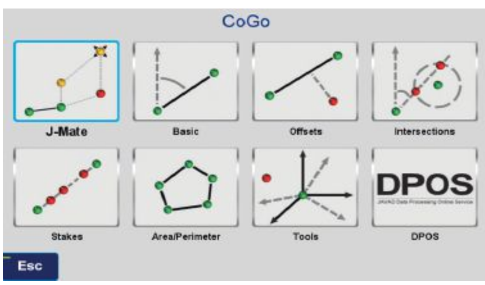
As with the TRIUMPH-LS, with the J-Mate we also provide software improvement updates regularly and free of charge. Download the J-Mate update in your TRIUMPH-LS and then inject it to the J-Mate. When you connect the TRIUMPH-LS to the J-Mate, the injection will be done automatically; but with your consent.

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 in our website.

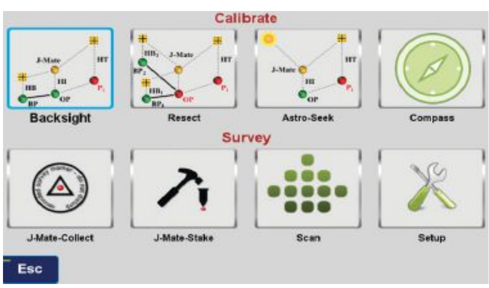
Connecting J-Mate to TRIUMPH-LS:

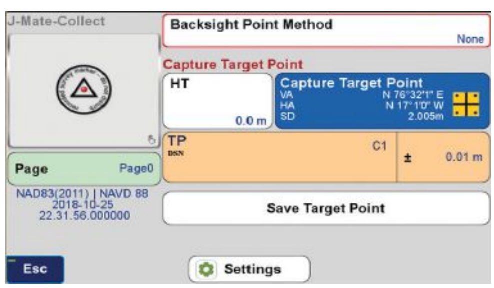
TRIUMPH-LS communicates with the J-Mate through Wi-Fi. Turn on both the TRIUMPH-LS and the J-Mate. Click the Wi-Fi icon of the TRIUMPH-LS Home screen to connect to the J-Mate, much the same way as you connect TRIUMPH-LS to your Wi-Fi access point. J-Mate has ID of the form JMatexxx.





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.





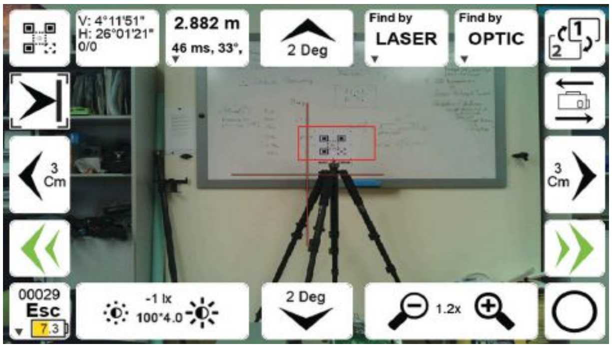
Finding the target automatically:

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 by laser for the object of the specific flat size and focus on its center, including the J-Target that we supply.

3) Third is with the camera to search for the J-Target. We will discuss these later.



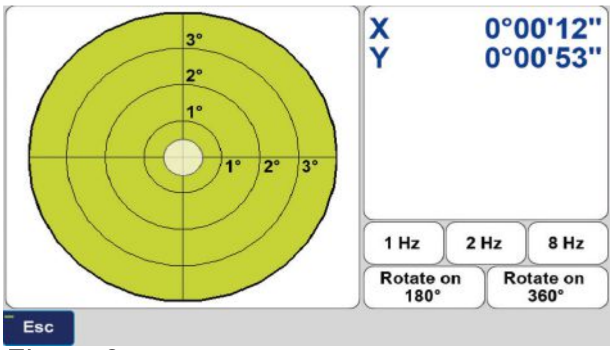


Figure 3

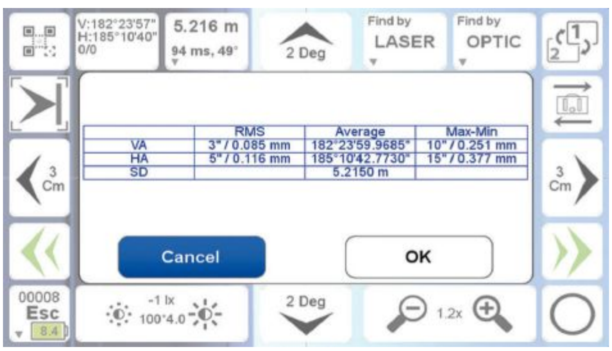


Figure 4

Figure 5

Switching between the two cameras:

You can view the scenes by the wide-angle (about 60 degrees) camera of TRIUMPH-LS, while sitting on top of J-Mate; or by the narrow angle (about 5 degrees) precise camera of the J-Mate. Click Button **“8”** of Figure 1 to switch between the two. A rectangle on the wide angle camera of the TRIUMPH-LS shows the viewing area of the J-Mate camera which helps in aiming to targets.

Viewing the embedded Inclinometer:

Hold button **“8”** or click button **“19”** of Figure 1 to see the embedded 0.001-degree electronic inclinometer of the J-Mate as shown in Figure 3. It updates 10 times per second.

Taking a point:

When you focus on your target manually or automatically, you can click the “Take” button (**“10”** in 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 also automatically take measurements around that point. Hold Button **“10”** to set up the area around the target.

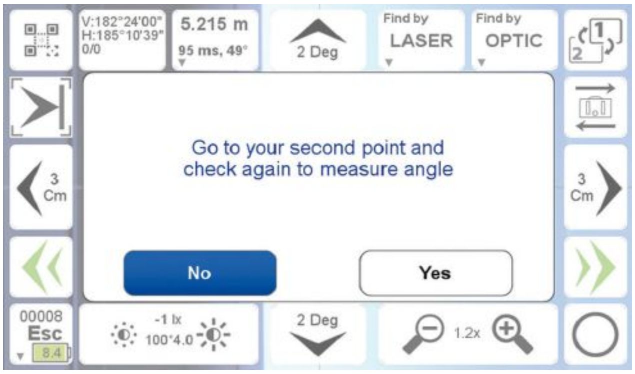
You can access and treat them like any other points in the TRIUMPH-LS.

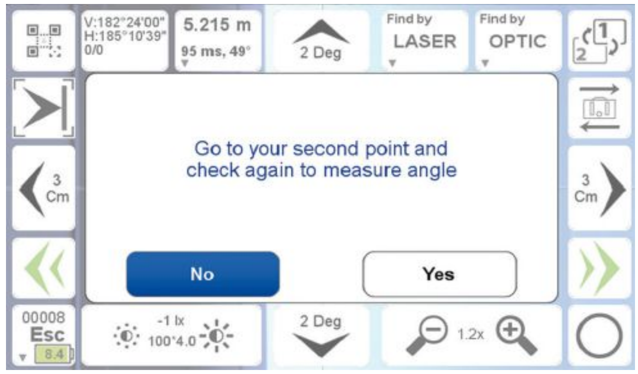
Viewing the measured points:

Clicking button **“7”** in Figure 1 will change some control buttons. Hold it long and you will see live view of the points taken by J-Mate (Figure 5).

Measuring angles quickly:

Aim at the first point and click button **“2”** of Figure 1. Then Aim to the second point and click this button again. You will see the horizontal angles between the two points. You can save the measured angles in clip boards and use it elsewhere when you need.





Saving and Recalling Orientations:

Aim at a point and click button **“17”** of the Figure 1 to save the horizontal, vertical, or both of that orientation (Figure 6). Click button **“16”** to rotate to that saved orientation.

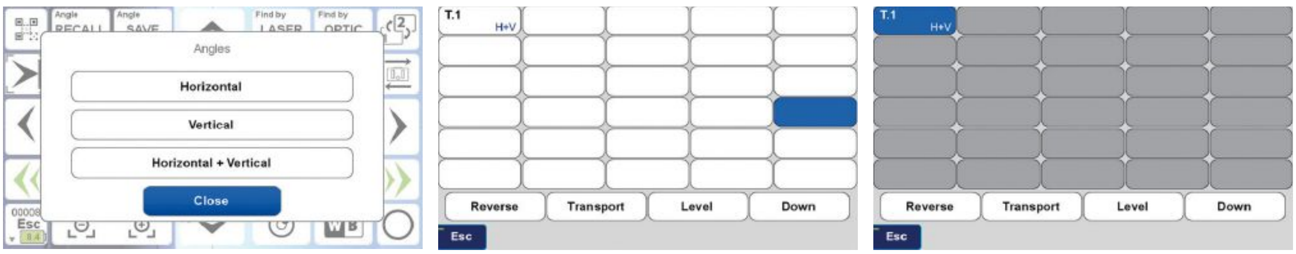


Figure 6

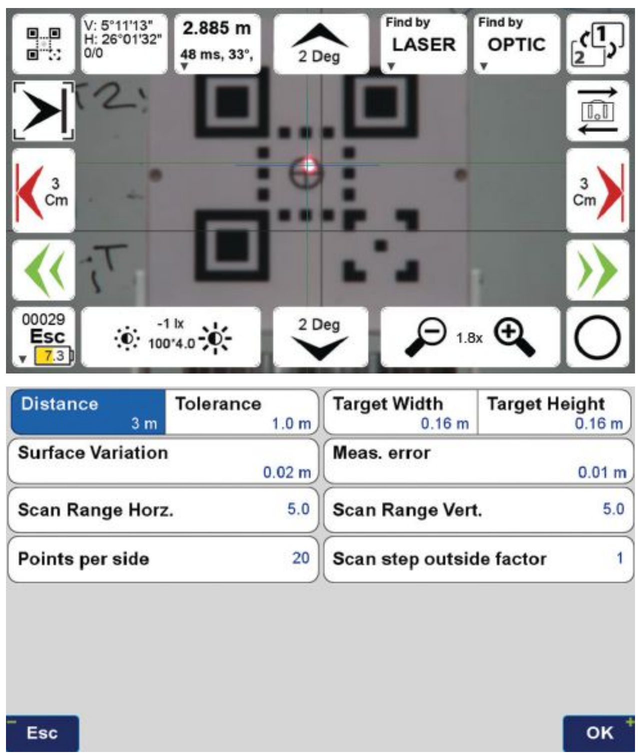
Scanning and snapping to an object:

Click button **“15”** of Figure 1 and see that the left and right motion buttons (**“14”** on Figure 1) change to red which means when you click them scanning to snap will start. Hold long button **“15”** to get to the screen.

In this screen you can define the scan range and ask the scan to stop when range changes by the specified value and snap to it. Then you can select to save the point that was measured before the stop or after the snap.

You can scan the ranges that you have specified and record the 3D image. When you click button 15 to end the scanning mode, 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 as shown at the end of this article.



