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2019 **Buyers Guide**

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Resilient PNT Protects Data Centers and Mobile Devices

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A NORTH COAST MEDIA PUBLICATION

JUNE 2019 | Vol 30 | No 6


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COVER STORY

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2019 BUYERS GUIDE

The only industry resource for GNSS manufacturers and service providers lists 265 companies and their offerings in more than 100 categories.

CORPORATE PROFILES

20 marketplace leaders describe their corporate capabilities in special advertiser-sponsored pages throughout the Buyers Guide. Also look for highlights from additional sponsors.

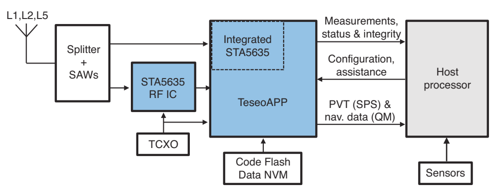

Image: Authors

ADDED DEPTH

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JUNE 2019

OPINIONS AND DEPARTMENTS


Photo: Impossible Aerospace

MARKET WATCH

Corrections

In our May print edition's Market Watch, we regretfully incorrectly identified CHC Navigation's new GNSS sensor series in a headline. CHC Navigation recently launched its P2 sensor series, which provides high-accuracy positioning and heading for reference stations, marine systems, unmanned navigation, industrial automation, robotics, machine control and other applications.

In our April print edition's Launchpad, we regretfully incorrectly identified Talen-X's wavefront simulator. The corrected text appears below.

WAVEFRONT SIMULATOR
ADDED TO SOFTWARE-DEFINED PLATFORM

The BroadSim Wavefront Simulator is a new addition to Talen-X'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.
Talen-X, www.talen-x.com

Over 80 Million Sold

BY ALAN CAMERON
EDITOR-AT-LARGE

When I was a kid, two of my hometown's burger drive-ins attracted the hungry attention of my sister and myself, causing us to hound our parents to take us "out to dinner" upon the slightest pretext. Only one of them, however, boasted a sign claiming "400 million served." This was a staggering number to an eight-year-old. I hypothesized that everyone in the world must have consumed several by now — a very good argument for me to have one tonight.

The desire to provoke similar reasoning could form part of the motivation for the China Satellite Navigation Office to announce that sales of BeiDou-based chips have exceeded 80 million. Ran Chengqi, director of the CSNO, delivered the number in a report on the 10th China Satellite Navigation Conference held in Beijing on May 22.

Now, 80 million falls well short of 400 million, but that next hurdle is well within reach, considering the size, potential and explosive growth of the Chinese market, to say nothing of others along the Great Belt and Road, a global development area of infrastructure development and investments in 152 countries and organizations in Asia, Europe, Africa and the Middle East.

The BeiDou number pales in comparison to the 3.15 *billion* units of total GNSS chips that global consumption is expected to hit in 2022. By a reasonable projection, BeiDou-enabled chips will by then constitute a major if not the lion's share of that number. Of course, GPS-enabled chips will form a greater majority, if not the totality. All chips will — unless the world radically changes — be GPS-enabled to start, and then have some combination of other GNSS in addition.

BIG NUMBERS. Ran Chengqi further said that 22-nanometer dual-frequency BeiDou chips are ready for commercial applications.

According to the China Global Television Network, 116 new positioning-capable cellphone models applied to enter the Chinese market in the first quarter of 2019; 82 of them carry BeiDou-enabled chips. The latest government report on the scale of China's satnav industry anticipates it will reach 400 billion yuan (US$ 57.8 billion) by 2020.

The news agency stated that more than six million vehicles in 36 cities use BeiDou; long-distance operations and precision farming help raise output by 5% while saving 10% of fuel costs; and more than 70,000 fishing vessels employ BeiDou's short messaging service.

> "It would be stretching a point to say that satnav chips are the burgers of the future, but it's not an exaggeration to assert that they are becoming a commodity on the world market."

BeiDou's rapid success in a relatively short term echoes that of GPS and GNSS in general. It would be stretching a point to say that satnav chips are the burgers of the future, but it's not any exaggeration or distortion to assert that they are becoming — if they have not already become — a commodity on the world market.

By the way, those golden arches have since 1994 stopped counting and updating their published burger tally. All the signs simply say "billions and billions served." ⊕

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EDITORIAL
Publisher and Editorial Director Marty Whitford
mwhitford@northcoastmedia.net | 216-706-3766
Senior Editor Tracy Cozzens
tcozzens@northcoastmedia.net | 541-255-3334
Editor-at-Large Alan Cameron
editor@gpsworld.com | 541-984-5312
Staff Editor Diane Sofranec
dsofranec@northcoastmedia.net | 216-706-3793
Digital Media Manager Allison Barwacz
abarwacz@northcoastmedia.net | 216-706-3796
Art Director Charles Park

CONTRIBUTING EDITORS
Innovation Richard Langley | *lang@unb.ca*
Defense PNT Michael Jones | *mjones@gpsworld.com*
Professional OEM & UAV Tony Murfin
GeoIntelligence William Tewelow | *wtewelow@gpsworld.com*
Survey Tim Burch and Dave Zilkoski | *tburch@gpsworld.com* and dzilkoski@gpsworld.com
General Matteo Luccio | *matteo@palebluedotllc.com*

BUSINESS
PUBLISHER AND EDITORIAL DIRECTOR Marty Whitford
mwhitford@northcoastmedia.net | 216-706-3766
SR. ACCOUNT MANAGER Mike Joyce
mjoyce@northcoastmedia.net | 216-706-3723
ACCOUNT MANAGER Ryan Gerard
rgerard@northcoastmedia.net | 216-363-7921
DIRECTOR OF AUDIENCE ENGAGEMENT Bethany Chambers
bchambers@northcoastmedia.net | 216-706-3771
SR. MARKETING & EVENT MANAGER Michelle Mitchell
mmitchell@northcoastmedia.net | 216-363-7922
MARKETING & EVENT MANAGER Angela Gibian
agibian@northcoastmedia.net | 216-363-7936
MARKETING & SALES MANAGER, BUYERS' GUIDE Chloe Scoular
cscoular@northcoastmedia.net | 216-363-7929

PUBLISHING SERVICES
Manager, Production Services Chris Anderson
canderson@northcoastmedia.net | 216-978-5341
Senior Audience Development Manager Antoinette Sanchez-Perkins
asanchez-perkins@northcoastmedia.net | 216-706-3750
Reprints & Permissions Brett Petillo
bpetillo@wrightsmedia.com | 877-652-5295
Circulation/Subscriber Services
gpsworld@omeda.com | USA: 847-513-6030

NORTH COAST MEDIA, LLC.
1360 East 9th St, Tenth Floor
Cleveland, OH 44114, USA
President & CEO Kevin Stoltman
kstoltman@northcoastmedia.net | 216-706-3740
Vice President of Finance & Operations Steve Galperin
sgalperin@northcoastmedia.net | 216-706-3705
Publisher and Editorial Director
Marty Whitford | *mwhitford@northcoastmedia.net* | 216-706-3766
VP Graphic Design & Production
Pete Seltzer | *pseltzer@northcoastmedia.net* | 216-706-3737

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Crimes that Shouldn’t Have Happened

BY Tracy Cozzens
SENIOR EDITOR

Law enforement agencies have been quick to adopt GPS monitoring of offenders on parole or awaiting trial. An estimated 300,000 people in the U.S. are wearing ankle bracelets. Proponents say the systems enhance public safety, reduce prison costs and provide social benefits.

However, technology is only as good as the people who use it, as a tragic case from Ohio illustrates. In February 2017, 21-year-old Reagan Tokes was kidnapped and murdered after leaving work in Columbus. The man convicted of killing her had been recently released from prison. Yes, he was wearing a GPS monitor, but no one was tracking his movements until after he robbed six people and killed Tokes.

In response, Ohio lawmakers introduced a bill to improve real-time monitoring of parolees by shrinking the work load for parole officers, who now are responsible for 90 to 100 offenders at one time.

In cases in Florida and New York, the system worked as intended and alerts were sent, but authorities took no action. In the Florida case, no one was on duty, despite the suspect having triggered more than 100 alarms.

An offender in Syracuse, New York, was able to remove and reassemble his ankle bracelet in less than a minute, using techniques he learned when he watched the officers put the bracelet on him. Because of numerous false alarms, the monitoring company had set a five-minute limit before officers were notified, at the police department’s request. Having beat the monitoring system, the offender committed a murder.

A nationwide investigation by ABC’s “20/20” news magazine program found at least 50 murders allegedly committed since 2012 by people ordered to wear monitored ankle bracelets.

“Public safety is only as good as the supervising entity we provide our products to,” Jennifer White of monitoring company BI Analytics commented on “20/20.” Criminal justice experts say the monitoring system should not be used for anyone who is a risk to the public.

While polucymakers and law-enforcement authorities determine the most effective use of such systems — and how to address issues of monitoring response, overtaxed officers and tight budgets — the monitoring industry continues to improve the “tamper-resistant” devices as well as the services offered.

After all, no one wants to live with a false sense of security.

PNT Q&A — EDITORIAL ADVISORY BOARD

What is the best way to protect data centers and mobile devices from spoofing and jamming?

Ellen Hall
Spirent Federal Systems

“After speaking to our head of engineering, Roger Hart, he explained this as something akin to ‘What’s the best way to achieve world peace?’ As the strengths and vulnerabilities of static and mobile devices vary considerably, the best solution will be achieved through a tailored application of algorithms, antenna siting and design, multi-constellation, multi-frequency and non-GNSS inputs.”

Alison Brown
NAVSYS Corporation

“Spoofing and jamming presents a very credible threat today to users of GPS for navigation and perhaps the greatest threat is vulnerability within our national infrastructure to spoofing of GPS timing. Congress, recognizing this threat, has tasked the Department of Transportation (DOT) in the National Timing Resilience and Security Act of 2017 to provide a backup for the timing component of the GPS. Specifically this backup is to ‘ensure the availability of uncorrupted and non-degraded timing signals for military and civilian users if GPS timing signals are corrupted or otherwise unavailable.’ Although the act directed the DOT that this system should be operational in two years (2019), little progress appears to have yet been made in deploying a backup timing system. This system not only would reduce vulnerability to spoofing for timing users, but could also be used by mobile users for detection of spoofing, allowing for national alerting when jamming or spoofing is detected. These alerts, tied with a quick response mechanism for law enforcement to take action, would provide an effective method for protecting all GPS users nationwide from jamming or spoofing.

For the National Timing Resilience and Security Act of 2017, go to www.govtrack.us/congress/bills/115/s2220/summary. *See also System of Systems page 10.*

Jean-Marie Sleewaegen
Septentrio

“Take full benefit of multi-frequency multi-constellation redundancy. Perform signal monitoring and authentication using advanced receiver architectures and signal-based protection (e.g., Galileo’s Open Service Navigation Message Authentication). Foresee non-GNSS redundancy to bridge gaps, such as precise clocks for data centers or IMUs for mobile devices.”

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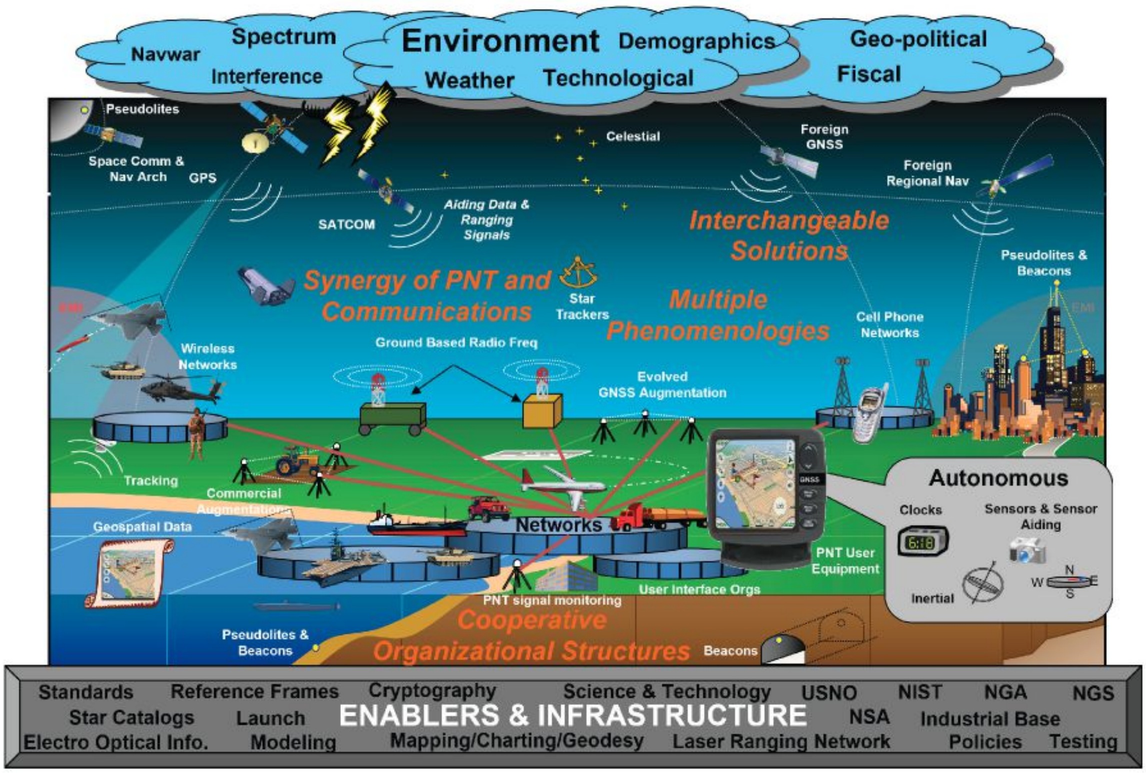
DOT Gets Cracking on a New PNT Concept

Congress Mandated Movement in December 2017



Graphic: U.S. Department of Transportation

U.S. NATIONAL PNT ARCHITECTURE from a 2007 Department of Transportation report, updated in 2017.