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

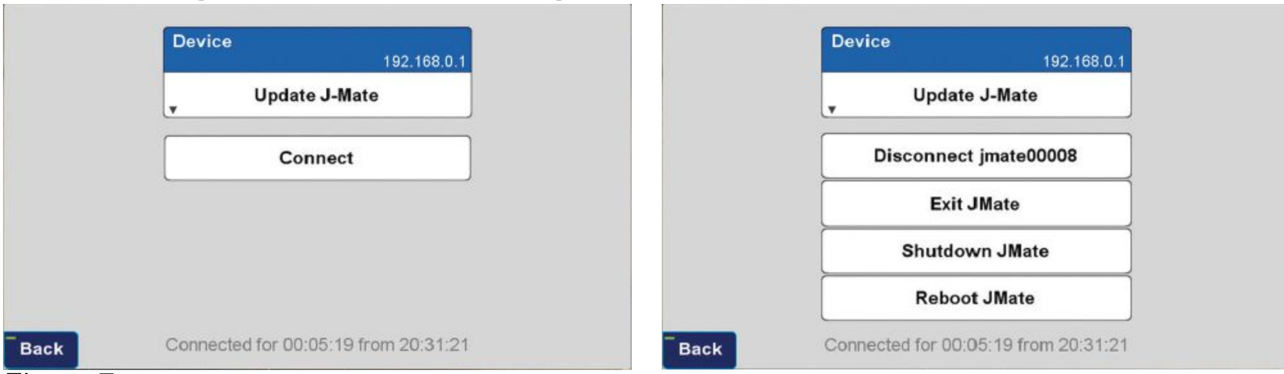


Figure 7

Holding the button **"13"** or **"15"** in Figure 1 which will take you to the set up screen and then to Figure 7 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 and angular measurements

Boxes **"2"** and **"3"** of the Figure 1 show the range and angular measurements. It reads up to 20 times per second. Click box 3 to enter the measured offsets between the two cameras.

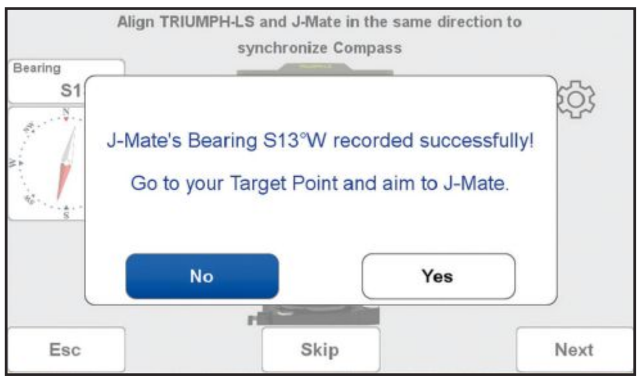
Automatic finding of the Target:

Click the J-Target icon (**"1"** 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.

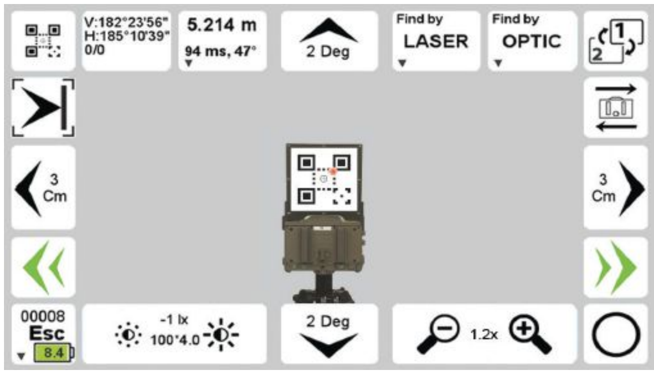
You can skip this and the next step if you are in an area that the compass readings are not valid or you can aim manually in the next steps.



2. Go to your target, Put the J-Target 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.

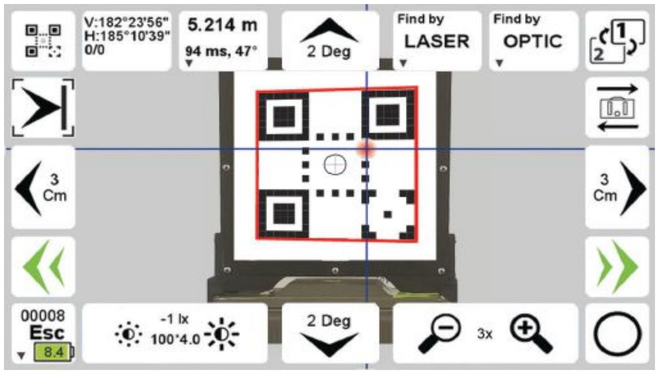
This will help the J-Mate to know the general direction to the target and limit its search range. You can go back to previous step to fine tune view of the J-Mate. Or you can skip these two steps.

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 J-Target panel and take your shot.

4. Click "Optic" if you want the J-Target panel to be scanned and centered automatically.



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

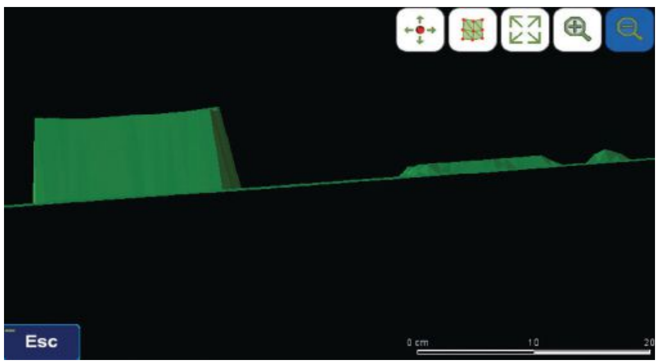
5. If you also want to find the center of the J-Target by Laser scanning, you can click the " Laser". If Laser scan is successful, you can click the "Take" button to replace the previous measurement with the current measurement done by laser scanning.

The center of the J-Target is vertically collocated with the GNSS antenna and you don't need to be exactly perpendicular to the J-Mate path.

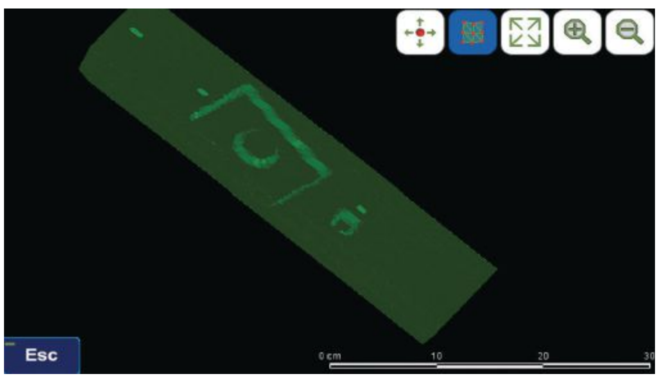
If light condition is such that camera cannot find the J-Target, chances are better that laser scanner can find it.

View scanned Images:

You see the 2 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.

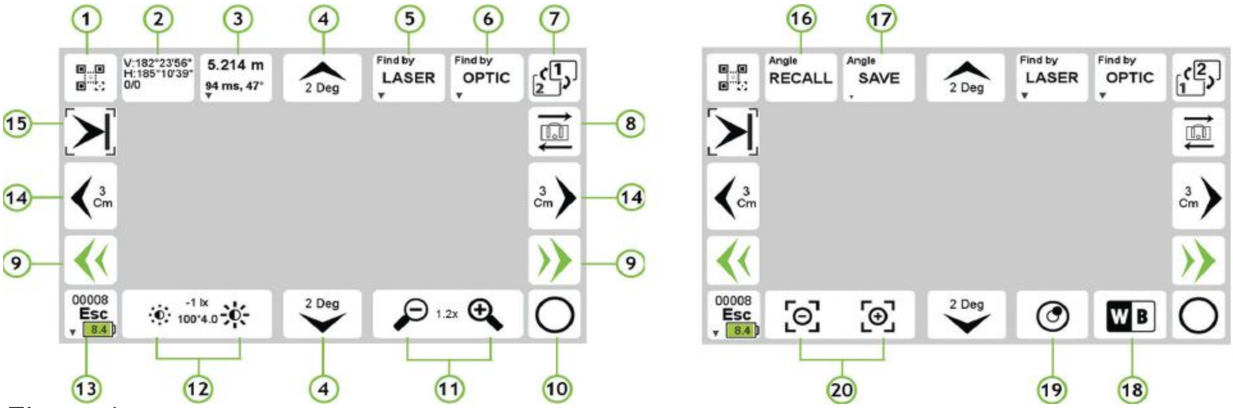


Figure 1

This is the **Main Navigation Screen.**

Clicking the button **"7"** in Figure 1 will switch some controls as shown above.

Aiming at Targets:

You can find targets manually or automatically.

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

1. There are Left/Right/Up/Down buttons around the screen (**"4"** and **"14"**). Each click moves the J-Mate according to the value that you assign to them in the setup screen, as shown in Figure 2.

2. While holding these buttons down, J-Mate rotates about 5 degrees per second.

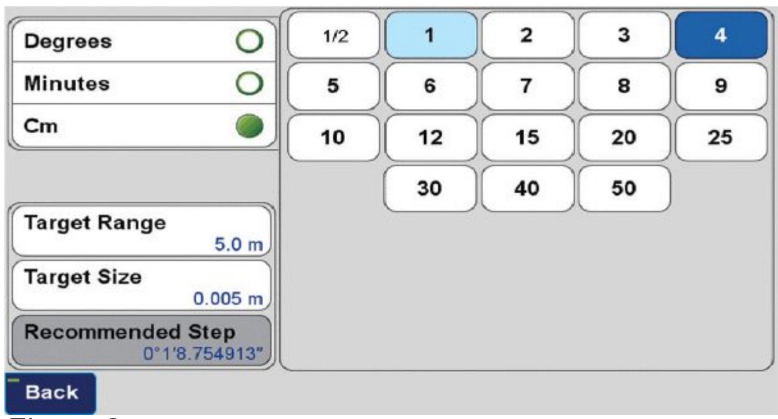


Figure 2

3. Buttons **"9"** are "Fast Motion" buttons. While you hold them the J-Mate rotates about 30 degrees per second.

4. You can point J-Mate towards points by touching points on the screen 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, not to apply backpressure to motor.

Motor manufacturer does not prohibit manual motion, but we think it is better to avoid it as much as possible.

TRIUMPH-3

The new TRIUMPH-3 receiver inherits and builds on 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, and as a scientific station collecting information for individual studies, such as ionosphere monitoring and the like.