The U.S. Department of Transportation (DOT) says it will implement a terrestrial timing system to complement and back up GPS signals, and plans to demonstrate the new system "towards the end of the calendar year." The demo is anticipated to include a range of technologies, including among others local positioning systems such as Locata and NextNav, wide-area coverage by eLoran, and — though the parameters of DOT's mandate specified terrestrial backup — space-based signals furnished by Satelles.

The statement came in response to an inquiry in March from the House of Representatives' Transportation and Infrastructure Committee concerning progress on a GPS Backup Technology Demonstration that was mandated in December 2017. Although funds were appropriated for the project, committee chair Peter DeFazio of Oregon saw little to no evidence of work being done, and so required a status report.

DOT issued a Request for Information (RFI) on May 3, with a due date of June 3. The RFI asked for "readiness-level six" technologies (bearing demonstrated results in a relevant environment) "capable of providing backup positioning, navigation, and/or timing services to critical infrastructure in the event of a temporary disruption to GPS.

"This demonstration effort also is expected to encompass technologies capable of providing complementary PNT functions to GPS by either expanding PNT capabilities, including cross checks, or extending them to

SEE DOT, PAGE 12. >>

Anti-Jam, Anti-Spoof Readied for European Market

New initiatives from the Navigation Innovation and Support Programme (NAVISP), a program of the European Space Agency (ESA), have targeted counter-jamming and counter-spoofing efforts, as Europe's Galileo program gains progressive foothold in the marketplace, particularly in safety-critical systems such as driverless cars.

"We are looking for new and disruptive ideas in navigation and that is why we created NAVISP," stated ESA Director General Jan Wörner.

TeleConsult Austria is working with JH Joanneum University of Applied Sciences on the GNSS Interference Detection and Analysis System (GIDAS), to automatically detect, classify and pinpoint all intentional interference sources within a given area by monitoring all civil GNSS signals in real time.The aim is to build a multi-frequency scalable system. GIDAS plans to begin commercialization at the end of 2019.

France Developpement Conseil has developed a hardened satnav module called DRACONAV, combining hardware and software to combat jamming and spoofing. Targeting intelligent transport applications, it seeks to identify cyber attacks and continue to provide authenticated positioning information as they occur. DRACONAV would deliver a level of confidence to let users know if they can continue relying on the data the module delivers, and yield an estimate of the receiver's true position as the attack continues. A prototype design has undergone more than 3,000 km of field tests and is moving to industrialization.

> "We are looking for new and disruptive ideas in navigation and that is why we created NAVISP."

Intecs Solutions of Italy has created G-Passion, using a software-defined radio to analyze a few tens or hundreds of milliseconds of Galileo signals at a time, to tell the user whether or not the signal is authentic or spoofed.

In Romania, InSpace Engineering' MARGOT assesses the multipath and interference impact on PNT information in maritime environments.

The Norwegian company SINTEF is developing its Advanced Radio Frequency Interference Detection, Alerting and Analysis System (ARFIDAAS) project, offering as wide a spectral coverage as possible — including all current GPS, Galileo and GLONASS signals — to identify disruptions due to intentional or unintentional interference.

UK company Helix Technologies has developed compact helical antennas, built around a dielectric ceramic core, primarily for driverless cars. The multi-frequency design aims to reduce susceptibility to interference as well as multipath. Testing will soon get underway in several European cities.

DOT

« Continued from page 10.

GPS or Global Navigation Satellite System (GNSS)-denied or degraded user environments."

The DOT said it is "interested in leveraging PNT service technology initiatives." Possibly, the agency intends to contract for a service rather than build a new system.

Congress first required DOT to establish an operational terrestrial timing system to back up GPS signals, then expanded that definition to include positioning and navigation services.

Systems or services, or combinations thereof, must now provide all three functions.

CGI, Thales Team for Galileo Security

CGI has signed an agreement with Thales Alenia Space France to enhance and maintain security software for the Galileo satellite navigation system. Valued at approximately 14 million euros, the contract will last until the end of 2020. CGI experts are working on this strategic project from Rotterdam and Toulouse.

CGI will improve the functionality, robustness and reliability of Galileo's ground infrastructure, as well as enhance and maintain software for its Public Regulated Service Key Management Facility (PKMF). The Public Regulated Service (PRS) is one of the key features that distinguishes Galileo from other satellite navigation systems. It ensures that only government-authorized entities have access to Galileo's secure PRS signal that meets strict security standards in areas such as defense, law enforcement and customs.

"We look forward to working with CGI to ensure the highest level of security for Galileo, along with an efficient, high-performance infrastructure," said Guillermo Salgado, Galileo Ground Mission and EGNOS Programs Director, Thales Alenia Space France. "CGI's significant space and security experience, combined with its local presence and global resources, gives us access to the experts we need to launch and operate one of the world's most advanced satellite navigation systems."

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INERTIAL + CAMERA

Two Little Eyes That Can See and Navigate

The Intel RealSense Depth Camera D435i, designed for positioning and maneuvering mobile robots and other portable systems, includes an inertial measurement unit (IMU) that enables developers to create solutions with advanced depth-sensing and tracking capabilities. Intel introduced the camera in 2018 and an advanced version early this year.

As robots, drones and other autonomous mobile devices must — eventually — interact independently and intelligently with their environments, they must track their locations as they move, navigating unfamiliar spaces while discovering, monitoring and avoiding still and moving obstacles in real time.

Moving toward that goal, the D435i includes two fisheye lens sensors, an IMU and an Intel Movidius Myriad 2 video processing unit (VPU), a system-on-chip component for image processing and computer vision at very high performance per watt.

Vision-based simultaneous localization and mapping (V-SLAM) algorithms run directly on the VPU with very low latency. The T265 has demonstrated less than 1% closed-loop drift under intended use conditions. It also offers sub 6 ms latency between movement and reflection of movement in the pose.

The RealSense device measures 1 x 0.5 x 4 inches (108 mm x 24.5 mm x 12.5 mm), weighs around two ounces (55 g), and draws 1.5 watts to operate the entire system, including the cameras, IMU and VPU. Its spatial sensing and tracking capabilities are based on technology developed by RealityCap, acquired by Intel in 2015.

Images: Intel

THE REALSENSE camera uses two fisheye lenses and an IMU to construct location awareness.

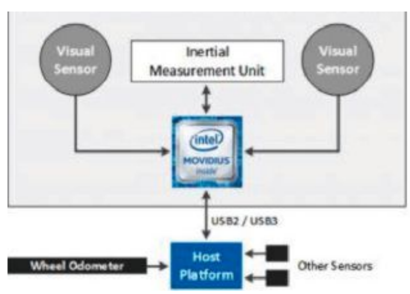
The camera performs inside-out tracking: it does not depend on external sensors to understand its environment. Tracking is based on information gathered from the two fisheye cameras, each with a 163-degree range of view (±5 degrees) and capturing images at 30 frames per second. The wide field of view from each sensor keeps points of reference visible to the system for a relatively long time, even if moving quickly.

Visual-Inertial Odometry. A key strength of visual-inertial odometry is that the sensors complement each other. The images from the camera are supplemented by data from the onboard IMU, which includes a gyroscope and accelerometer. The aggregated data from these sensors is fed into the SLAM algorithms.

The algorithm identifies sets of salient features in the environment, such as a corner of a room or object that can be recognized over time to infer the device's changing position relative to those points.

The visual information prevents long-term drift from the inertial that degrades position accuracy. The IMU operates at a higher frequency than the cameras, allowing for quicker response and recognition by the algorithm to changes in the device's position. A map of visual features and their positions is built up over time. In re-localization, the camera uses the features it has seen before to recognize when it has returned to a familiar place. The camera can locate its point of origin with an error margin of less than one percent.

Drone testing demonstrated that, in both cases, the tracking and position data generated by the peripheral was closely correlated with what was provided by GPS. This supports the viability of using it for navigation in areas where GPS is not available, such as under a bridge or inside an industrial structure.



BLOCK DIAGRAM of camera components.

MARKET WATCH

Segment Snapshot: Applications, Trends & News

OEM

Module Aimed at Urban Lane Accuracy

The new u-blox ZED-F9K GNSS and dead-reckoning module is designed to bring continuous lane-accurate positioning to challenging urban environments.

Building on the u-blox F9 platform, the ZED-F9K offers both high-precision multi-band GNSS and inertial sensors. It combines the latest generation of GNSS receiver technology, signal processing algorithms and correction services to deliver down to decimeter-level accuracy within seconds, addressing the evolving needs of advanced driver-assistance systems (ADAS) and automated driving.

Compatibility with GNSS correction services further improves positioning accuracy by compensating for ionospheric and other errors.

The real-time kinematic (RTK) receiver module receives GNSS signals from all orbiting GNSS constellations.

The inertial sensors constantly monitor changes in the moving vehicle's trajectory and continue to deliver lane-accurate positioning when satellite signals are obstructed, such as in parking garages, tunnels, urban canyons or forested areas.

The module's accuracy and low latency makes it suitable for automotive OEMs and Tier 1 automakers developing V2X (vehicle-to-everything) communication systems. By continuously sharing their location, V2X systems help increase overall road safety and reduce congestion.

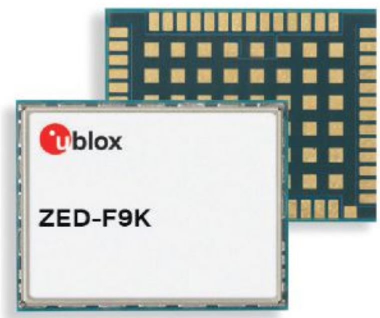


Photo: U-blox

CHC Navigation Launches P2 GNSS Sensor Series

CHC Navigation's new P2 GNSS sensor series provides high-accuracy positioning and heading in a compact, rugged enclosure. The series is suitable for a wide variety of applications such as reference stations, marine systems, unmanned navigation, industrial automation, robotics and machine control.

Photo: CHC Navigation

P2 Elite GNSS sensor.

Integration. The P2 GNSS series is designed to significantly reduce system integration efforts by combining numerous connectivity interfaces including RS232, low-latency PPS output, Ethernet, CAN bus protocol and a comprehensive web interface for configuration set-up.

The series integrates the latest GNSS technology in a rugged IP67 and lightweight enclosure. It delivers reliable, uninterrupted, high-accuracy, real-time positioning and heading measurements.

Three models. The P2 GNSS sensor offers cost-effective and powerful real-time kinematic (RTK) positioning.

The P2 Pro GNSS adds a dual-antenna input for precise heading data.

The P2 Elite integrates additional 4G and UHF modems to provide a powerful, all-in-one GNSS sensor.


Photo: Robotic Research

Customizable Module Ready for Ground Navigation

Robotic Research's RR-N-140 navigation system provides accurate, absolute and relative 3D localization information for ground vehicles of all sizes. It features dual-antenna GNSS for zero-speed heading detection and redundancy.

The device delivers exceptional localization performance in GPS-denied or compromised areas, the company said. It is designed specifically for use on unmanned ground vehicles and is customizable to incorporate a wide variety of sensor inputs into the navigation solution.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"While I had the J-Mate running, I performed a solar observation for orientation. That was about the sweetest execution I could imagine. I see so much potential here."

John Evers, PLS

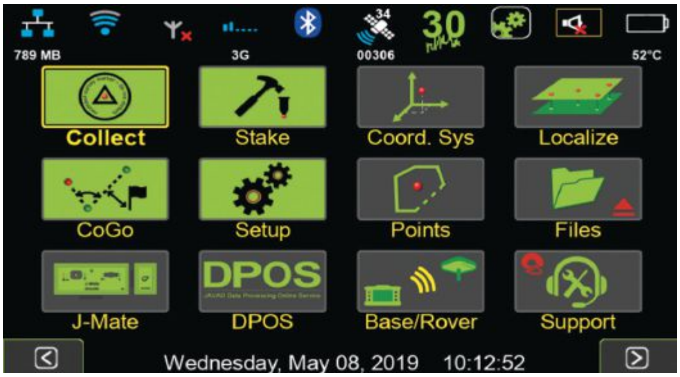
Introduction

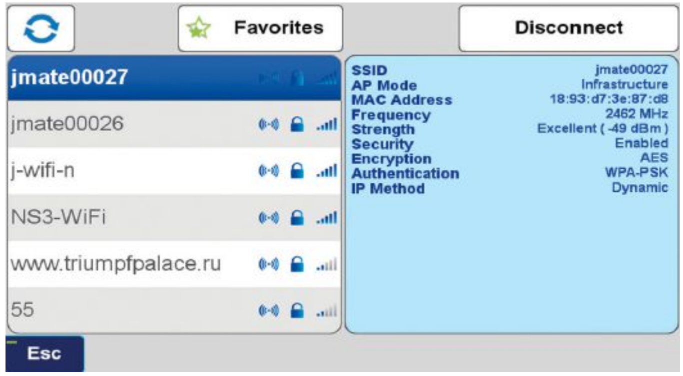
Let's set the record straight: J-Mate is not a total-station. **J-Mate and TRIUMPH-LS together** make the **"Total Solution"** which is a combination of GNSS, encoder and laser range measurements that **together do a lot more than a total station**. For long distances you use GNSS and for short distances (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**.

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. The J-Mate SSID will be in this format JMatexxx, where xxx is your J-Mate's serial number. After a Wi-Fi connection is established, click the J-Mate icon and then click Setup. When you are prompted to connect to the J-Mate, click yes and then follow the remaining prompts.

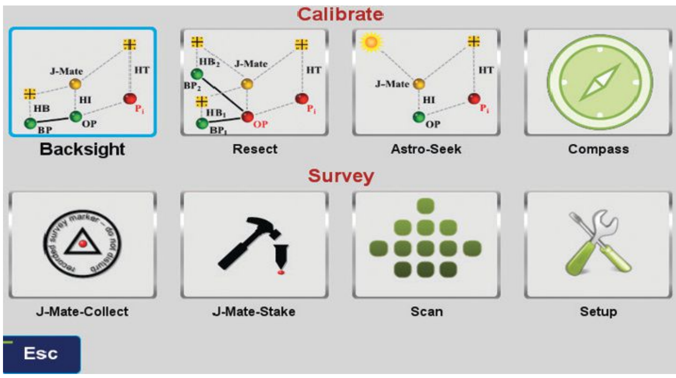
Connecting the TRIUMPH-LS to the J-Mate

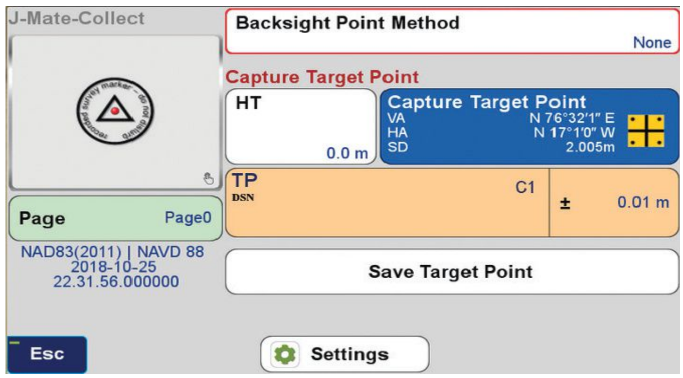
TRIUMPH-LS communicates with the J-Mate through Wi-Fi. Turn on both the TRIUMPH-LS and the J-Mate. Click the Wi-Fi icon on the TRIUMPH-LS Home screen to connect to the J-Mate, much the same way as you connect TRIUMPH-LS to your Wi-Fi access point.





After connection, click the J-Mate icon on the TRIUMPH-LS Home screen and then J-Mate/ J-Mate Collect/Capture Target Point to get familiar with the Main J-Mate screen.





Main J-Mate Screen

This is the Main J-Mate Screen. Click button **"7"** in Figure 1 to switch some controls as shown above. Below are explanations of some buttons of these screens.

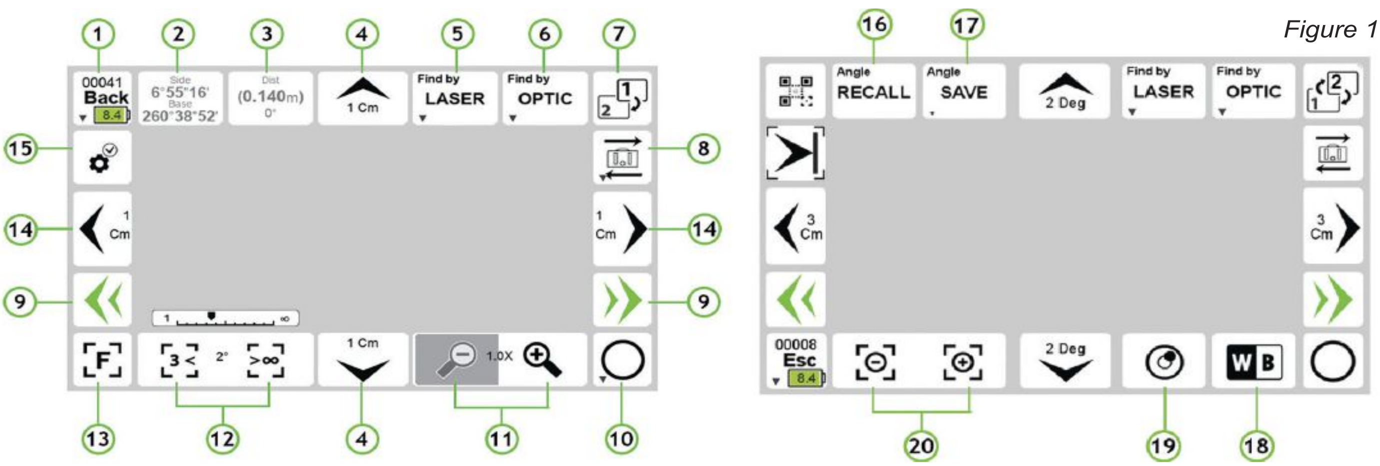


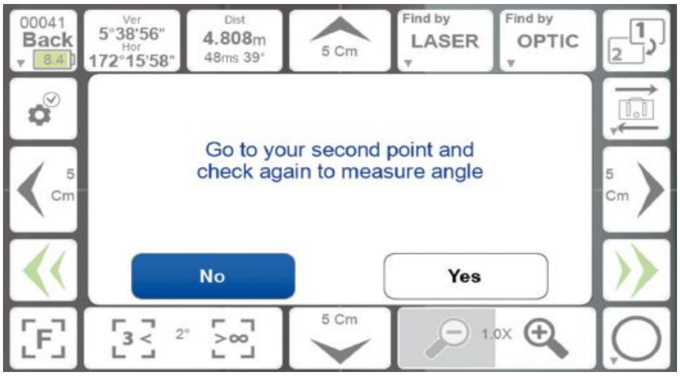
Figure 1

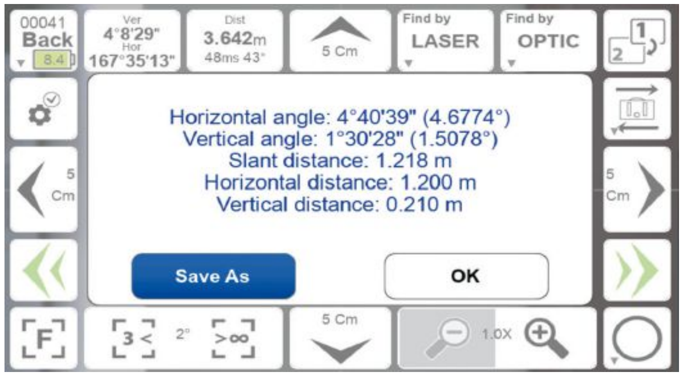
Aiming at targets manually

You can find targets manually or automatically.

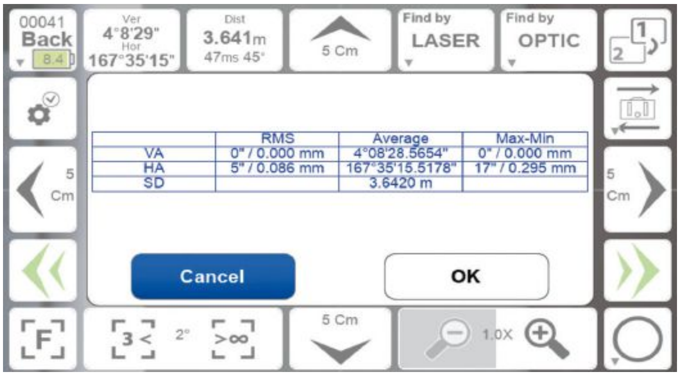
Measure angles between two points:

Aim at the first point and click button **“2”** of Fig. 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.





Taking a point



Aim at your target and click **“10”**. J-Mate will take 10 readings and average them. The average, RMS and spread of the ten readings are shown. Optionally, you can specify four points around the target point to be measured too, to ensure that you have aimed at the desired target. To specify the distance of the four points around the target, hold **“10”**.

Instantaneous angular and range measurements are shown in boxes **“2”** and **“3”** in Fig. 1.

Camera operation and settings

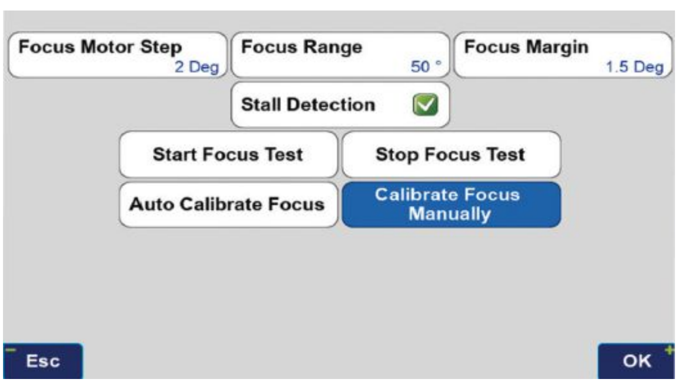
White balancing the J-Mate camera when the light setting changes: 1)Put a white paper in front of the J-Mate camera about few meters away, such that it covers at least half of the viewing angle of the camera. 2) Click **“18”** to start white balancing. It will take about 10 seconds to finish.

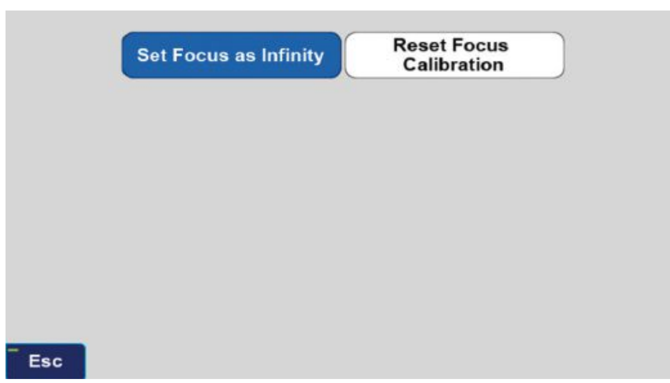
Zoom buttons: **“11”**

Contrast/Brightness buttons: **“20”**

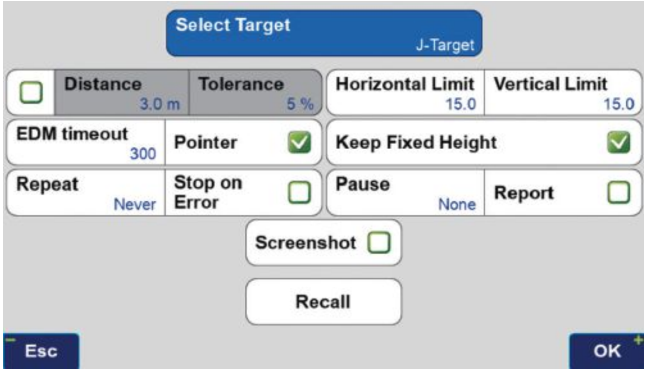
Focus: use buttons **“12”** to focus manually. Click **“13”** for autofocus on the subject.

Occasionally you may need to calibrate the Focus motor. Click Setup **“15”** → “Focus” → “Auto Calibrate Focus” or “Calibrate Focus Manually”. In Manual focus, 1)click “Rest Focus Calibration”, 2) using **“12”** buttons, focus to infinity, 3) Click “Set Focus as Infinity”.





Searching and finding objects by laser and Object types



Hold the Laser button (**“5”**) to see the setup screen for laser target selection and parameters. If you know the approximate distance to the target, click the check box and enter the distance and accuracy percentage. This will help J-Mate to ignore targets that are outside the range.

Horizontal and Vertical Limits are the limits that J-Mate will search around the starting point to find targets. In this example is 15 degrees on left and right, and 5 degrees up and down.