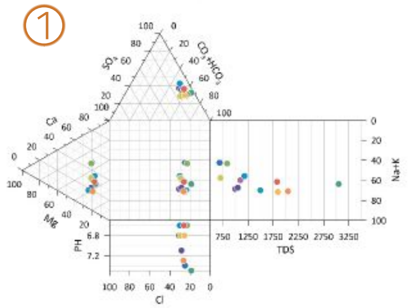
It includes options for all of the software and hardware features required to perform a wide variety of tasks.

- UHF/Spread Spectrum Radio
- 4G/LTE module
- Wi-Fi 5 GHz and 2.4 GHz (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

SURVEY & MAPPING | LAUNCHPAD

1



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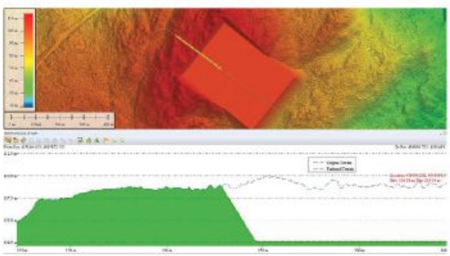


4

1. GRAPHING SOFTWARE

NEW PLOTTING FEATURES

Version 14 of the Grapher scientific graphing package offers new plotting and customizing functionality based on user feedback. The Grapher software gives users deeper insights into their data by providing them with 80 flexible and easy-to-use 2D and 3D graphing tools for plotting, analyzing and displaying scientific data sets. The package is used extensively by scientists and engineers in oil & gas operations, hydrologic/geochemical studies, environmental consulting, mineral exploration and academic research. New or upgraded features include Enhanced Plotting (the ability to plot data in rows and columns, perform one-button Durov class plots, and easily generate multi-plot reports); and Improved Bar Charts (bar charts are more versatile, offering variable bar widths and differentiated fill colors for negative and positive).
Golden Software, www.goldensoftware.com

2. GIS SOFTWARE UPDATE

NEW LIDAR FUNCTIONALITY

Global Mapper version 20.1 offers new and updated geospatial tools, as well as performance improvements throughout the application. Enhancements to version 20.1 include a new zooming function in the path profile window, a digitizer tool for automatically closing gaps between features and, for lidar module users, a point proximity query function.
Blue Marble Geographics, www.bluemarblegeo.com

3. SURVEY APPLICATION

FOR THE GEOSPATIAL INDUSTRY

The GNSS Surveyor mobile application provides location information and quality position data in real time with sub-meter to centimeter accuracy. It connects to any external GNSS receiver via Bluetooth. Features include a one-touch configured command to communicate directly with the GNSS Bluetooth device; location information and quality of the position data in real time with centimeter accuracy; GPS data such as position, height, satellites and velocity; and constellation information for GPS, GLONASS, Galileo, BeiDou, QZSS and SBAS satellites. It also includes a direct IP feature for real-time kinematic (RTK) corrections data. An internal NTRIP client loads RTCM data from the internet. Location information is collected as latitude and longitude, altitude, speed or pace, bearing and UTC time. GNSS precision includes global coverage, centimeter-level accuracy, fast time to first fix, multi-constellation and multi-band, and highest security. Navigation uses include ground robotics navigation, lane-level navigation, heavy machine navigation, industrial navigation and tracking, and commercial UAV.
Global GNSS, globalgnss.com

4. INDOOR MAPPING

SLAM TECHNOLOGY REMOVES POINT CLOUD ARTIFACTS

The SLAM-based NavVis M6 Indoor Mobile Mapping System (IMMS) now automatically detects and removes point cloud artifacts, including moving objects in static scenes. The latest IMMS release removes artifacts from point clouds during the post-processing of scan data (see before and after image above). Fringe points and dynamic objects are two common types of point cloud artifacts that affect all 3D laser scanning devices. The NavVis M6 IMMS uses laser scanners to capture a high volume of measurement points of an environment. With the latest software update, the algorithms applied during the post-processing of scan data uses the multiple observations to detect whether measurement points actually exist in the physical space. If it is determined that the point does not exist and is instead resulting from the laser beam hitting an edge or an object moving through the space, this point is automatically removed. The result is a much cleaner, crisper point cloud that requires less clean-up time in point-cloud editing software and that is easier to use for applications such as BIM modeling.
NavVis, www.navvis.com

LAUNCHPAD | MOBILE & UAV

1. ADVENTURE HANDHELDS

LARGER DISPLAY, IMPROVED ACCESS TO SATELLITE IMAGERY

Garmin has updated two premium adventure-oriented handhelds, the GPSMAP 66s and the GPSMAP 66st, with expanded wireless connectivity, direct-to-device access to BirdsEye satellite imagery, weather forecasting and a larger 3-inch sunlight-readable color display. The GPSMAP 66st offers preloaded topographic maps for U.S. and Canada, with detail of coastlines, rivers, summits, terrain contours and geographical points. Connectivity to the new Garmin Explore app and the BirdsEye Satellite Imagery (no annual subscription) bring high-resolution photo-realistic route views. Weather updates come via Bluetooth to a compatible mobile device. The Explore app includes features for outdoor navigation, trip planning, mapping and data sharing. Features include multi-GNSS satellite support and altimeter, barometer and compass sensor capabilities; 16 hours of battery life in full GPS mode; LED flashlight and SOS beacon; built to military standards for thermal, shock and water performance (MIL-STD-810G); RINEX data logging that enables sub-meter accuracy of GPS position after post processing.

Garmin, garmin.com

2. RTK HEXACOPTER

INTEGRATED GNSS IMPROVES ACCURACY

The H520 hexacopter is now available with a real-time kinematic (RTK) system. The fully integrated RTK satellite navigation enables extremely accurate recurring images and faster 3D mapping. It also makes automated inspection flights easier and more precise. The H520 RTK is suitable for commercial applications that require maximum precision. By using RTK technology, the H520 can now fly much closer to objects for inspection because the UAV positions itself precisely in the centimeter range (1 cm + ppm horizontal / 1.5 cm + ppm vertical) rather than in the meter range, which is standard for the H520.

Yuneec International, us.yuneec.com

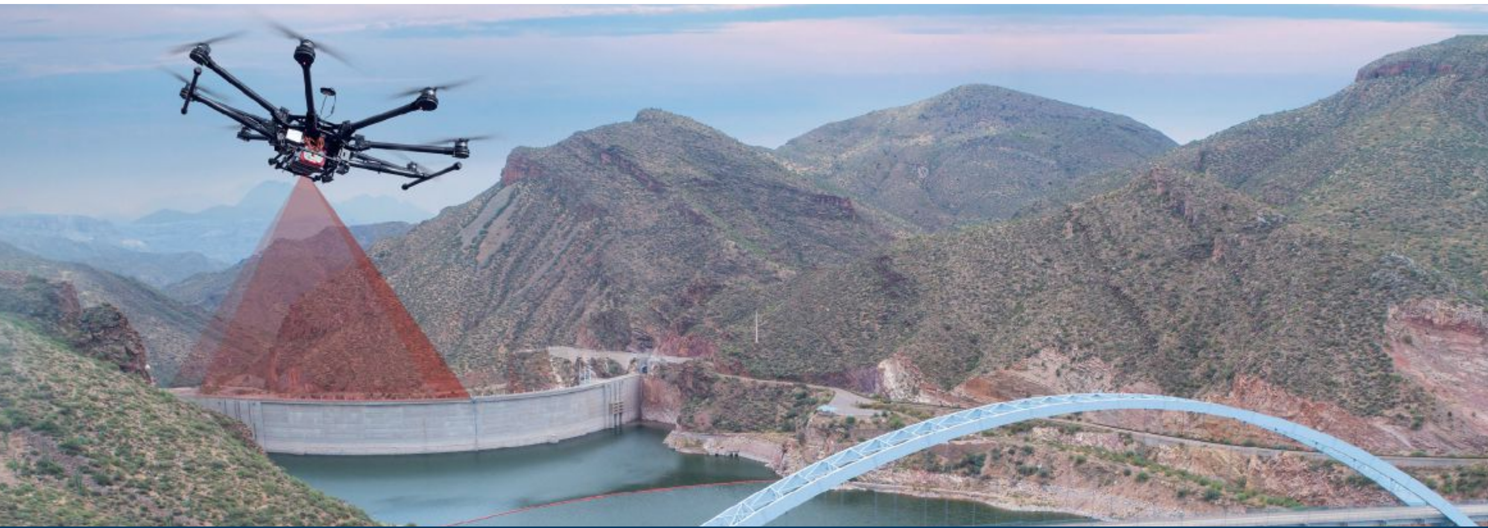
3. WEB-BASED DATA SERVICE

ENABLES SHARING OF UAV DATA SETS

MAGNET Collage Web is a web-based service enabling the sharing and collaboration of UAV and scanning data sets. Version 1.3 allows operators to work with more types of data with greater flexibility, including the ability to import BIM models, as well as CAD and GIS data. It can be used to overlay as-built laser scans and design data to visualize proposed changes and detect construction issues. The software supports OBJ, FBX and 3DS formats. The upgrade also includes new direct publishing functionality for CAD and GIS data files through the browser.

Topcon, topconpositioning.com

Qinertia PPK Software



INS/GNSS Post-processing made easy!

QINERTIA POST-PROCESSING SOFTWARE

Qinertia uses the inertial data and raw GNSS observables to provide astonishing attitude, heading and position performance, thanks to a forward, backward and merge processing.

Centimetric position after your mission

Obtain the centimetric position without the constraint of an RTK radio link. Just drag and drop your base station, Qinertia PPP function will automatically determinate your base station coordinates.

Extensive Quality Indicators

» Interactive quality indicators assessment
» Display of separation, standard deviation, bias, scale factor, lever arm
» Statistics report generation (RMS, min/max)

Qinertia BUNDLE

Tight Coupling INS/GNSS fusion

Modern & Intuitive User Interface

+ 7,000 Base Stations always up-to-date

AUVSI XPONENTIAL™ ALL THINGS UNMANNED

Ask for a demo!
BOOTH #3916

SBG SYSTEMS

Photo: Collins Aerospace

ROLLING OUT THE BIG M

NEW MILITARY CODE NEARLY READY TO BOARD 700+ PLATFORMS

MUCH DEVELOPMENT HAS BEEN NECESSARY TO ENABLE THE NEW M-CODE **capability on more than 700 weapon systems that require it. This story overviews M-code, the updates to antenna and receiver technology to make these varied platforms M-code ready, and perspectives from key stakeholders in the M-code community.**

BY MIKE JONES

December 23, 2018, marked an important milestone for GPS. The successful launch of satellite USA-289 represented a key success in what has been a monumentally expensive government program, beset by delays and overspends. The launch of the first GPS Block III satellite, the first that can provide the full military M-code capability, effectively commenced the physical roll-out of modern M-code hardware.