“Keep Fixed Height” check box, scans horizontally on fixed target height. You may rarely need to use this feature. It will reduce the scanning speed by a factor of 2.

In Target Selection screen, the following targets are defined:

- **J-Target** is a printed pattern glued to 166x166 mm plywood of about 25 mm thick. It can be attached to a 226x226 mm plywood of 10 mm which provides flaps around the pattern. Select check boxes related to Sides, Top and Bottom flaps, if they exist and you want J-Mate to consider the depth of the flap (about 25 mm).
- If the J-Target is not sitting on another object and its bottom boundary is clear, then check the box Measure to Bottom. If not checked, J-Mate will measure to the top and will come down half of the height to aim at center. This feature applies to other target types too.
- In laser scanning and finding, the pattern on the J-Target has no effect.

J-Target Custom: This option allows you to build your custom J-Target type.

TRIUMPH-LS Back: searching for an object similar to the back of TRIUMPH-LS.

Search Tube: Searches to find a tube with given diameter and height. If Measure to Bottom is not checked, it will go to the top of the tube and then come down half of the specified height, irrespective of the actual height of the tube.

Measure Tube: Searches for a tube that has the given width and then it measures the tube depth.

Corner identifies an abrupt change on a flat surface.

Snap: scans with the resolution given in “Step” and stops when range changes by “Edge Depth”.

Scan: Scans according with the resolution given in “Step” and saves the scanned files if the box is checked. The scanned files can be viewed in the Main screen / File icon.

Selected objects and their parameters can be saved and recalled by **“Save”** button on this and **“Recall”** button of the previous screen.

Follow me and robotic operation

J-Mate can search and find the J-Target and robotically follow it. J-Mate also measures the distance to the Target optically, and shows distance and tilt on top and the bottom of the J-Target image.

For J-Mate to follow the J-Target robotically, check the **"Follow Me"** box in the OPTIC set up (hold **6** to reach its setup).

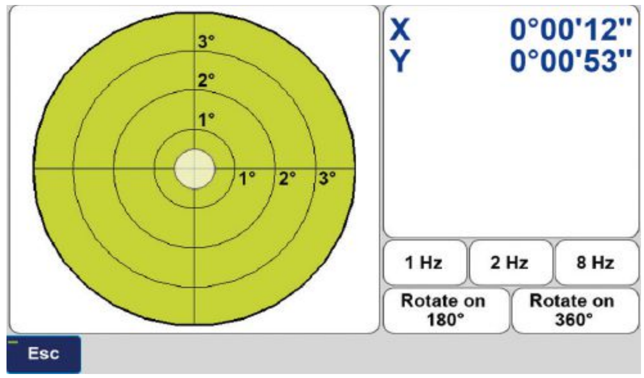
J-Mate can also optically search and find the "Zebra Cylinder" Target. It will target the center of the Zebra Target (Half the specified height from the top). If you don't check the "Measure to bottom" box, you can make the Zebra Cylinder of any height and J-Mate will aim half of the specified "Target Height" from the top of the cylinder. The Zebra Cylinder is omnidirectional and you can hold it in any direction towards the J-Mate.

Calibrating the J-Mate laser and camera offset.

1. Select an area where range changes between 2 to 10 meters when J-Mate rotates.

2. Hold **"15"**, select "Advanced" → "Calibration" → "User Calibration" and click "Start". It will take about 10 minutes to finish calibration. This will be adjust the laser cross hair identification to where it should be.

Viewing the 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.

The embedded inclinometer monitors and corrects for tilts automatically.

Saving and recalling orientation of J-Mate

Click **"17"** to save the current orientation of the J-Mate to a scratch pad.

Click **"16"** and select the scratch pad orientation that you want to orient to.

Laser time limit

The time that it takes for a laser measurement depends on the reflective surface of the target and weather conditions (dust and moisture in the air).

On a good white reflective surface and in clean air, it takes about 50 milliseconds to have a laser reading. If there is no reflective surface, or the reflective surface is black, it may take up to 4 seconds to have a laser reading.

If the surface of the object that you want to scan is a good reflective surface, limit the laser time to a fraction of a second. This will cause the laser to skip points that do not reflect enough energy in the time limit that you specified. This will significantly increase the scan speed and will ignore points that are not possibly your target and reduces the chance of identifying a wrong object.

Hold "LASER" (**"5"**) to set the laser time limit.

Option to Help J-Mate to find you

At Occupation point, click the J-Target icon (**“21”** of the Figure 1). You will be guided through the following steps for J-Mate to aim at you holding the TRIUMPH-LS with the J-Target, when going to the Backsight, for example.

1. At Occupation point, 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.

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.

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 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 searched and centered automatically.

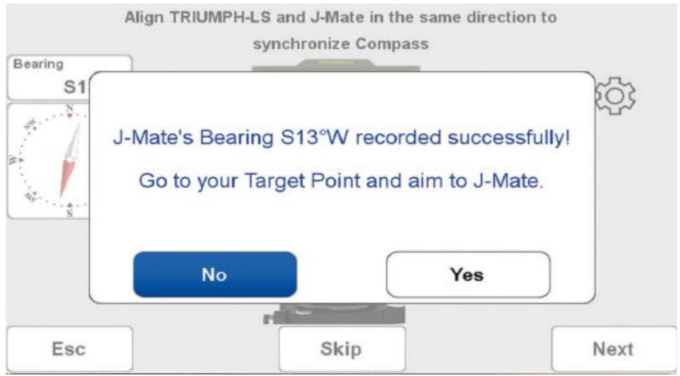
When J-Mate focuses on the center of the J-Target, you can click the “Take” button. You will be asked if you want to record the point.

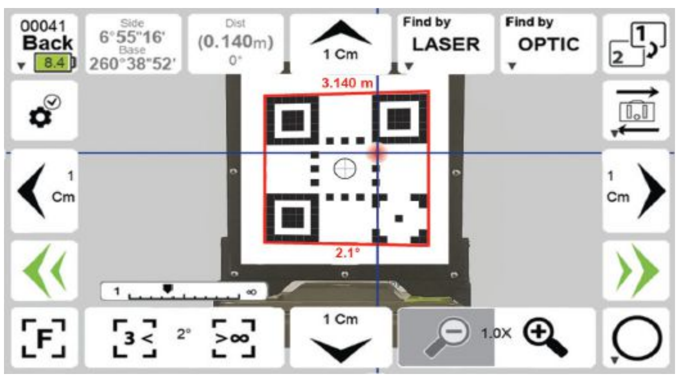
5. If you also want to find the center of the J-Target by Laser scanning, you can click the “Laser”. If Laser scan is successful, you can click the “Take” button to replace the previous measurement with the current measurement done by laser scanning.

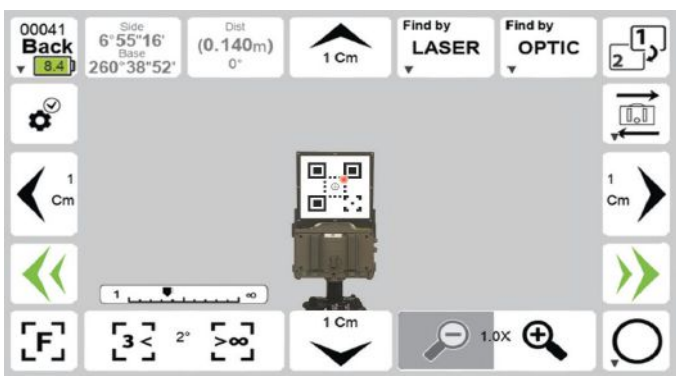
The center of the J-Target is vertically collocated with the GNSS antenna and you don’t need to be exactly perpendicular to the J-Mate path.

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

Even after the J-Target is found optically, you can continue the laser search with “On J-Mate” option to measure the J-Target and find its center more accurately by laser.



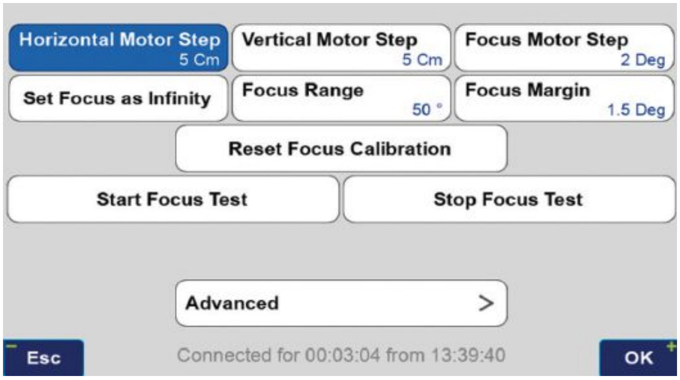




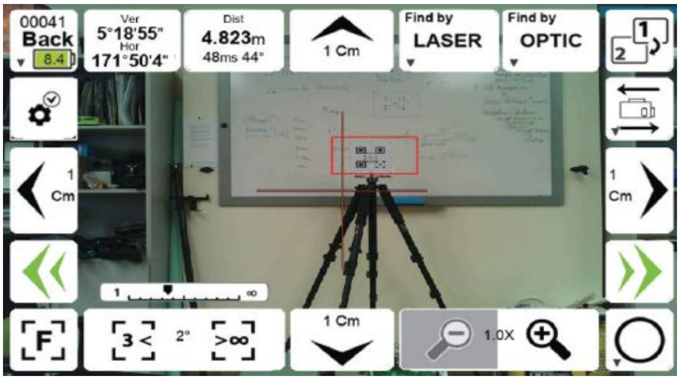
There are five ways that you can manually aim the J-Mate towards your targets:

1. Each click of the Left/Right/Up/Down buttons around the screen (**"4"** and **"14"**) moves the J-Mate according to the value that you assign to them in the setup screen (**"15"**), as shown in Figure below (Horizontal and Vertical Motor Step).
2. While holding these buttons **"4"** and **"14"**, J-Mate rotates about 5 degrees per second.
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 (moving finger on the screen).
5. You can also rotate the J-Mate manually while it is not moving by motors, but limit that to 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.

Setup screen



The two cameras



The viewing angle of the TRIUMPH-LS camera is 60 degrees wide, while that of the J-Mate is about 5 degrees. The viewing area of the J-Mate camera is represented on the TRIUMPH-LS camera by a small red rectangle. While TRIUMPH-LS is sitting on top of the J-Mate, you can view your target on the TRIUMPH-LS camera (Click Button **"8"** of Fig. 1), bring it to the rectangle by touching the target or using the navigation buttons, and then switch to the J-Mate camera.

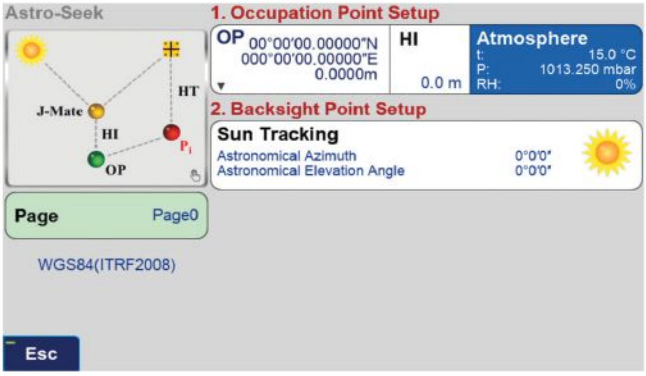
To calibrate the camera of J-Mate with the camera of the TRIUMPH-LS, while TRIUMPH-LS sitting on top of the J-Mate:

1. Click **"3"** and clear existing Horizontal and Vertical calibration offsets (if non-zero).
2. Aim J-Mate **laser** to the target.
3. Click **"2"** to set the first position of the offset angle.
4. Click **"8"** to switch to the TRIUMPH-LS camera and note the small rectangle that represents the J-Mate camera viewing area.
5. Aim the J-Mate to bring that target to the center of the rectangle.
6. Click **"2"** to finish measuring the offset angles between the laser center and the rectangle.
7. Save them to a location on the scratch pads.
8. Click **"3"** to recall the measured offsets from the scratch pad that you saved in.

Backsight point and the Sun

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

With J-Mate you can do these in three different ways as shown in the J-Mate screen of the TRIUMPH-LS. Via the J-Mate-Backsight; J-Mate-Resect and J-Mate-Astro-Seek icons.



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

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

The tripod is setup at the “Occupation Point” (OP). The J-Mate is secured on top of the tripod.

Next, TRIUMPH-LS is put on top of the J-Mate with its legs registered to the matching features on the J-Mate.

Next Use the RTK Survey feature of the TRIUMPH-LS to quickly determine the accurate location of the Occupation Point. You can use your own base station or any public RTN.

Next, slide the J-Target on top of the TRIUMPH-LS, lift it from the J-Mate and move to the “Backsight Point” (BP). The camera of the J-Mate will search the J-Target. The camera’s view is visible from the TRIUMPH-LS screen, which mostly focuses on this J-Target. When at the Backsight Point, its accurate position is determined by the TRIUMPH-LS, and the Azimuth from the Operation Point to the Backsight Point is determined, and the J-Mate is calibrated and ready for use.

After this calibration is complete, if the tripod is disturbed, the red LED on the front of the J-Mate will blink to show that re-calibration is required.

We can now replace the TRIUMPH-LS on top of the J-Mate at the Occupation Point and proceed to shooting as many “Target Points” as the job requires. From now on TRIUMPH-LS is used as a controller and you can hold in your hand too, but it is more convenient to put it on its place to have free hands.

If GNSS signals are not available at the Occupation Point, click the “J-Mate-Resect” icon to shoot two known points to establish its accurate position and calibrate its encoders. Then continue to shoot the unknown points.

Astro-Seek feature: Sun as the Backsight point!

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

Attach the Sun filter to the camera of the J-Mate, click the “J-Mate-Astro-Seek” icon and click the “Sun” icon in the screen which appears and J-Mate will automatically find the Sun, and use its position to calibrate the angular encoders automatically.

SURVEY

Tersus Launches Dual-Antenna Receiver with Heading

Tersus GNSS Inc. has launched the David Plus, a dual-antenna GNSS receiver that offers centimeter-accurate positioning and heading. It is designed for intelligent transportation, construction, machine control, precision agriculture and navigation applications.

David Plus is designed for efficient and rapid integration. The compact, lightweight receiver tracks GPS, GLONASS and BeiDou signals: GPS L1/L2, GLONASS L1/L2, BeiDou B1/B2 from the primary antenna, and GPS L1/GLONASS L1 or GPS L1/BeiDou B1 from the secondary antenna.

The modular and flexible design can provide robust positioning and heading accuracy in a compact footprint for UAVs and other smaller autonomous projects.

Photo: Tersus GNSS

The David Plus GNSS receiver is built for outdoor environments with IP67-rated enclosure. Its compact palm-sized design makes it easy to integrate with various application systems.

Four gigabytes of in-built memory are available to record data for post-processing.

The David Plus GNSS receiver supports RTK positioning mode or RTK positioning + heading mode. It supports 384 channels. It's easy to connect an external powerful radio for long range communication.

Rugged Tablet Captures Detailed Images

DT Research's new DT301X-TR rugged tablet includes an Intel RealSense 3D camera. The lightweight military-grade tablet is built to enhance precision for bridge and construction inspections, 3D surveying and mapping of underground utilities.

It provides multi-frequency GNSS real-time kinematic (RTK) with carrier phase for mapping and positioning, and supports GPS, GLONASS, BeiDou, Galileo and QZSS. An optional foldable antenna supports high-accuracy field work, which can be measured with RTK GNSS positioning directly, or used to connect to an external antenna for higher precision.

The optional RealSense Depth camera provides real-time 3D imaging to quickly and accurately create measurements for CAD, engineering, design, utility and project management, and crime/crash scene forensics. Scientific-grade data, important for evidence as well as building plans, is now easier to access and use for specialists and non-credentialed workers alike.


Photo: DT Research

NEWSBRIEFS

CHC NAVIGATION OPENS NA HEADQUARTERS IN ARIZONA

Shanghai-based GNSS technology and solutions company Shanghai Huace Navigation Technology Ltd. — also known as CHC Navigation — has opened a North American subsidiary, CHC Navigation USA Corporation, in Scottsdale, Arizona. CHC Navigation has customers in more than 100 countries and has been providing GNSS and RTK products and solutions to the U.S. marketplace since 2009. CHC USA specializes in CORS GNSS base-station infrastructure, deformation monitoring, surveying and mapping.

GENEQ LAUNCHES WEBSITE

Geneq Inc., a manufacturer and provider of GNSS receivers and positioning solutions to GIS professionals and surveyors, has launched its newly designed website. The website features new functionalities, better product viewing options, and improved product support options. The website was completely redesigned to support Geneq's product and service improvement program, the company said. The new website will be regularly updated with news on SXblue products, product support, software updates, events and social media feeds. The company welcomes feedback from clients, distributors and partners.

SITELINK UPGRADES TO 2.0

Topcon Positioning Group offers a new edition of its real-time 3D job-site monitoring and management system, Sitelink 2.0. The update includes a new pay-as-you-go point-based service model, new features to Sitelink Support Desk, and a new Haul Truck application. Remote configuration via the support desk allows Topcon personnel to directly access and configure receiver components on connected machines, while simultaneously retaining an active remote session of the 3D-MC machine-control software.

TRANSPORTATION

Rhode Island Roads Get Driverless Shuttles

Rhode Island officials have launched the Little Roady autonomous vehicle pilot project in Providence. The research project, which aims to evaluate autonomous mobility technology, began service May 15.

The free service is a focus of research to help the Rhode Island Department of Transportation (RIDOT) better understand the opportunities and challenges that come with integrating this new technology into its transportation planning.

Passenger shuttles use a suite of sensors — including some from Middletown-based KVH Industries — and intelligent software to help the vehicle understand its environment and how to safely navigate through it.

The entire fleet has undergone 500 hours of testing both at Quonset Point this winter and in Providence this spring, which included detail mapping so the machines know every inch of their route and how to operate in a variety of traffic and weather conditions.

The Little Roady shuttles are provided by May Mobility Inc., which entered into a public-private partnership with RIDOT in the fall of 2018, following a competitive request-for-proposals process.

The project will provide valuable data for states across the country on transit services that are cleaner and more accessible, according to Gov. Gina Raimondo.

The shuttles run on a continuous 5.3-mile loop on low-speed roads with an average wait time of about 10 minutes.

Photo: Rhode Island Department of Transportation (RIDOT)

The cost of the project, including the research component, is $1.2 million. RIDOT's contract with May Mobility includes options to extend the service for an additional two years.

May Mobility, a Michigan-based startup, is developing self-driving shuttles for college campuses, corporate clients, and central business districts. It launched a private corporate service in Detroit in June 2018 and a public service in Columbus, Ohio, in December 2018. It has also entered into an agreement for public service in Grand Rapids, Michigan.

SecureSync Provides Timing for FAA Radar

Orolia's SecureSync time and synchronization servers have been selected to support enroute radar systems across the U.S.

The selection comes as part of the Federal Aviation Administration's (FAA) move towards a Next Generation Air Transportation System.

NextGen is about halfway through a multi-year investment and implementation plan. The FAA plans to keep rolling out NextGen technologies, procedures and policies through 2025/2030 and beyond.

While NextGen will rely heavily upon GNSS to increase capacity, efficiency and safety in the National Air Space, legacies such as radar will be integrated into the system for maximum robustness to error and disruption, Orolia said.

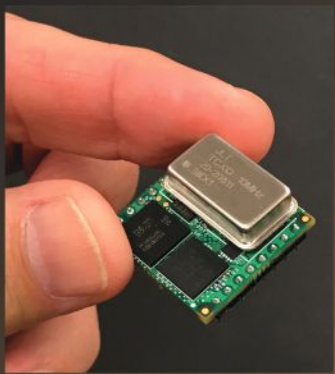
Photo: Orolia

SecureSync provides the timing outputs and signals for the radar systems. The reliable timestamps are used to quickly organize the data for the aircraft control user interface.

SecureSync combines multi-GPS/GNSS signal synchronization, options for alternative signals and BroadShield GPS anti-jamming/spoofing protection for transportation systems. It also includes Orolia's precision master clock technology and secure network-centric approach with a compact modular hardware design.

The Next Generation of Timing & Frequency

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

DEFENSE

NovAtel Anti-Jam Antenna Fits Smaller Spaces

NovAtel has added the GAJT-410ML to its GPS Anti-Jam Technology (GAJT) portfolio. Designed specifically for rapid integration into space-constrained military land applications, the easy-to-use system protects GPS-based navigation and precise timing receivers, including M-code, from both intentional and accidental interference, the company said.

The GAJT-410ML is the next evolution of NovAtel's battle-proven anti-jam technology. It maintains the high levels of interference rejection performance as in the larger GAJT-710ML system, but in a lower size, weight and power (SWaP) design.

Working alongside the GAJT-410ML, the Power Injector Data Converter (PIDC) provides access to the jammer status and direction-finding (DF) information. It also provides clean power and data over the same cable that delivers the protected GPS signal back to the receiver, which reduces the need for costly platform modifications. The PIDC can be supplied in either an enclosure or board and is available to license for installation into third-party equipment.

Image: NovAtel

The GAJT-410ML addresses the needs of smaller land-based platforms and adds situational awareness capability to already high levels of mitigation performance. It offers more choices for system integrators and end users to protect against GPS denied or constrained situations.

Photo: DroneShield

DroneShield Detector Protects Warfighters

DroneShield Ltd. has released a body-worn drone detection product, RfPatrol. Customers are expected in military, law enforcement, security and VIP markets.

Weighing under 1 kilogram, RfPatrol is a passive (non-emitting) product, which substantially broadens the range of customers to whom the product is lawfully available. It was developed in response to customer interest. Already, a small quantity of the units has been ordered for evaluation by a western country's defense department.

In addition to its stand-alone use, it can serve as a companion to the company's DroneGun product.

Microwaves + Lasers Down Drones

Raytheon's high-power microwave and mobile high-energy laser systems engaged and defeated multiple unmanned aerial system targets during a recent U.S. Air Force demonstration. The mature HPM and HEL technologies offer an affordable solution to the growing UAS threat, the company said.

HEL and HPM give frontline operators options for protecting critical infrastructure, convoys and personnel. HEL, paired with Raytheon's Multi-Spectral Targeting System, uses invisible beams of light to defeat hostile UASs. Mounted on a Polaris MRZR all-terrain vehicle, the system identifies, tracks and engages drones.

HPM uses microwave energy to disrupt drone guidance systems. High-power microwave operators can focus the beam to target and instantly defeat drone swarms. With a consistent power supply, an HPM system can provide virtually unlimited protection.

Raytheon's HEL and HPM were the only directed energy systems that participated in the USAF demo. The event expanded on similar earlier demonstrations.

UAV

Where UAVs Go to See and Be Seen

AUVSI Xponential 2019 took place April 30–May 2 in Chicago. This excerpt from the online column by Tony Murfin, contributing editor for professional OEM and UAVs, summarizes show highlights.

BY Tony Murfin

This year's AUVSI Xponential show demonstrated how large, thriving and visionary the UAV market is. On the large-format side:

Bell Helicopter. The Bell Nexus demonstration tilt-rotor — judging solely by the number of smartphone picture takers — was the hit of the show. Nexus is gleaming blue, with six 8-foot tilt-rotors. The booth featured a massive display screen] running a loop of its exploits, along with animations of futuristic flying transport around city-center skyscrapers.

This brings up lots of potential failure modes to be mitigated (six rotors rather than one regular helicopter rotor blade and a complex control system, for instance) for the Federal Aviation Administration (FAA) to chew on during the certification process.

Boeing. A prototype version of a tilt-rotor UAV from Boeing is designed as a heavy cargo lifter. The Cargo Air Vehicle has six tilt-capable dual-rotor systems, weighs 1,100 pounds and is 17.5 x 20 x 5 feet tall. It's interesting how similar the Bell and Boeing (production concept) configurations seem to be.

Ballard. Most multi-rotors on UAVs are driven by electric motors, so battery capacity determines the duration of flying time. Ballard has developed the FCair hydrogen fuel cell, which can extend flight time to up to 90 minutes, almost three times that of lithium-ion battery-powered drones.

Insitu, AeroVironment, Lockheed-Martin, and others have flown the Ballard fuel-cell system; apparently this list also

Photo: Allison Barwacz

THE BELL NEXUS **air-taxi prototype stole the show.**

includes the U.S. Naval Research Laboratory and the Air Force.

Grand Sky. The Grand Sky Aviation Park in North Dakota, co-located with the Grand Forks Air Force Base (AFB), has FAA approval as a UAV beyond-visual-line-of-sight (BVLOS) test range. North Dakota has invested more than $34 million in UAV efforts, with a good chunk going towards the infrastructure at Grand Sky. Now only UAVs fly out of the facility, with Northrop Grumman and General Atomics making it an operational base for Global Hawk, Reaper and Predator drones.

One of the principal benefits is the ability to fly BVLOS operations for large drones. The system uses two long-range primary radars, one at Grand Forks AFB and the other in Hillsboro, that can detect non-cooperative aircraft.

Harris RangeVue radar and Harris ADS-B sensors coupled with the Air Force's DASR-11 radar enable BVLOS testing without using a chase plane or otherwise staying within line-of-sight. This enables 10–12 hour missions within the 30-mile, 18,000-foot BVLOS range, with continuous electronic

Xsens Launches Inertial Sensors

Xsens launched a new series of inertial sensors at Xponential. The MTi 600-series comes in a 31.5 x 28.0 x 13.0 millimeter IP51-rated case. It produces roll and pitch readings accurate to ±0.2 degrees.