Ground Control. As far as the space segment is concerned, M-code is finally underway. What about the ground segment? The next-generation GPS operational control system, GPS OCX, is essential for use of the full capabilities of the new Block III satellites. It has been under development for some time.

OCX has drawn Congressional criticism and correlative media attention, but recent reports have been more positive. Since the Nunn-McCurdy breach of 2016, when the project's future hung in the balance, accounts have grown gradually optimistic. Budget and schedule were re-baselined, and contractor Raytheon's corrective actions generated results. In the fall of 2017 the Air Force took delivery of OCX Block 0, marking a significant milestone. Block 0, also known as the Launch and Checkout System (LCS), demonstrated compliance with contractual requirements and was accepted by the Air Force. In spring 2018, Block 0 underwent a series of cybersecurity tests and passed, validating the security architecture of the system. All this puts Raytheon on track to deliver OCX Block 1 in 2021, providing full operational capability. Block 1 and Block 2 are intended to be delivered together, adding operational control of the modernized satellites and signals, including L1C and the modernized M-code.

"There have been no schedule slips with the GPS OCX program since 2017, and the GPS III launch last December was clear proof of our progress," stated Dave Wajsgras, president of Raytheon's Intelligence, Information and Services business. "We will continue to meet all of our commitments, and importantly, we will meet our June 2021 contractual deadline."

Col. Steve Whitney of the GPS Directorate wrote in this magazine in December 2018 that "The journey over the past few years has been challenging, but we have emerged stronger, armed with better metrics, and a culture of integrated development (often called DevOps) which puts us on a path to success. There will be challenges and risks in the path ahead but rather than mountains to climb, I see these more as standard blocking and tackling of a software-intensive program."

Meanwhile. The Air Force plans to deploy M-code capability in 2020, and OCX seems unlikely to be ready. For this reason, Lockheed Martin was awarded a contract to modernize the existing ground infrastructure as a "gap filler." The GPS Control Segment Sustainment II (GCS II) contract was awarded on December 21st 2018, and is worth $462 million. GCS II will support operational capability of M-code in 2020, and continues until 2025, and so there will be a period of overlap between GCS II and OCX, essentially providing two options for controlling the new GPS III constellation. In one view, the Air Force is backing two horses to improve chance of winning: OCX the preferred solution, with GCS II almost like an insurance policy.

With the GPS III ground and space segments looking relatively healthy, attention turns again to the user segment.

WHY M-CODE?

Until now, the military has used the classic P(Y) signal: a binary phase shift keying (BPSK)-modulated encrypted wideband signal. It offers both greater accuracy and increased jamming resistance when compared to the civilian C/A code still employed by the vast majority of GPS receivers. But the P(Y) code has its drawbacks in the modern world: its wide main lobe sits directly over the top of the C/A code signal (see **FIGURE 1**), essentially occupying the same spectrum. When the civilian C/A signal is jammed, the military P(Y) signal is at the very least degraded, if not also jammed itself. It also uses a relatively simple encryption scheme that does not meet today's cyber security requirements.

The M-code signal, on the other hand, is the first military GPS signal to use the BOC modulation scheme. BOC modulation gives signals their distinctive two-lobe appearance, spreading the signal's energy away from the band center.

The wide spacing of the two sidebands separates the M-code signal from the civilian signals (the legacy C/A signal or the new L1C signal on the L1 frequency, and the L2C signal on the L2 frequency). Amongst other things, this allows the military to jam the civilian codes without noticeably degrading the M-code signal. Often referred to as blue force electronic attack (BFEA), this is essentially a new facet to navigation warfare (NAVWAR), where enemy use of GPS can be denied whilst allowing friendly forces to continue using it. The wider occupied bandwidth and increased signal power also help to make M-code more resistant to jamming. M-code also makes use of more modern and flexible encryption methods, ensuring it will be secure and safer from threats such as spoofing attacks.

Scepticism. Defense programs are known for their long procurement cycles, but even by these standards, M-code has taken an extremely long time to get where it is today. Given the enormous cost of the program, and the fact that there is still, as yet, no operational benefit to show from it, many people have questioned its worth. At the time it was conceived it represented a dramatic step forward in military capability but, because it has been so long in development, its operational benefit is becoming diluted.

When M-code was conceived, GPS was still the only operational GNSS in town: everybody had to use GPS — or nothing. Today, the picture differs greatly. During M-code's insanely slow progress, other GNSS systems have come along, offering their own encrypted signals of a similar ilk. Looking at **FIGURE 2**, M-code no longer appears as special as

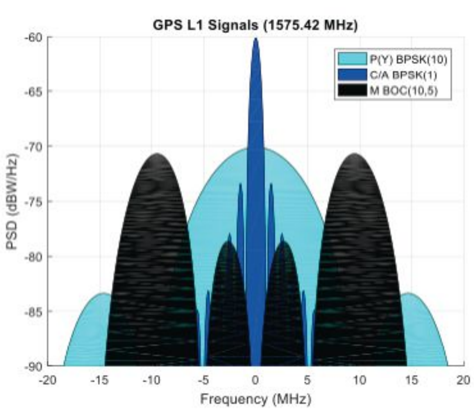


FIGURE 1 **C/A, P(Y), and M-Code signal power spectra.**

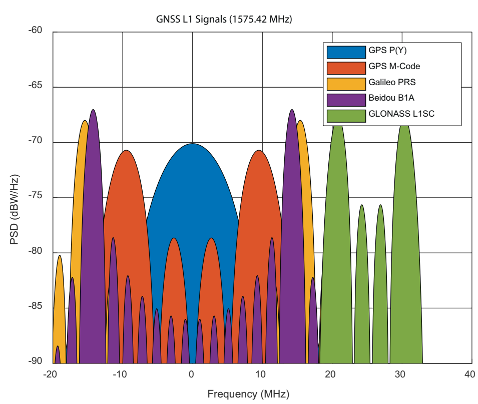


FIGURE 2 **GNSS encrypted signals around the L1 frequency.**

Graphics: Mike Jones

Graphics: Mike Jones

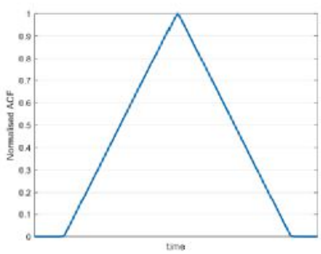


FIGURE 3 C/A code ACF.

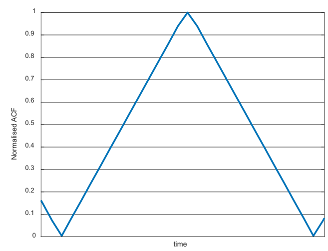


FIGURE 4 L1Cd ACF.

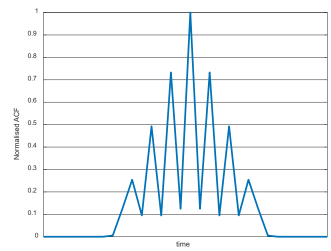


FIGURE 5 M-code ACF.

it once was. Its BOC(10,5) signal sits inside the main lobes of Europe's Galileo PRS signal, which uses a BOC(15,2.5) scheme, and China's Beidou B1A signal using BOC(14,2).

If you were China, you might consider jamming the central 24 MHz of the L1 band, taking out M-code, whilst still having an operational military service for yourself. Or if you were Russia, you might jam 34 MHz of bandwidth, taking out the US, Chinese, and European systems, whilst still having your GLONASS L1SC military service to use. The situation is more complex than that, of course: each service has the potential to increase signal power in times of conflict, and there is more than one frequency that can be used. But it does demonstrate the essence of the problem: The modern battlespace has moved on, and M-code hasn't.

CHALLENGES OF RECEIVER DESIGN

With complex signals come complex receivers, and there several headaches when it comes to M-code receiver design. The first is the nature of the BOC signal itself, which has a complex correlation function. Consider **FIGURE 3**, which shows the autocorrelation function (ACF) of the traditional civilian C/A code signal. The single peak of the function makes acquisition and tracking a simple process; traditionally early, prompt and late (E,P,L) correlator arms can be used in the tracking process.

The newer BOC-type signals have a more complex ACF. **FIGURE 4** shows the ACF of the new L1Cd civilian GPS signal, which uses a form of BOS(1,1) modulation. In addition to the main lobe, there are now two side lobes. Receivers must be careful not to lock on to one of the side lobes instead of the main lobe: the receiver architecture starts to become a little more complex.

Now consider the ACF of the M-code signal, shown in **FIGURE 5**. Like other high-order BOC-type signals, M-code exhibits multiple lobes in the ACF, making robust acquisition and tracking a far more troublesome process. Furthermore, the high bandwidths require high sample rates, which lead to higher power consumption in the hardware.

Another major headache associated with M-code receivers is, of course, the encryption process. Not because encryption is difficult, but again because of the power consumption implications. Consider that each GPS receiver needs to run an encryption engine instance, for each satellite it might wish to receive. Running a high-grade encryption algorithm at a high chipping rate, for a dozen satellites, is a power-consuming process. For dismounted soldiers with limited battery capacity, this is a big deal.

Some people argue that the high-grade encryption process for M-code is too complex. Consider why we want to encrypt a GNSS signal in the first place: firstly to prevent someone from spoofing our signal, and secondly to prevent unauthorised users from using the service. Given that the encryption keys are rolled regularly, how much does it matter if an adversary manages to compromise the encryption? This isn't a communications security problem: we are not talking about loss of classified information, so there's an argument that a simpler, less power-hungry form of encryption might have been used instead.

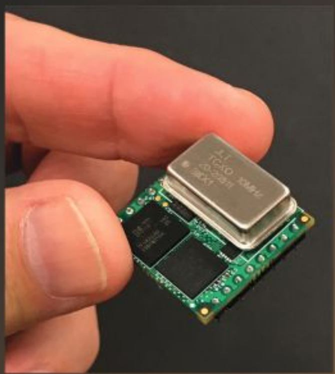
ANTI-JAM ANTENNA COMPATIBILITY

Although M-code offers a certain level of jamming resistance, it is still vulnerable to attacks. As a signal it might have a bit more power, and a bit more bandwidth, than some other signals. But it is, after all, still a GNSS signal, and it can be jammed by an adversary. Where an operational threat analysis indicates that an increased level of jamming resistance is required, then M-code receivers need to be integrated with anti-jam antennas.

Anti-jam antennas, usually referred to in the GNSS community as controlled reception pattern antennas (CRPAs), have been the anti-jam tool of choice for several decades now. I overviewed these in an April 2017 e-newsletter (**gpsworld.com/crpa**). CRPA manufacturers have had to ensure that their products are "M-code ready," such that they can be seamlessly attached to M-code receivers as and when they appear. This hasn't been a recent process: as far back as 2002, the GAS-1 antenna (Raytheon) underwent a series of qualification tests to ensure compliance with M-code. Around 2005, the ADAP antenna (also Raytheon) was launched with a host of M-code features — again an illustration of just how slow the M-code program has moved, given that other technology has been "M-code ready" for 10 or 15 years already.