GNSS-assisted heading (yaw) measurements are accurate to ±1.0°. Xsens' sensor fusion algorithms optimize output from new accelerometer, gyroscope and magnetometer components. It also has a CAN bus interface.

The MTi 600-series modules are the first from Xsens to include an NMEA-compatible interface for GNSS receivers. Users can choose any GNSS receiver chip, module or system to work alongside the MTi-670, a GNSS/INS device that supplements the pitch, roll and yaw outputs available from other MTi 600-series products with global positioning information.

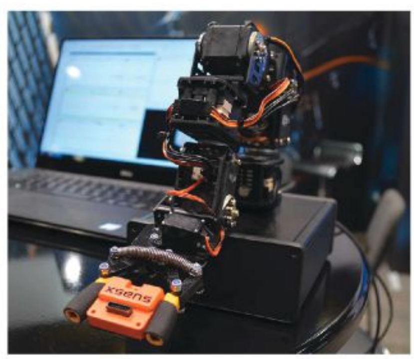


Photo: Allison Barwacz

XSENS' AUVSI BOOTH: **A robotic arm manipulates the MTi 600 while a laptop displays position information.**

UAV

monitoring by the ground-based radar system.

A new operational center is being built to house the integrated system and provide access for visiting drone operators, and the BVLOS range is expected to be ultimately extended all the way to the Canadian border.

Flyability. The Elios 2 UAS system has evolved to include a rotatable thermal and high-definition visual camera payload, 10,000-lumen oblique lighting system, and reversible rotors that enable the UAV to back out of tricky situations. A geodesic-like cage surrounding the drone makes it collision-tolerant and enables flight in restricted indoor areas such as refinery enclosures, mines, vats, cargo holds and nuclear containment vessels — anywhere, in fact, that inspections today are regularly conducted by people.

A typical nuclear plant inspection might cost $500,000, while this drone system costs around $35,000, and an inspection might take around 10 minutes. For traditional inspections, plants might have to go offline completely while people crawl around in extremely difficult, often dangerous spaces, and manual reports might take significant time to produce.

Flyability claims huge savings in inspection time with their system, as well as automated analysis and production of reports.

AeroVironment. SoftBank, Japan and AeroVironment announced their HAPSMobile Joint Venture to address the lack of communications access in many parts of the world. Almost 3.7 billion people, or half the world's population, currently do not have internet access.

SoftBank wants to provide internet inexpensively, without the need for extensive ground infrastructure, by operating high-altitude pseudo-satellite (HAPS) UAVs. HAPS is expected to fly in the stratosphere at a 20-kilometer height for up to six months, powered by solar cells and equipped with payloads

Photo: Flyability

THE ELIOS 2 **is a collision-tolerant drone for indoor inspections.**

that enable direct connection to the internet for users on the ground.

Airborne-type certification and spectrum will be required for the uplink/downlink. Both present significant challenges, but HAPS suppliers, including Airbus, Facebook and others, are joining the fight for spectrum. AeroVironment has a $65 million contract from **HAPSMobile** to develop and produce HAPS UAVs, and build of their Hawk 30 HAPS UAV is well underway.

HAPSMobile has taken a minority $125 million position with Loon, which has been flying stratospheric balloons for several years, providing wireless coverage in Puerto Rico after Hurricane Irma, and network coverage in South America. Other suppliers exploring the HAPS market at the show included Airbus, which displayed its Zephyr UAV and recently announced the opening of the Wyndham HAPS launch site in Western Australia; and UAVOS, which announced a new control system for its HAPS vehicle.

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

Auterion Enables Launch of US-1 Drone for First Responders

Auterion and Impossible Aerospace are collaborating to bring to market the US-1 UAV; its two-hour flight time is important for public-safety incident response.

Auterion is the provider of Auterion Enterprise PX4, an open-source-based enterprise operating system for drones. Auterion builds the open-source infrastructure so that drone manufacturers can go to market faster with new products flying its software, PX4.

Impossible Aerospace is a Silicon Valley drone manufacturer. The US-1 quadcopter made its public-safety debut in February with a California-based police force. The drone gives police agencies a new category of assets that sit between lower-end drones and police helicopters. This enables a wider usage of aerial imagery while reducing the cost for first responders.

Photo: Impossible Aerospace

THE US-1'S **two-hour flight time gives public-safety professionals time to respond.**

TIME

SEE WHAT RESILIENCY BRINGS

WITH THE SMARTPHONE REVOLUTION, we are increasingly reliant on today's global technology networks. The importance of protecting data centers and mobile devices with resilient PNT can't be overstated. But what is the best way to accomplish this?

BY ROHIT BRAGGS, *OROLIA*

Connected devices and cloud applications are the primary technology sources for most people today, and an exponentially growing number of those devices are connected to data centers in some way. Across the world, you can drive past countless acres of data centers that are storing, updating and retrieving the world's data.

GNSS signals localize and timestamp the data collected from connected devices scattered across the world in diverse time zones and locations. They also provide the critical time synchronization that supports high-efficiency data storage, routing and exchanges across multiple data centers in various locations.

It is essential to protect data centers and their GNSS signal connections from system failure, jamming, spoofing, interference and denial of service. As the reliance on GNSS signals and the number of connected devices grow, so too does the threat of GNSS failure. False or unavailable positioning, navigation and timing (PNT) information at any point within this network can compromise security and completely disrupt user service.

This article explores the role of data centers and how their constant connection to devices enables almost every digital technology that we use today. It identifies key reasons why we should protect this interconnected data system from GNSS signal interference and disruption, in addition to providing information on how to ensure continuous signal monitoring and protection with a practical, cost-effective approach.

Global Technology Networks

Data centers and connected devices affect nearly every aspect of our digital lives, from cloud software and applications to mobile phones and laptops. They store our personal documents, photo libraries and other priceless personal data. They also keep track of business documents, software licenses and other essential business information. In critical infrastructure, they support the daily operations of society's most important services such as public utilities, banking and financial transactions, telecom, security, medical and defense systems, among others.

Data centers use timestamps as a key mechanism to store, organize and retrieve data. In addition to categorizing data by authorized users and other relevant identification information, the timestamp enables data centers to monitor revisions and retrieve the most recent version of the data.

A good example of timestamped data use is in cloud-based applications, accessed simultaneously by hundreds of thousands of users. In such environments, data is dynamic and changing frequently, which can lead to data conflicts. With accurate, reliable timestamps, a cloud-based application can resolve such conflicts to determine the order in which the data was received.

Why do we need to protect data centers and connected devices from GNSS signal interference?

GNSS signals are the quiet facilitators of many of our day-to-day tasks. In discussing why it is important to protect these signals, it is often easier to imagine what would happen without the accurate, reliable PNT information that these signals provide.

We need to understand two key pieces of information to operate systems: location and time. We need to know exactly where data or assets are located, and we need reliable, consistent time references to synchronize the movement of data and assets for system operations.

There are many documented examples of GNSS signal jamming, spoofing and denial of service attacks worldwide, and these are easy to find with a simple internet search. Here are a few examples of what can happen when the signal is compromised at a mobile or fixed location, but not taken offline. The user might still see that the signal is working, with no indication that the two critical pieces of information, location and time, are being disrupted:

- Imagine that the timestamp on a security camera system was spoofed to show a different time than the actual time. Incorrect or missing timestamps on video from surveillance systems is the most common reason for video evidence being deemed as inadmissible in a court of law. A bad timestamp corrodes the credibility of the video as irrefutable evidence and makes it easy to dispute.
- Imagine that a bad actor spoofed the time used by financial trading systems. Since these critical systems rely on GNSS-based time and synchronization, an attack on their underlying timing infrastructure could significantly impact the market and cause billions of dollars in damage.
- What if the GPS guidance system on your phone or vehicle gave you wrong directions? You could get lost in a wilderness or encounter dangerous driving conditions by trusting the route shown on your device.
- What if more people started using commercially available jammers? Some truck drivers have already been caught using unauthorized GPS jammers in their vehicles to avoid monitoring by their employers. In many cases, these deevices have affected nearby critical systems such as air traffic control, financial data centers, and other critical operations simply by being driven past with active jammers. The incidence of these disruptions is on the rise.
- Imagine a secure facility using an access control system that is set to automatically lock and unlock doors at a

specific time. If someone spoofed the time used by that system, they could trick the doors into unlocking and gain entry.

We are also seeing an uptick in unintentional or environmental signal interference, which can occur in high-density development areas where various wireless transmitting systems can interfere with GNSS reception.

Which technology solutions are best suited to protect data centers and GNSS signals?

The first step toward protecting a GNSS-reliant system is to test the system for vulnerabilities. GNSS simulators and testing protocols can simulate a spoofing, jamming or denial of service attack to evaluate how the system responds to each situation. Knowing the system's unique challenges and weaknesses can help resilient PNT experts design the best solution for that system.

One of the most common configurations for a fixed site location includes a highly reliable network time server to ensure that accurate timestamps are applied to each data point. A time server that can identify erroneous or spoofed GNSS signals is recommended for any critical application. In addition, a time series database could be installed to categorize and organize the timestamped data, while identifying any irregularities in the data.

Once you have reliable timestamps and time server management systems, you also need to continuously monitor the signal to detect interference and raise an alarm. A GNSS signal monitoring system can let you know the minute your system is under attack. A GNSS threat classification system can identify the type of threat and mitigate it, depending on the nature of the threat, by filtering the signal to neutralize the interference.

The best way to prevent GNSS jamming is to deny interfering signals access to the receiver in the first place. Smart antenna technology focuses antenna beams to track the good signals from the satellites and reject the bad signals from interferers. Less sophisticated solutions such as blocking antennas can be employed to reject terrestrial-based interference, which is where most GNSS interference sources exist, and they provide a good first-level protection.

Continuous PNT access can also be achieved by using an alternative signal that operates separately from GPS/GNSS and is less vulnerable to the signal attacks that plague GNSS signals.

Emerging PNT Technologies

Over the next few years, new applications of mobile PNT

Is Internet Time Good Enough?

BY Jeremy Onyan
DIRECTOR, TIME SENSITIVE NETWORKS, OROLIA

CYBERSECURITY IS CRITICAL to all facets of the internet. Companies spend millions on cybersecurity every year. Still, often-overlooked areas degrade security. A key example of this is time.

Time plays an essential role in synchronizing core business and network systems. It supports authentication protocols as well as accurate log files critical for an audit trail — necessary for any cyber forensics program. As such, synchronization is often a requirement for network security standards.

A deployment of network time protocol (NTP) sychronizes a local system to a time server. The time source can come from within the network or outside of it.

NTP Over the Internet. NTP time servers are widely available on the internet. National authorities operate internet time servers based on extremely accurate atomic clocks, such as the National Institute of Standards and Technology (NIST) or the U.S. Naval Observatory.

But even with these sources, many factors impact traceability. According to ntp.org, "If business, organization or human life depends on having correct time or can be harmed by it being wrong, you shouldn't 'just get it off the internet'."