What's involved in making a CRPA M-code compatible? Firstly the increased bandwidth: the antenna electronics must digitize the wider bandwidths. Along with the wider bandwidth comes new filtering shapes to ensure

JACKSON LABS



Micro-Transcoder™
RSR Transcoder™
CSAC Transcoder™

Making M-Code retrofits trivially easy

The Jackson Labs Technologies, Inc. Transcoder technology allows continued fielding of existing GPS equipment by adding the M-Code capability upgrade externally. Thus the users' existing equipment, training, supply chain, logistics, and investments are safe-guarded, and equipment-lifetimes extended.

The JLT Transcoders use miniature embedded GPS Simulation technology to allow retrofitting any GPS receiver to M-Code or any other emerging GNSS capability by simply swapping out the users' GPS antenna.

The Transcoders take the secure Position, Navigation, and Timing (A-PNT) solution from the M-Code receiver, and convert that into a GPS L1 RF antenna signal that any legacy GPS receiver can read. This allows a retrofit to M-Code capability without having to open or modifying the users' GPS equipment in any way. This makes upgrading legacy equipment to M-Code capability as easy as removing the existing antenna, and plugging-in the Transcoder/M-Code receiver assembly to the users' GPS RF antenna connector.

Available with Optional Chip Scale Atomic Clock for Holdover

The CSAC Transcoder™ adds Miniature Atomic Clock Holdover capability to the system which allows the users' GPS equipment to maintain microsecond-accurate UTC time for many hours during a completely GPS-denied mission, and thus allows the mission to continue in even the most challenged environments. Additional features are adding Inertial, Optical or other Alternative Navigation capabilities, adding Concurrent GNSS capability, and using the Transcoders as general-purpose GPS simulators to test user equipment for i.e. Week Number Rollovers, Leapsecond compatibility, or other functions.

The JLT Transcoders are extremely small (Micro-Transcoder™: 1 inch square), consume very low power (<1.2W with CSAC option), work over extended temperature ranges, and are very cost effective.

Jackson Labs Technologies, Inc. | www.jackson-labs.com | sales@jackson-labs.com | P: +1(702)233-1334 | F: +1(702)233-1073

optimum performance. Space-time adaptive processing (STAP) and space-frequency adaptive processing (SFAP) techniques potentially require more taps to ensure high null depths can be maintained across the full bandwidth. The increased power of the M-code signal, particularly if features like spot beam are used, presents another complication to CRPAs: they must not treat the high-power satellite signals as jammers, and try to remove them.

Testing CRPAs presents a challenge to manufacturers: how do you prove that your antenna doesn't corrupt the M-code signal, when there's no M-code signal to test it with? To work around this issue, pseudo M-code signals have been used for testing, where representative BOC(10,5) signals without the real encryption are passed through the CRPA and examined for distortion.

RECEIVER DEVELOPMENT STATUS

Due to the security considerations surrounding M-code, only three US organizations are authorized to produce modules: Collins Aerospace, Raytheon and L3. Here are the answers from Collins Aerospace and L3, the answers from Raytheon will appear in later issue.

What are the technical challenges associated with developing an M-code receiver?

Collins Aerospace. The Collins Aerospace Modernized GPS User Equipment (MGUE) Increment 1 development like the SAASM PPS receiver developments faced very challenging technical requirements to support our war fighter needs in an ever-evolving threat environment. Like other complex developments the challenges are initially technical and then transition to integration/test and certification. On the technical front optimizing receiver performance balanced against power consumption are always at the forefront. In addition, it is important to maximize backwards compatibility so as to minimize downstream integration costs while adding an entirely new signal that runs in parallel to the existing system. Collins Aerospace is pleased with the technical development and are actively supporting the integration with both receivers and technical support.

To date we have delivered more than 770 MGUE receivers to the Air Force to support Air Force, lead platform and DoD-wide Integration and test. Soon the total will grow to nearly 1,100 receivers to support expanded integration and test following the completion of Collins Aerospace security certification.

L3. M-code GPS User Equipment (MGUE) technologies exist today. L3's Ground Based GPS Receiver Application Module – Modernized (GB-GRAM-M) is a fully-functioning unit that is currently baselined and undergoing an independent Technical Requirements Verification (TRV) by the GPS Directorate.During TRV, each requirement from the Technical Requirements Document (TRD) is independently evaluated for compliance. Upon completion of the TRV, the design isbaselined with complete documentation enabling platforms and prime equipment to integrate from a known baseline with low risk. Following integration, operational testing can start immediately to support fielding when M-Code Early Use (MCEU) becomes operational. The TRV of L3's GB-GRAM-M is planned to be completed by the second quarter of 2019.

L3 resolved numerous technical challenges in developing M-code GPS technologies. The first and ever-present challenge is changing and evolving requirements. Most of these requirementchanges are in response to evolving threats that have drivenchanges into the GPS receiver and/or to higher-level systems. Asan example, the U.S. Army's Assured PNT (A-PNT) is implementing M-Code GPS along with external sensors to establish and maintain an assured solution even in GPS-challenged environments. Other challenging requirements include meeting the security requirements, implementing and testing anti-spoofing algorithms, and ensuring backward compatibility with legacy receivers.

Photo: Collins Aerospace

DEFENSE ADVANCED GPS RECEIVER (DAGR) from Collins Aerospace, equipping infantry and other warfighters.

What are the intended platforms for your MGUE?

Collins Aerospace. The Collins Aerospace MGUE receivers are intended to support all Warfighter domains: ground, airborne, maritime and munitions to support compliance with Public Law 111-383 SEC. 913 issued in Fiscal Year 2011. Per this directive, M-code is intended for all DoD applications with the exception of passenger vehicles or commercial vehicles with GPS installed. Now that the satellite and control segments of the capability are coming on line, we are working diligently to ensure that user equipment is available for all domains.

L3. L3 has products to meet current market demand. Under the MGUE program, L3 developed a GB-GRAM-M, which is a standard Modular Open Systems Architecture (MOSA) design. The GB-GRAM-M is designed to fulfill retrofit replacements of SAASM receivers, as well as being a primary component of A-PNT systems. L3's M2GRAM ASIC is the core of our receiver, a GPS module that incorporates signal processing, cryptography, and positioning, velocity, and timing (PVT) processing. The M2GRAM

Where CSWaP Matters!

EMCORE Inertial Measurement Units (IMU)

THE EMCORE IMU ADVANTAGE:

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

- Three-axis closed-loop FOG design for improved drift stability, higher linearity and greater flexibility
- Designed to operate as an IMUs or navigators
- Low-noise line-of-sight stabilization
- Vertically-integrated manufacturing in Alhambra, CA

Applications

- Inertial navigation system for missiles, UAVs
- Platform stabilization in gun targeting systems
- Dismounted soldier north finding and navigation
- Operation where GPS is denied or unavailable

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Photo: U.S. Air Force/Bobby Garcia

B-2 SPIRIT multi-role bomber capable of delivering both conventional and nuclear munitions. In December 2017, the Air Force completed a series of successful flight tests of M-code GPS using a Raytheon Company receiver on board a B-2 Spirit at Edwards Air Force Base, California.

ASIC is capable of being implemented in other form factors for applications beyond ground-based applications. As an example, the M2GRAM is implemented in a GPS receiver specifically designed for Precision Guided Munitions (PGM) applications and was used in a gun launched, guide-to-target demonstration operating as a PGM receiver.

L3 is also augmenting the GPS receiver through the integration of several other technologies, including controlled reception pattern antennas with digital antenna electronics, inertial systems and external sensors, and GPS-denied capabilities. M-code technologies are being implemented in Mounted A-PNT Systems (MAPS), Dismounted A-PNT Systems (DAPS), and handheld systems to bring capabilities to the warfighter.

What is the expected timeline for your MGUE development, acceptance testing, and delivery?

Collins Aerospace. The Collins Aerospace receivers are supporting on-going DoD integration and test and our MGUE Increment 1 program is aligned with the Air Force GPS Enterprise roadmap. Ultimately, the Department of Defense (DoD) M-code programs will set the production delivery schedules.

Photo: Karolis Kavolelis/Shutterstock.com

ARMY Stryker ground combat vehicle.

We anticipate that the M-code production ramp-up and continued SAASM PPS receiver production will have a production overlap. Our Collins Aerospace in-house PPS GPS receiver manufacturing capability is ready to support the DoD demand for both M-code and SAASM. Collins Aerospace is fully committed to manufacturing Increment 1 M-code receivers to meet the Warfighter's needs across Airborne, Weapons and Ground, we know the transition from SAASM to M-code will take years. Therefore, Collins Aerospace will continue to manufacture SAASM receivers for years to come as the International MOD Policy for M-code use is still being formulated.

L3. L3's GB-GRAM-M is now available. L3 received security certification and approval in 2016 and TRV is planned for completion in the second quarter of 2019. With TRV, L3 is receiving a new security certification and approval of the latest receiver update. Government agencies, prime contractors and laboratories can order GB-GRAM-M now with delivery in the fourth quarter of 2019.

What does testing and verification process involve?

Collins Aerospace. As with any Precise Positioning Service (PPS) GPS development, the testing involves functional verification of the receiver in a wide variety challenging of environmental, thermal, electromagnetic interference/high-intensity radiated field (EMI/HIRF) environments. Collins Aerospace is leveraging proven test and verification approaches founded upon our long history of successful product introductions and field performance. As this is a PPS receiver it is also essential the receiver design comply with the government's required Security Approval process.

L3. The testing and verification of L3's GB-GRAM-M included internal testing and independent testing through the GPS Directorate's TRV process. Further risk reduction testing within the MGUE program is planned as Phase IV testing where the GB-GRAM-M is integrated into a lead platform for the U.S. Army and a lead platform for the U. S. Marine Corps. An operational assessment is performed on both lead platforms to assure common problems associated with integration and operational testing are addressed prior to implementing M-Code GPS Receivers across all of the platforms.

Will the MGUE be compatible with CRPA anti-jam antennas; are there any special considerations for this?

Collins Aerospace. The Collins Aerospace product family includes our Digital Integrated Anti Jam Receiver (DIGAR) product family that leverages CRPA anti-jam antennas for enhanced anti-jam (AJ) performance. Our DIGAR AJ technology enhances the performance with fixed reception pattern antenna (FRPA), CRPA and is compatible with all PPS waveforms. Regarding the interfaces between the receiver and the anti-jam antenna electronics, a GPS receiver with a standard RF interface is compatible with a CRPA in nulling mode and FRPA antennas. Advanced capabilities such as beamforming/beamsteering require tight coordination and additional interface with the GPS receiver.