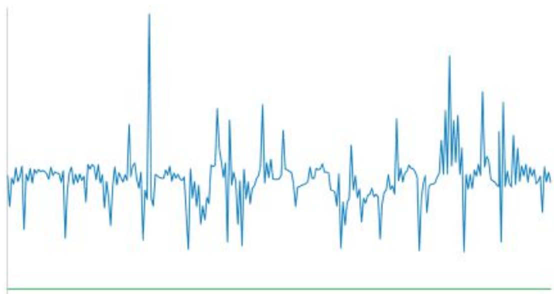


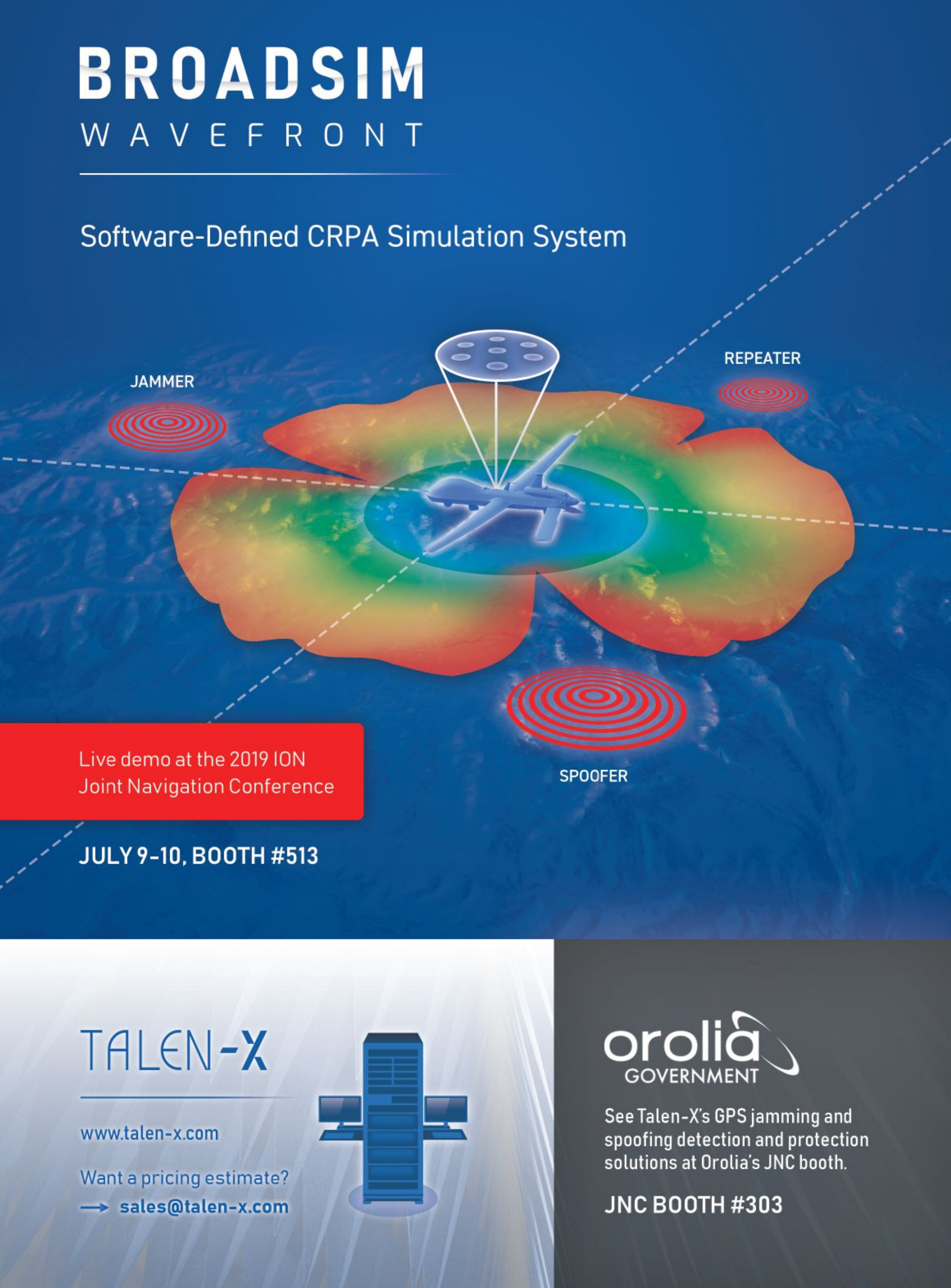
Chart: Orolia

FIGURE 1. The comparison between two GPS time servers on the same LAN using NTP results in 15–20 microseconds offset.

One problem with time synchronization is the variability of network conditions. Network load, variable path delays and firewall settings can impact time quality on the local system. To illustrate this effect, we can use the time-quality monitoring feature of a time server with a built-in GPS receiver as its reference that is accurate to tens of nanoseconds. NTP can be used to compare it to another GPS time server on a local area network. The offset is around 15-20 microseconds (FIGURE 1).

We connected the SecureSync time server to some of the most popular internet time servers. The variation result, shown in FIGURE 2, is as high as tens of milliseconds — 1,000 times worse

SEE INTERNET, PAGE 38. >>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See Talen-X's GPS jamming and spoofing detection and protection solutions at Orolia's JNC booth.
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data will further emphasize the need to maintain system integrity against threats. Here are a few examples of emerging technologies.

5G is here for mobile Internet and telecom service, yet with the specific need for microsecond-level synchronization, the challenge to protect the fidelity of the time used in these systems will become more important.

With rising awareness of the need to protect GNSS signals against threats, individuals will need to determine how they can protect their own GNSS-reliant systems as they navigate the Internet of Things and GIS enabled e-commerce. **Personal PNT protection** is an emerging technology area that could help protect people and their mobile devices on an individual basis, to ensure GNSS is there when it matters. Whether you are embarking on a remote hiking or sea expedition, sharing your coordinates with an emergency dispatcher after an accident, or simply trekking your way through a new city late at night, having resilient GNSS signal support is becoming a necessity.

Alternative signals are now available, and these new signal options, such as STL (Satellite Time and Location), could play an important role in providing better privacy and security functionality. This signal diversity will help protect against threats and interference by adding resilience to the device's ability to receive reliable PNT data.

Another exciting technology development is the concept of **smart cities**, where technology has the opportunity to increase efficiency, reduce waste and provide many conveniences for the public. As we automate more city systems, it is essential to protect these systems from both accidental and malicious GNSS-based interference to ensure that these systems can make decisions based on reliable, precise PNT data.

Intelligent Transportation Systems (ITS) have the capacity to transform how people and freight travel today, saving lives and bringing goods to market more efficiently than ever. The need to know exactly where a driverless vehicle is in relation to other vehicles at any moment in time is just one of the resilient PNT technology requirements that will rely on GNSS signals.

Finally, **authenticated time and location information** can help increase cybersecurity for many applications, by limiting data access to a very specific window of time and only in a precise location. This is an area of cybersecurity which has the potential to add new layers of authentication to protect users and their data. With connected devices at

See RESILIENT PNT, *page 42.* >>

INTERNET

<< *Continud from page 36.*

than NTP across a local area network. If we assume all the time servers are accurate, then the difference is solely due to greater path delay and other dynamic conditions. This variation is enough to question the traceability of time from the internet.

The Internet Obscures Time Traceability. Perhaps more important for a security-critical network is the validity of the source used by the time server that distributes time to your network. Time from GPS/GNSS signals is recognized as the most accurate, available and traceable time source. GPS/GNSS-based time servers are easy and simple appliances to add to the local network. Even when different GPS/GNSS time servers are deployed in different locations, they will provide the same time regardless of geography. What's more, GPS/GNSS as a local time source can be monitored, so its logs can become part of the audit trail.

Of the seven internet time servers monitored over a 24-hour period, 20 different time sources were identified. Less than half of the sources could be identified as coming directly from GPS/GNSS. In one case, GPS/GNSS time was distributed through three different time servers.

The best practice of using NTP server pools is one reason why there are more sources than time servers. Server pools rotate among various internet time servers, each with their own source of time, to reduce the chance of one bad or unavailable time server catastrophically affecting the synchronization. But this is a problem for traceability. The source of time is not known, nor can it even be determined.

Indeterminate source identification, indeterminate accuracy variation and the inability to log the resulting time synchronization calls into question the efficacy of getting time from the internet. Internet time servers are also subject to being spoofed (bad NTP data sent from a faked IP address) and to direct attacks, including NTP poisoning, replay and denial of service.

When there is a business-critical need to trace time to an accurate source, a GPS/GNSS-based time server should be deployed on the local network.

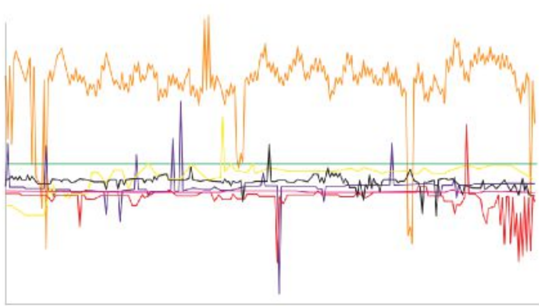

Chart: Orolia

FIGURE 2. The comparison of internet time servers as measured by NTP on a local GPS time server. The scale is 1,000 times greater than in Figure 1.

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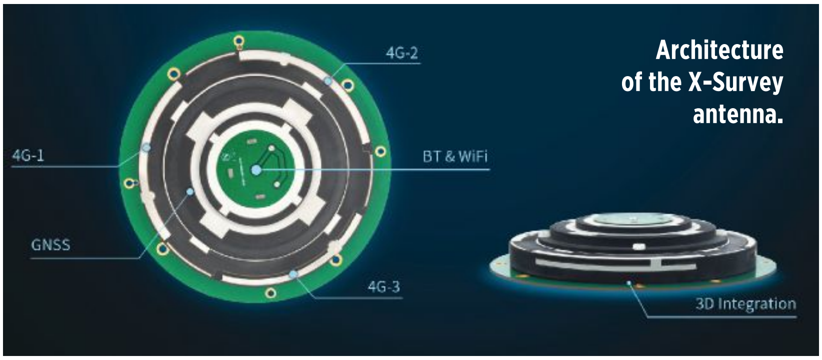
Fighting for GNSS Resilience

BLOCKING INTERFERENCE

Interference can be blocked at the data-collection stage, using an advaned antenna.

Harxon's X-Survey is a compact high-precision GNSS antenna. It provides superior navigation and communication performance in surveying applications. A frontal band-pass filter setting effectively rejects out-of-band signals before they enter the low-noise amplifier of the antenna for signal augmentation.

Meanwhile, the filter itself has insertion loss, making a low insertion loss filter a prerequisite for optimal system noise reduction. To avoid this situation, X-Survey employs ceramic filter with low signal loss and in-band flatness to significantly improve system anti-interference capability and ensure reliable signal receiving.



Architecture of the X-Survey antenna.

Image: Harxon

RESILIENT RECEIVERS

Septentrio began to tackle the interference problem more than 20 years go, designing and manufacturing high-precision GNSS receiver technology with emphasis on reliability and robustness. The result is Advanced Interference Monitoring and Mitigation (AIM+) technology which secures the company's GNSS receivers against jamming and spoofing interference. AIM+ has recently been upgraded with an extended anti-spoofing functionality.

Building on its existing spoofing detection, Septentrio has developed a new anti-spoofing algorithm for its commercial receivers. The algorithm leverages Galileo Open Service Navigation Message Authentication (OSNMA) for spoofing resistance. It was developed in the framework of the GSA FANTASTIC project with the goal of improving the security of timing in critical infrastructure.

Mobile devices and cloud applications increasingly rely on GNSS technology used by telecom companies. Having secure and robust GNSS receivers in telecom infrastructure is key to reliable mobile and positioning services.

ALTERNATIVE SIGNALS

A new reference receiver, **Jackson Labs'** PNT-5500, includes a custom Satelles/Iridium (STL) and GPS receiver, and an optional Edge Grandmaster/PTP1588 capability.

Using STL signals received directly through a small antenna mounted on the device, the PNT-5500 provides nanosecond timing synchronization in GPS-challenged environments, including deep indoors (no rooftop antenna required). It provides secure timing during GPS jamming and spoofing events. The unit is designed for high-volume, low-cost telecom small-cell synchronization, and is optionally available with holdover oscillators such as DOCXO and CSAC atomic clocks.

While GPS is vulnerable to jamming and spoofing, the PNT-5500 uses the Iridium infrastructure to provide

Image: Septentrio

THE MOSAIC module provides AIM+ mitigation technology.


Image: Jackson Labs Technology

PROTOTYPE design of the PNT-5500.

RESILIENT PNT

« CONTINUD FROM PAGE 36.

the forefront of our access to the world, secure and reliable PNT technologies are more critical than ever.

These are just a few examples among many of the new technology innovations that are in the works to provide us with new benefits in leaps and bounds.

Protecting Our Virtual Brain

Data centers are the technology hubs of today, and their constant connection to devices fuels our ability to access critical information instantly. This networked system serves as a virtual brain that holds our personal memories, charts our progress, enables us to share results and helps us deliver new technology advancements faster than we could ever do before.

As we prepare to embrace our new technology, we should first address the PNT technology challenges of today and ensure that our GNSS signals are resilient and reliable. With this strong foundation in place, we can better protect our current systems and keep pace with evolving threats that would otherwise jeopardize the functionality, safety and security of these new capabilities.

Rohit Braggs is the chief operating officer at Orolia *(www.orolia.com)*. Based in Rochester, New York, he is responsible for the development and execution of the company's global business strategy and corporate initiatives. He also serves on the board of directors for Satelles Inc., which provides time and location solutions over the Iridium constellation of low-Earth-orbiting satellites.

FIGHTING

« CONTINUD FROM PAGE 40.

assured timing that is impervious to spoofing and provides 1,000X higher signal strength compared to GPS, producing jamming resilience and deep-indoor reception. The system is designed to be fully interoperable with legacy equipment, for a low-cost, fully-deployed Assured PNT capability alternative to GNSS today.

ASSESSING VULNERABILITY

Qascom offers several robust PNT services and products, including vulnerability assessment, robust navigation and interference localization.

Vulnerability assessment is the key proactive measure, using cutting-edge signal generators to design and test tomorrow's receivers. For example, Qascom's QA707 GNSS simulator tests receivers against emerging jamming and spoofing threats, allowing OEMs to discover in advance any potential vulnerability that may affect the availability and the integrity of the signal.

Robust navigation is supported by advanced mitigation algorithms, equipped with pre and post-correlation algorithms, as well as the

Image: Qascom

inclusion of sensor fusion and dead-reckoning features.

Qascom's attack detection products include external monitoring networks that support GNSS receivers. These networks provide an accurate perception of the operational environment, allowing threat characterization, classification and forecast. For instance, Qascom's QB100 enables the simultaneous threat detection and localization by means of a monitoring cluster that delivers 24/7 situational awareness to a set of target receivers within the protection area.