L3. The GB-GRAM-M is designed to operate with a fixed reception pattern antenna (FRPA). A CRPA antenna using digital antenna electronics to generate signals matching the characteristics of a FRPA is fully compatible with the GB-GRAM-M. With a higher level of integration of a GPS receiver and a CRPA, the system capabilities are greatly enhanced. L3 has performed thisintegration and can perform advanced capabilities such as angle of arrival and beamforming using M2GRAM, digital antenna electronics, and CRPA technologies. These capabilities can be found in L3's Mounted Assured PNT System (MAPS) and Anti-Jam Antenna System (AJAS) products.

OPERATIONAL DEPLOYMENT

The U.S. Air Force GPS Directorate provided answers to the following questions regarding MGUE.

Which platforms will be equipped with M-code-capable MGUE, and how many of each?

GPS Directorate. The Air Force is developing M-code-capable GPS receivers under the MGUE Increment 1 program. The receivers in development will be provided to four service-specific lead platforms for integration, developmental, and operational testing. Lead platforms are:

- the Army Stryker ground combat vehicle,
- the Air Force B-2 Spirit bomber,
- the Marine Corps Joint Light Tactical Vehicle (JLTV),
- and the Navy Arleigh-Burke class destroyer (DDG).

Following the lead platform efforts, procurement of M-code-capable GPS receivers will be decided by the Services and executed by individual platforms and programs.

What are the timelines for rolling out M-code on these platforms?

GPS Directorate. Early integration and test activities have already begun for each MGUE lead platform. Operational testing is expected to begin in 2020 and complete in 2021, which is a key activity to enable the fielding of M-code-capable systems.

What advantages will M-code bring, over existing military GPS receivers?

SEE M-CODE, PAGE 39. >>

Going Beyond the Newest Generation of GPS

U.S. positioning, navigation and timing (PNT) capabilities are vitally important to millions of civilians, as well as U.S. and allied militaries.

The third Navigation Technology Satellite will go 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.

HARRIS CORPORATION
Joe Rolli
Director Business Development,
Space and Intelligence Segment

Over the past decade, military leadership and national strategists have shared their concerns about U.S. dependence on GPS for everything from financial transactions to commercial transportation scheduling to precision weapon system guidance. The new generation of Air Force GPS satellites, which began launching in late 2018, marks a significant step toward improving GPS services with three times greater accuracy and up to eight times improved anti-jamming capabilities over the previous GPS satellite block.

Now the Air Force Research Laboratory and the Space and Missile Systems Center are focusing the Department of Defense's first experimental Navigation Technology Satellite (NTS) in more than 40 years: on initiatives that will demonstrate new tactics, techniques, and procedures to improve PNT resiliency and counter threats to GPS.

As a unique satellite that flies outside of the GPS constellation, NTS-3 will host experiments with impact across the PNT user spectrum — military, civil, academic and commercial. It will explore innovations in atomic clocks, antennas, reprogrammable digital waveform detectors, signals and other technologies.

Harris, the satellite prime contractor for NTS-3, is approaching these mission innovations from the standpoints of responsiveness and resiliency as well as technology advancement. For example, the design will support the simultaneous broadcast of dual-frequency, regional high power, and Earth coverage signals. An agile waveform platform will demonstrate the ability to rapidly develop and deploy new signal waveforms with total flexibility throughout the satellite life cycle. These innovations will allow operation in multiple contested environments, a key to achieving resiliency that can combat electronic jamming, spoofing and more.

Another strategy is the design of a modular NTS-3 payload that can be reprogrammed in space. Based on open, industry standards and interfaces, the payload will be scalable and can be hosted on diverse platforms and in varied orbits with minimal changes.

When NTS-3 launches for its planned one-year experimental campaign — anticipated to begin in 2022 — it will be the latest in a series of experimental spacecraft that have blazed the trail for the extraordinary technological advances that led to the GPS system we enjoy today

M-CODE

« Continued from page 37.

GPS Directorate. Modernized GPS receiver cards under development with the Air Force MGUE Increment 1 program will enable the use of M-code and provide U.S. forces with enhanced position, navigation, and timing capabilities, in addition to improving resistance to threats, such as jamming efforts by adversaries.

How will keys and key distribution be managed?
GPS Directorate. None of this is publically releasable.

Will M-code be made available to other friendly nations? If so, how is this managed?
GPS Directorate. The current policy allows for the sale of M-code equipment to all 57 authorized GPS PPS nations. The M-code technology will be made available to these nations through the Foreign Military Sales process.

USER PERSPECTIVE

The Department of Defense supplied answers to the following questions for users and warfighters.

What are the benefits you perceive will come from new M-code GPS equipment?
DoD. Provides U.S. forces with enhanced position, navigation, and timing capabilities, in addition to improving resistance to threats, such as jamming efforts by adversaries.

Will it change how you perform military operations, or enable any new ones?
DoD. Modernized GPS receivers provide the next-generation GPS capabilities to the warfighter. Operational testing will enable the services to determine operational utility of MGUE. It will ensure our soldiers, sailors, airmen, and marines have the ability to get in, accomplish their mission, and get home accurately.

How will M-code-based GPS receivers be brought into operational service? Will there be a mass upgrade of assets, or a phased introduction?
DoD. Procurement of M-code-capable GPS receivers will be decided by the Services and executed by individual platforms and programs. 🌐

OEM

US OEMs Get Galileo

Following a Nov. 2018 waiver by the U.S. Federal Communications Commission (FCC) allowing devices in the United States to access signals transmitted by Galileo, leading U.S. manufacturers are preparing to roll-out Galileo on U.S. territory. The FCC ruling permits access to two Galileo signals: E1 in the 1559-1591 MHz band and E5 signal in the 1164-1219 MHz band.

"The FCC ruling means that industry can now benefit from the use of Galileo signals," said Carlo des Dorides, executive director of the European GNSS Agency (GSA). "The added accuracy and robustness of multi-constellation and multi-frequency capability will be a key differentiator on the market."

Both Broadcom and Qualcomm already have dual-frequency solutions that support Galileo E1/E5a signals: the Xiaomi Mi-8 smartphone was fitted with a Broadcom BCM47755 chip and, in December, Qualcomm Technologies launched the newest generation of its 8 Mobile Platform Series, the dual-frequency Qualcomm Snapdragon 855 Mobile Platform. About 100 smartphone models are fitted with chipsets from the two manufacturers. "Following the FCC ruling, we are expecting to see a significant increase in Galileo users coming from the U.S.," said Justyna Redelkiewicz Musial of the GSA.

Access to multi-constellation and multi-frequency capability means that U.S. users will benefit from better positioning and navigation particularly in urban environments where the unique shape of the E5/L5 signal makes it easier to distinguish real signals from multipath reflected by buildings.

The simultaneous use of E5/L5 frequencies also mitigates other sources of error, such as ionospheric distortions, and makes the signal more robust against interference and jamming.—*News courtesy of the GSA.*

Photo: Jackson Labs

Jackson Signal Analyzer

Jackson Labs announced a new product line, the PhaseStation ADEV Frequency Stability phase noise test system (signal source analyzer).

The test system is:

- useful in testing signal performance in a host of products such as GPS or GNSS disciplined oscillators.
- useful to qualify and evaluate local oscillator (LO) performance for GNSS receiver design, including GPS TCXO evaluation and parametrization.
- stability measurements of 1PPS and arbitrary frequency outputs from GNSS receivers
- useful in optimization of GNSS receiver Kalman filter design via the GNSS receiver 1PPS output signals.
- automatically synchronizes and syntonizes (calibrates) the internal dual oscillator DOCXO option to external GNSS receivers via 1PPS input.

Allystar Launches Tiny Dual-Band GNSS Module

Allystar Technology Co. Ltd. has launched its smallest multi-band multi-GNSS module, the TAU-0707 series. Within its 7.6 x 7.6 millimeter size, the TAU-0707 supports GPS / Galileo / GLONASS / BeiDou / QZSS / IRNSS and all civil bands (L1, L2, L5, L6).

The TAU-0707 series module is a concurrent multi-band multi-GNSS receiver embedded with a cynosure III single-die standalone positioning chipset, which offers multi-frequency measurements and simplifies integration for third-party applications.Allystar also provides the built-in low-noise amplifier which affords the module improved RF sensitivity and acquisition and tracking performance even in weak signal areas.

Allystar offers two modules to fully support all civil signals on the L5 band for the standalone market. The TAU1206-0707 and TAU1205-1010 are expected to be better in multipath mitigation mainly due to the higher chipping rate of L5 signals relative to L1 C/A code.

For professional applications, module TAU1303-0707 comes with built-in support for standard RTCM protocol (MSM), 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.

Engineering samples and reference design of the TAU-0707 and TAU-1010 series module will be available in April.

SURVEY

SBG's Horizon IMU Equips for Hydrography

The Horizon fiber-optic gyro (FOG) inertial measurement unit (IMU) now forms part of SBG Systems' Navsight Marine Solution, dedicated to hydrographers.

Navsight is available at different levels of accuracy to meet the various application requirements and can be connected to various external equipment such as echo-sounders and lidar.

Navsight Marine Solution already offered two levels of performance with the Ekinox and Apogee IMUs. These MEMS-based IMUs address most of the hydrographics market, whether shallow or deep water. The new Horizon IMU enables customers to deploy Navsight in the most demanding environments such as surveying highly dense areas (such as bridges and buildings) as well as applications where only a single antenna can be used.

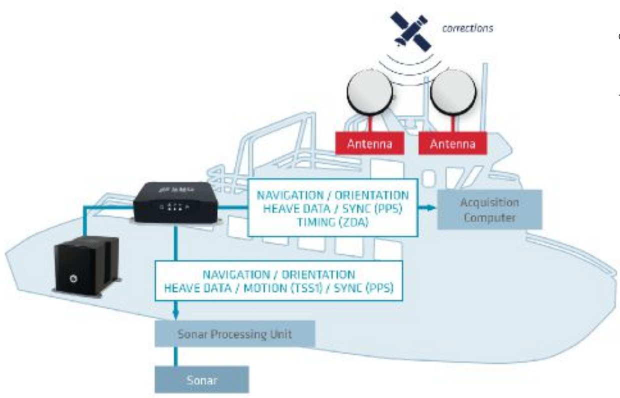

Image: SBG Systems

Horizon IMU is based on a closed-loop FOG technology that enables ultra-low bias and noise levels. This technology allows robust and consistent performance even in low dynamics surveys.

Navsight is easy to install, as the sensor alignment and lever arms are automatically estimated and validated. Once connected to the Navsight processing unit, the web interface guides the user to configure the solution. A 3D view of the vessel shows the entered parameters so that the user can check the installation.

The Navsight unit also integrates light emitting diode (LED) indicators for satellite availability, real-time kinematic (RTK) corrections and power. It comes with a rugged enclosure or in a rack version for larger vessels.

Completing the Navsight offer, Qinertia — SBG's post-processing software — gives access to offline RTK corrections from more than 7,000 base stations in 164 countries. Trajectory and orientation are then greatly improved by processing inertial data and raw GNSS observables in forward and backward directions. Computation takes less than three minutes for a six-hour log, thanks to the forward and backward calculations being processed at the same time.

Waypoint GNSS+INS Post-Processing Enhanced

NovAtel's Waypoint Products Group has released version 8.80 of its GNSS and GNSS+INS post-processing software products, including Inertial Explorer, Inertial Explorer Xpress, GrafNav and GrafNet.

Key features of the 8.80 release include:

- high-rate precise satellite orbit and clock corrections available in minutes with the TerraStar-NRT option
- increased accuracy for pedestrian and vehicle applications by applying vehicle constraints using our SPAN intelligent vehicle dynamics modelling
- ability to use L5, E5a, B3 in differential solutions
- 14 percent faster processing with 64-bit support.

For applications requiring highly accurate post-mission position, velocity or attitude, post-processing maximizes the accuracy of the solution by processing previously stored GNSS and inertial measurement unit (IMU) data forward and reverse in time, and combining the results. The position, velocity and attitude solution can be smoothed and output at the required data rate and in the coordinate frame required. This process also provides the ability to assess the solution reliability and accuracy.

A software development kit is available to allow developers to customize the entire processing workflow to suit their customers or application.

THE WAYPOINT PROCESS

Step 1. Capture raw GNSS and IMU data.

Step 2. Waypoint post-processing software maximizes the accuracy of the solution by independently processing data forward and reverse in time and combining the results.

Step 3. The position, velocity and attitude solution is smoothed to deliver an unparalleled level of accuracy. In-depth quality analysis tools verify the quality of the trajectory.

Step 4. Export your results at the required data rate and in the coordinate frame required.

MAPPING

Nearmap Imagery Wins Business for Solar Installer

High-resolution aerial maps from NearMap are helping Auric Solar, a solar power provider, accelerate site assessments, develop complete and accurate views of properties, and create winning proposals.

Auric accesses Nearmap imagery through Aurora Solar, a solar sales and design software program. By utilizing Aurora software integrated with Nearmap imagery, Auric analysts have access to clear, current imagery. With theprogram, analysts can make accurate measurements, run production numbers, identify roof obstructions and craft proposals.

The absolute horizontal accuracy of Nearmap's georeferenced imagery is 0.75 meter (RMSE) or better. Measurements taken with Nearmap measurement tools are accurate to within 15 centimeters for an individual photo. The company's HyperCamera aerial photography system captures overlapping photographs along a flight path covering a survey area.

Each photograph is tagged with its GPS location. Proprietary HyperVision technology then triangulates, orthorectifies and stitches these GPS-tagged photographs into a georeferenced photomap with an absolute horizontal accuracy of 0.75 m (RMSE) and relative accuracy of 15 cm. The process combines GPS positioning, high photo redundancy and triangulation of ground features to ensure accuracy without the use of ground control points.

Image: Nearmap

NEARMAP AERIAL IMAGE of Zions Bank Stadium/Real Academy, with solar installed by Auric Solar.

Auric also has access to Nearmap historical imagery, including leaf-on and leaf-off imagery, which presents the presence or lack of the foliage depending on the season. This greatly enhances shading analysis, making it easier to place the panels for maximum sun exposure.

TRANSPORTATION

ST, Virscient Collaborate for Connected Cars

STMicroelectronics and Virscient are collaborating to enable faster delivery of connected-car systems with ST's Telemaco3P automotive application processors. Virscient offers support to ST customers in the development and delivery of advanced automotive applications based on the ST Modular Telematics Platform (MTP).

STMicroelectronics is a global semiconductor leader serving customers across the spectrum of electronics applications. Virscient is a provider of hardware and software development services and support for customers building automotive solutions using ST's Telemaco3P secure telematics and connectivity processors.

Image: U.S. Department of Transportation

Virscient's connected-car systems rely on technologies such as GNSS (precise positioning), LTE/cellular modems, V2X technologies, Wi-Fi, Bluetooth and Bluetooth Low Energy.

MTP is a comprehensive development and demonstration platform incorporating ST's Telemaco3P telematics and connectivity microprocessor.

MTP enables the rapid prototyping and development of smart-driving applications, including vehicle connectivity to back-end servers, road infrastructure and other vehicles, the companies said.

The Telemaco3P incorporates Dual-Arm Cortex-A7 processors with an embedded hardware security module (HSM), an independent Arm Cortex-M3 subsystem, and a set of connectivity interfaces. With security at its core, and considerable flexibility in both hardware and software configurations, the Telemaco3P provides a platform for connectivity within the vehicular environment.

UAV

Cooperative Effort Takes Off with Topcon

An Arizona electric cooperative that serves more than 33,000 customers is helping prove the value and potential of unmanned aerial systems (UAS) in enhancing the utility's geospatial information system (GIS) effort.

Using an Intel Falcon 8+ Drone — Topcon Edition, UAS specialist Skynetwest is performing missions to illustrate the viability of UAS technology. Initial work for the Navopache Electric Cooperative (NEC) included inspection of a substation, conducted on a windy day that might have grounded traditional aircraft.

Image: Topcon

Windspeed limits for the Falcon 8+ in GPS mode are set at 26 mph; in height mode that threshold is extended to windspeeds as high as 35 mph.

Using ContextCapture and Agisoft PhotoScan software, Skynetwest created a detailed georeferenced 3D model of the substation.

The Falcon 8+ also has triple redundancy inertial measurement units (IMUs), double redundant compasses, dual-constellation GPS, eight propellers and two batteries. An algorithm selects the most accurate of the redundant systems to use when the UAS is flying near the electromagnetic frequencites emitted by power lines.

The team easily switched between a camera payload for inspections and one for mapping. Skynetwest's mapping package takes high-resolution geo-referenced aerial images from various heights within set GPS tolerances. Its RGB camera delivers both orthophotos and 3D models in Topcon ContextCapture software, powered by Bentley Systems.

DEFENSE

Orolia Acquires Simulation Company Skydel Solutions

Orolia has acquired Skydel Solutions, a GPS/GNSS signal simulation company based in Montreal, Canada.

Orolia made the announcement at the Association of the U.S. Army's Global Force Exhibition in Huntsville, Alabama.

Orolia is a resilient positioning, navigation and timing (PNT) solutions company and a partner of U.S., NATO and allied forces. The company provides end-to-end resilient PNT solutions, including scalable, modular and cost-effective technology to support PNT-reliant and critical defense and commercial applications.

Skydel's capabilities allows Orolia to offer customers more diverse resilient PNT solutions with sophisticated testing and simulation protocols, additional customized signals, and superior vulnerability assessments for military and commercial applications where GNSS failure is not an option.

According to Orolia, as the latest addition to the Orolia portfolio, Skydel brand solutions bring a new paradigm to the GNSS simulator scene by combining innovative algorithms and off-the-shelf hardware to help protect the world's most critical GNSS-reliant systems operating through GPS, Galileo and other GNSS.

Skydel technology also supports secure communications signals such as SAASM, M-code, PRS and other alternative signals with approved partners to provide real-world PNT vulnerability testing for critical infrastructure applications worldwide.

By combining graphics processing unit (GPU) accelerated computing and software-defined radios (SDR), Skydel-powered simulation solutions generate signals in real time, with uncompromising performance for demanding use cases. They are available as complete turnkey systems suitable for all GNSS simulation needs, including everything from compact test benches to complete CRPA test systems.

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MACHINE CONTROL

Drilling, Piling Operators Tighten Control with Trimble

Trimble's new Groundworks Machine Control System is aimed at drilling and piling operations. The next-generation system enables contractors to perform drilling and piling operations quickly, safely and accurately with centimeter-level accuracy.

Using a large touch-screen display, operators can personalize the interface to match their workflow.A variety of configurable views make it easier to achieve maximum productivity. The software aligns with other solutions in the Trimble Civil Engineering and Construction portfolio to make company-wide training easier.

Photo: Trimble

With Groundworks, contractors can achieve centimeter-level accuracy with stakeless navigation, which reduces rework and decreases the need for personnel working near the machine during operation.

Drilling. Groundworks drilling gives contractors the ability to drill to the specified location, depth, orientation and inclination angle. Better rock fragmentation and lower hauling costs can be achieved by optimizing drill-hole spacing, angles and the location of the machine for a more even blasting pattern. An auto stop feature automatically stops drilling at target elevation to reduce overdrilling, leading to flatter benches and reduced wear and tear on machines, which can result in significant cost savings.

Piling. Navigation time between piles is reduced, with less time moving the machine and more time piling maximizing daily production.Built-in, automated quality assurance and quality control reporting includes the capture of start and end positions, time and elevation as well as actual embedment depth.

RESEARCH Roundup

DESIGN AND EVALUATION OF INTEGRITY ALGORITHMS FOR PPP IN KINEMATIC APPLICATIONS

BY KAZUMA GUNNING, JUAN BLANCH, AND TODD WALTER, *STANFORD UNIVERSITY,* AND LANCE DE GROOT AND LAURA NORMAN, *HEXAGON POSITIONING INTELLIGENCE*

UAV and autonomous platforms can greatly benefit from an assured position solution with high integrity error bounds. The expected high degree of connectivity in these vehicles will allow users to receive real-time precise clock and ephemeris corrections, which enable the use of precise point positioning (PPP) techniques. Until now, these techniques have mostly been used to provide high accuracy, rather than focusing on high-integrity applications. The authors apply the methodology and algorithms used in aviation to determine position error bounds with high integrity (or protection levels) for a PPP position solution.

PPP techniques can provide centimeter accuracy without local reference stations in kinematic applications. These techniques have so far mostly been used to provide high accuracy, and it is only recently that they have been proposed to provide integrity, that is, position error bounds with a very low probability of exceeding them. There has been preliminary work on the application of integrity to PPP, but it remains a challenge to translate the benefits of PPP to accuracy while maintaining high integrity. Most of the integrity work in PPP and real-time kinematic (RTK) has dealt more with the ambiguity resolution process under nominal error conditions and less on the integrity of the position solution under fault conditions.

The authors overview their PPP filter implementation, and describe the threat model as well as two classes of integrity algorithms: solution separation and sum of squared residuals based (also called residual-based [RB], a misnomer, as all autonomous integrity monitors are based on the residuals.) They present data sets used to evaluate the algorithms, compare the protection levels (PLs) obtained with different algorithms, and present the results obtained with the most promising PL formulation in four different data sets: static, dynamic in open-sky conditions, dynamic in midtown suburban conditions, and in flight.

Concluding, they state: "We have formulated RAIM protection-level formulas using either solution separation or the sum of residual squares. Both formulations consist of straightforward adaptations of snapshot RAIM to a Kalman filter solution.

"For solution separation, we have shown an implementation where the computational cost of running a bank of filters is far from being proportional to the cost of one filter. Instead, we could run 50 additional filters for the cost of one.

"For residual based RAIM we have developed a set of formulas to update the sum of square residuals from one time step to the next one. Because this test statistic is exactly the same as the one used in snapshot RAIM (when we consider the problem as a batch least squares), we could use the formula that ties the slope of a fault mode to the standard deviation of the solution separation. The slope can therefore also be updated recursively."

Finallly, "we have refined the PPP filter, added one scenario (suburban driving conditions), and examined the effect of considering multiple faults in the formulation of the test statistics and the protection levels. The results are very promising: protection levels below 2 m appear to be achievable, and the computation load is lower than expected."

This paper was presented at ION-GNSS+ 2018. See **www.ion.org/publications/ browse.cfm.**

Pulling Jammers Out of the Air

Highway Gantries Identify Bad Actors

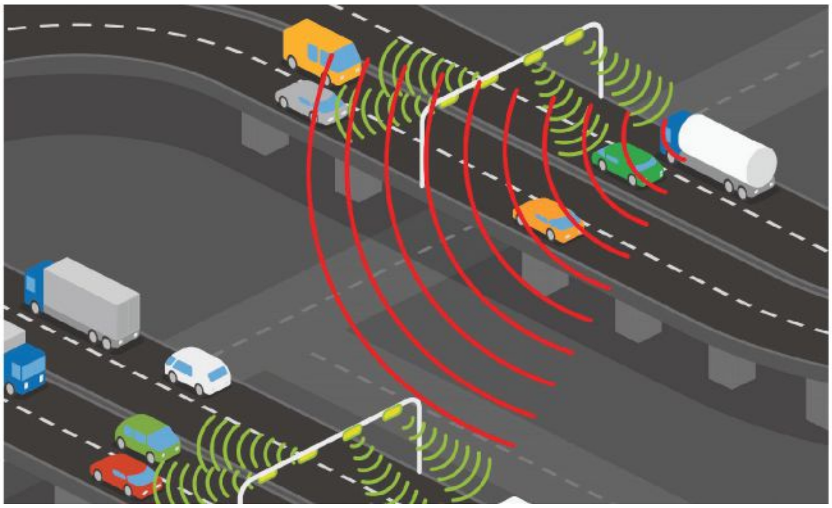
Recent years have seen an increase in drivers turning to cheap GNSS jamming devices in order to move around undetected or to thwart built-in anti-theft systems or road tolling systems. These jammers not only knock out their own GNSS receiver, they also block GNSS signal reception in a radius of several hundred of meters.There is a growing demand for automatic detection of these illegal jammers to help catching the offending driver.

An ION-GNSS+ 2018 presentation by Wim de Wilde and Jean-Marie Sleewaegen presentation showed how a multi-antenna GNSS receiver with built-in RF spectrum monitor and adequate processing tool can efficiently detect and classify jamming events and identify the offending car or truck. They conducted a five-day test with two Septentrio AsteRx-U dual-antenna receivers installed on an overhead structure above a busy highway.

In parallel to the GNSS tracking and built-in anti-jam functionality, the AsteRx-Ucan simultaneously sample the RF signal from its two antennas. One of the objectives of the test was to evaluate the possibility to perform lane detection by cross-correlating the jamming signal received by the two antennas. In addition, the antennas were mounted with a significant inclination angle to create an asymmetrical reception pattern. The goal was to assess the feasibility of detecting the driving direction from the time series of the received jammer power. Such lane or direction detection would greatly help identifying the offending driver in heavy traffic conditions when more than one vehicle crosses the overhead structure at the time of the jamming.

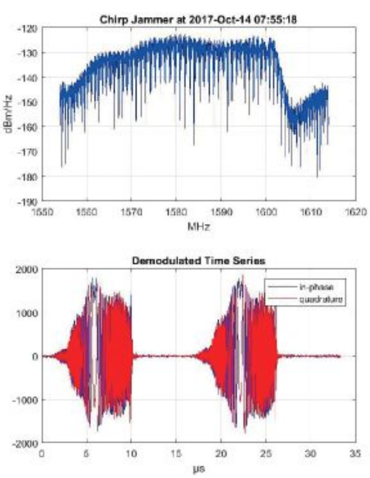
Over the five days of the experiment, 45 jamming events were recorded and analyzed, most of them intentional : continuous wave, chirp or even less-known pulse jammers. The researchers explained how the jamming events are automatically detected and classified by the processing tool, using pattern recognition to distinguish between intentional harmful events and unintentional interferences. They presented selected cases illustrating the RF signature of the most prevailing types of jammer. They then addressed the direction and lane sensing algorithm and discussed the effect of multipath propagation of the jammer signal. All algorithms are illustrated with real-life examples.

For further information on this case study, see **www.ion.org/publications/browse.cfm.**



Images and graphics: Septentrio

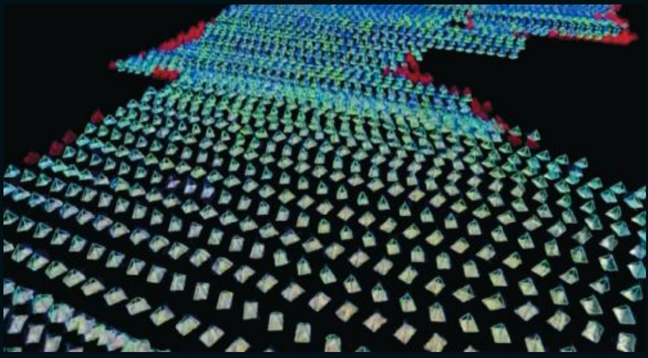
SEPTENTRIO GNSS antenna placement on highway gantry.



CHIRP JAMMER example.

Images: National Trust of Scotland/GeoGeo

FIVE DAYS of drone flights yielded 4,000 ultra-high-resolution images and 420 million data points.



Drone Aids Archaeology in Scotland

The National Trust for Scotland commissioned Glasgow-based GeoGeo to carry out a drone survey of the inner Hebridean islands of Canna and Sanday in November 2018. Using an ultra-high-definition camera, the GeoGeo team not only pinned down the exact locations of archaeological features, but also revealed new archaeological sites.

Over five days,the drone navigated 400 kilometers to capture 4,000 images at a 3-centimeter resolution. After processing, the images created a minutely detailed 3D map capable of being used in a 3D printer to create scale models of the islands. With more than 420 million data points, it is currently the world's largest complete island dataset captured by drone, claims GeoGeo founder Paul Georgie.

"We were blown away by the results and the possibilities of this technology," said Derek Alexander, head of Archaeology at the Trust. "We've previously recorded archaeology on Canna and Sanday which proves that there were inhabitants as far back as the Neolithic, but this survey gives us information and detail we just haven't had until now. We've been able to obtain exact plots of known sites, but also recorded the extensive traces of cultivation, such as rig and furrow field systems that range in age from the Bronze Age onwards."

The cameras and software also will be able to help with seabird counts and habitat and coastal erosion monitoring, which are currently expensive and labor intensive, Alexander said. The trust will use the maps to update archaeological records and prepare for future groundwork and excavations.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SEEN & HEARD

A NEW USE FOR GNSS SATELLITES

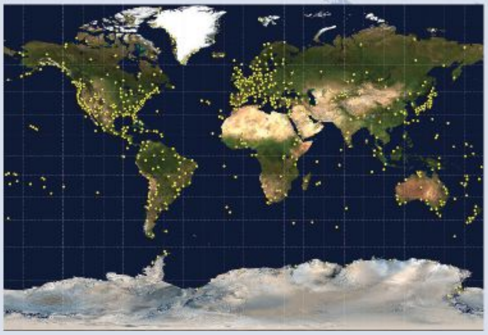
University of Padua researchers say GNSS satellites make possible global quantum communication, beaming information between a satellite and an Earth-based ground station. They exchanged a single photon over 20,000 kilometers to prove secure quantum communications can be implemented on a global scale using GNSS. Results show the first exchange of a few photons per pulse between two GLONASS satellites, using the passive retro-reflectors mounted on the satellites, and the Space Geodesy Centre of the Italian Space Agency. The results could provide solutions for GNSS security for satellite-to-ground and inter-satellite links by using quantum information protocols for quantum key distribution.

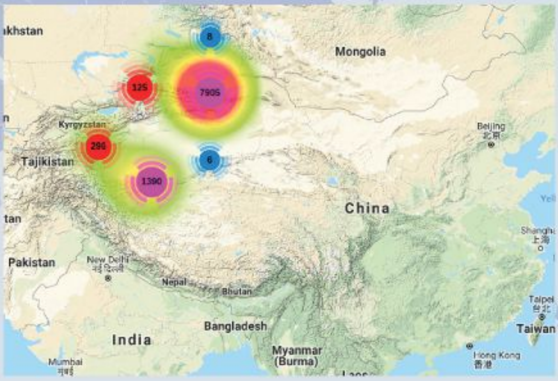
PIGEON SCIENTISTS

Engineers from the University of Birmingham have developed a compact backpack to collect climate and pollution data. When the birds return to their lofts, the sensors are retrieved and the data downloaded, including GPS location, temperature, humidity, ambient light and air pressure. So far, scientists have been able to collect data from five birds — they made a total of 41 flights with a total length of about 1,000 kilometers.

GRITSS TO IMPROVE REFERENCE FRAME

University of Massachusetts Lowell researchers have received a two-year, $1.2 million grant from NASA's Earth Science Division to develop a Geodetic Reference Instrument Transponder for Small Satellites (GRITSS) to significantly improve the accuracy of the International Terrestrial Reference Frame — the basis of GPS positioning and navigation. A virtual map of the Earth, the ITRF pinpoints specific geographic positions and describes Earth's precise shape, physical topography, orientation and rotation with time based on a stationary, Earth-centered coordinate system. The location of each GPS satellite is defined within the ITRF.





CHINA'S BIG BROTHER PROGRAM

Evidence that China is tracking its Uyghur Muslim population in the Xinjiang region has been uncovered. A facial recognition database was left open on the internet for months, Dutch security researcher Victor Gevers told ZDNet. The database contains information on 2.5 million people, along with a stream of GPS coordinates. Data includes detailed and sensitive information: names, ID card data, addresses, photos and employers, as well as GPS coordinates where the user had been seen via public cameras labeled mosque, hotel, police station, internet cafe, restaurant and more.

PHOTO CREDITS: Space Geodesy Centre/Italian Space Agency; Pigeon backpack/Rick Thomas; ITRF/NASA; China map/Victor Gevers/ZDNet.

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