RELIABLE TIMING

Meinberg provides GNSS timing solutions for nearly every application type. Its reliable systems are based on firmware built from the ground up by an in-house team of expert engineers. All Meinberg firmware is constantly checked and updated to ensure it adapts to evolving industry standards.

The company's synchronization systems use a built-in Meinberg GPS receiver or combined GPS/GLONASS clock. They also support a broad range of reference time sources, including 1 PPS, 10 MHz, inter-range instrumentation group time codes (both direct current level shift and amplitude modulated), or network time protocol (NTP) servers. This redundancy in synchronization sources means Meinberg's systems are protected against a loss of signal. Furthermore, to ensure the correctness of the reference time and date, an intuitive Secure Hybrid System (SHS) feature includes an independent secondary clock for enhanced plausibility checks.

For superior holdover performance, the Meinberg XHERB (with one or two Rubidium modules from Stanford Research) can be added to the Meinberg Intelligent Modular Synchronization (IMS) time and frequency systems. If the reference clock loses its sync source, the XHE chassis will provide the sync reference for the IMS chassis based on its holdover performance.

2019 BUYERS GUIDE

GPS WORLD — GNSS POSITION NAVIGATION TIMING

WELCOME TO THE 2019 GNSS BUYERS GUIDE. The only industry resource for GNSS manufacturers and service providers lists **265** companies and their offerings in more than a hundred categories. The Company Directory begins on page **44**; the Products and Services Directory starts on page **65**. To see the online Buyers Guide, and to create your free listing in the 2020 print edition of the *GPS World* Buyers Guide, go to gpsworldbuyersguide.com.

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#

4P Mobile Data Processing
Via Germania 15
Padova, PD 35127 Italy
390-498-069811
info@4p-online.com
www.4p-online.com

A

Accubeat
5 HaMarpeh St.
Jerusalem, 91450 Israel
972-2-586-8330
marketing@accubeat.com
www.AccuBeat.com

Advanced Navigation
Level 8
120 Sussex St.
Sydney, NSW 2000 Australia
61-2-9099-3800
info@advancednavigation.com.au
www.advancednavigation.com.au

AeroAntenna Technology Inc.
20732 Lassen St.
Chatsworth, CA 91311
818-993-3842
tami@aeroantenna.com
www.aeroantenna.com

Airobot
Kempische Steenweg 311/1.02
Hasselt, 3500 Belgium
003-249-8216285
contact@airobot.eu
www.airobot.eu

Allis Communications Co., Ltd.
10F-3, No. 31-1, Lane 169, Kangning St., Xizhi Dist.
New Taipei City, 22180 Taiwan
886-2-26952378
ellen.teng@alliswireless.com
sales@alliswireless.com
www.alliswireless.com

ALLSAT GmbH
Am Hohen Ufer 3A
Hannover, 30159 Germany
49-511-303-990
info@allsat.de
www.allsat.de

Allystar Technology (Shenzhen) Co., Ltd.
5F, Building No.4, Winlead Intelligent Park, No.3, FaDa road (middle), Bantian Subdistrict
LongGang District, Shenzhen City, Guangdong Province, China.
Shenzhen, 518129 China
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sales@antenova.com
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Applanix
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905-709-4600
astott@applanix.com
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800-112-7267
info@axio-net.eu
www.axio-net.eu

Azimap
Union House
Union St.
Co.Tyrone, BT80 8NP United Kingdom
44-028-8676-0990
nicola.hyndman@cianad.com
www.azimap.com

B

Back2You
Unit 58
The Evron Ctr.
Filey, North Yorkshire YO14 9DW United Kingdom
017-235-18053, 017-235-18053
boyescfio@gmail.com
www.back2you.com

BAE Systems Rokar
11 Alef Shin Hartom
Mount Hotzvim
Jerusalem, 9777511 Israel
972-2-532-9888
marketing@baesystems.co.il
www.baesystems.com

Baseband Technologies Inc.
3553 31 St. NW
Suite 114
Calgary, Alberta T2L 2K7 Canada
403-668-0699
info@basebandtech.com
www.basebandtech.com

Beijer Electronics
2212 South West Temple
Suite 50
Salt Lake City, UT 84115
801-466-8770
info@beijerelectronicsinc.com
www.beijerelectronicsinc.com

Beijng UniStrong Science & Technology
2nd Floor, Unit 12
159 Tianzhou Rd.
Xuhui District, Shanghai 200233 China
86-213-338-3000
overseas@unistrong.com
www.unistrong.com

Best-Fit Computing Inc.
17490 NW Woodmere Ct.
Beaverton, OR 97006
503-531-8819
info@bestfit.com
www.bestfit.com

Blue Sky Network
1298 Prospect St.
Suite 1D
La Jolla, CA 92037
858-551-3894
sales@blueskynetwork.com
www.blueskynetwork.com

Borealis Precision
Suite 205, 185-911 Yates St
Victoria, V8V 4Y9 Canada
778-430-5999, 1-855-OEM-GNSS (636-4677)
sales@gnss.ca
http://www.gnss.ca

Brandywine Communications
1153 Warner Ave.
Tustin, CA 92780
714-755-1050
info@brandywinecomm.com
www.brandywinecomm.com

Braxton Technologies
6 North Tejon St.
Suite 220
Colorado Springs, CO 80903
719-380-8488
www.braxtontech.com

Broadcom Corporation
5300 California Ave.
Irvine, CA 92617
949-926-5000
www.broadcom.com

C

Carlson
102 West Second St.
Maysville, KY 41056
800-989-5028, 606-564-5028
info@carlsonsw.com
www.carlsonsw.com

Cases Plus Inc.
700 Business Park Dr.
Lincoln, CA 95648
916-209-4040, 800-982-1880
jca@casesplus.com
www.casesplus.com

CAST Navigation LLC
One Highwood Dr.
Suite 100
Tewksbury, MA 01876
978-858-0130
sales@castnav.com
www.castnav.com
See our ad on pages 5 and 45

CellGuide Ltd.
Ha'Ogen Bldg. B, 3rd Floor
New Industrial Zone
Netanya, 4250410 Israel
972-9-864-9649
info@cell-guide.com
www.cell-guide.com

CHC Navigation
599 Gaojing Rd.
Building C
Shanghai, 201702 China
86-21-5426-0273
sales@chcnav.com
www.chcnav.com
See our ad on pages 47 and 93

Chemring Technology Solutions
Old Salisbury Ln.
Romsey, Hampshire SO51 0ZN United Kingdom
44-179-483-3000
info@chemringts.com
www.roke.co.uk

CAST Navigation, LLC

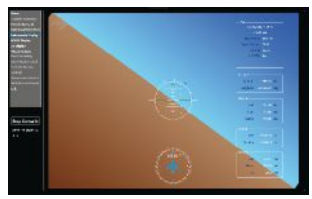
Corporate Description

CAST Navigation, LLC leads the way with over 38 years of GNSS experience, customer loyalty and product reliability. CAST simulators are powerful intuitive engineering tools designed to support navigation system research, development, systems integration and test. We employ FPGA technology that allows for rapid expansion of capabilities and unlimited growth. Our newest systems are cost effective and extremely reliable. CAST Navigation's only business is building simulators. We pride ourselves on being the best.

Available GPS Satellites

Product Research and Innovation

The **CAST-5000** Wavefront Generator is a high precision simulator. It produces a coherent wavefront of GPS RF signals to provide repeatable testing in the laboratory environment. With an intercard carrier-phase error of less than one millimeter, the CAST-5000 is extremely accurate. CAST's Coherent (in-phase) Jammer was designed to support the CAST-5000 for testing multi-element CRPAs (Controlled Reception Pattern Antenna) and is controlled during canned scenarios via the Graphic User Interface (GUI). The Jamming signals for each antenna element are coherent with each other, presenting a real life signal to the CRPA antenna. The powerful **CAST-3000** Integration System produces GPS RF signals coincident with a simulated IMU sensor. This provides the integration and dynamic testing of GPS/INS navigation systems where the Inertial Sensor and GPS receiver are either tightly or ultra-tightly coupled. Designed to provide maximum flexibility, this integration system boasts interoperability capabilities and can meet the most challenging military and government requirements.



Vehicle Instruments Display

Client Base

CAST has become a world leader in the design, development, manufacturing, and integration of globally innovative GNSS/INS Simulators and associated equipment for a broad list of customers including the military, prime US, foreign vendors and commercial users. Some of the platforms supported include: F-35 Lighting II, F-22 Raptor, B-2 Spirit, E-2 Hawkeye, E-3 Sentry, F-15 Eagle, F/A-18 Super Hornet, AH-64A/D Apache, UH-60 Blackhawk, and JDAM smart weapons.

CAST Commitment

The CAST Navigation team remains committed to maintaining the highest technical and ethical performance standards and dedication to excellence in all of our operational aspects. Our aspirations to exceed our customers' expectations are unsurpassed.

CAST NAVIGATION

CAST Navigation, LLC
One Highwood Drive,
Suite 100,
Tewksbury, MA 01876

Phone:
978-858-0130

Fax:
978-858-0170

Email:
sales@castnav.com

Web:
www.castnav.com

Chronos Technology Ltd.
Stowfield House
Upper Stowfield
Lydbrook, Gloucestershire GL17 9PD United Kingdom
44-159-486-2200
marketing@chronos.co.uk
www.chronos.co.uk

Clark Labs
950 Main St.
Worcester, MA 01610
508-793-7526
clarklabs@clarku.edu
www.clarklabs.org

C-Nav
730 E. Kaliste Saloom Rd.
Lafayette, LA 70508
337-210-0000
sales@cnav.com
www.cnav.com

Cobham AvComm (formerly Aeroflex)
10200 West York St.
Wichita, KS 67215
316-522-4981
AvComm.TechSales@cobham.com
www.cobham.com/avcomm

Communication & Navigation (C&N)
Durisolstrasse 7
Wels, A-4600 Austria
43-72-486-6233
gpsc-natoffice@traunau.at
www.c-n.at

ComNav
13511 Crestwood Pl #15
Richmond, British Columbia V6V2G1 Canada
604-207-1600
sales@comnav.com
www.comnav.com

ComNav Technology
No.618 Chengliu Middle Rd.
Building 2
Shanghai, 201801 China
86-21-6-405-6796
sales@comnavtech.com
www.comnavtech.com
See our ad on page 46

Connor-Winfield
2111 Comprehensive Dr.
Aurora, IL 60505
630-851-4722
sales@conwin.com
www.conwin.com

CSR plc
Churchill House
Cambridge Business Park
Cambridge, Cambridgeshire CB4 0WZ United Kingdom
44-1223-692000
sales@csr.com
www.csr.com

D

DataGrid Inc.
1022 NW 2nd St.
Gainesville, FL 32601
352-371-7608
info@datagrid-international.com
www.datagrid-international.com

deCarta
4 North 2nd St.
Suite 950
San Jose, CA 95113
408-294-8400
info@decarta.com
www.decarta.com

DeLorme
2 DeLorme Dr.
P.O. Box 298
Yarmouth, ME 04096
800-561-5105
sales@delorme.com
www.delorme.com

DigitalGlobe
1601 Dry Creek Dr.
Suite 260
Longmont, CO 80503
303-684-4000, 800-655-7929
info@digitalglobe.com
www.digitalglobe.com

E

Effigis Geo Solutions Inc.
4101 Molson St.
Suite 400
Montreal, Quebec H1Y 3L1 Canada
514-495-0018
OnPOZSales@effigis.com
www.effigis.com

Emcore Corporation
2015 Chestnut Street
Alhambra, CA 91803
626-293-3400
navigation-sales@emcore.com
www.emcore.com/navigation
See our ad on pages 13 and 49

Emlid Ltd.
Hong Kong
+85258088877
info@emlid.com
www.emlid.com

CHC Navigation

CHC Navigation at a glance

Founded in 2003, CHC Navigation (CHCNAV) is a publicly-listed company creating Innovative GNSS Navigation and Positioning Solutions. With a global presence across the world and distributors in over 100 countries and more than 1,300 employees, CHC Navigation is today recognized as one of the fastest-growing companies in Geomatics Technologies.

From GNSS survey to 3D Mobile Mapping

Technology integration for CHC Navigation means going beyond survey instruments and developing geospatial tools that will provide effective decision-making solutions to the geospatial community. CHCNAV and its affiliates are global providers of integrated solutions, from ground to airborne survey, from traditional GNSS RTK survey to mass data collection with 3D mobile mapping solutions such as our recently introduced Alpha3D, machine control and agriculture auto-steering, all within real-time infrastructure from network RTK solutions to advanced bridge monitoring systems.

Enabling Technology to support Geospatial Professionals

CHCNAV is rapidly expanding in geographically thought bespoke business and marketing centers. The proximity to our customer is a key factor to maintain a clear understanding of geospatial customer requirements in an extremely fast changing environment. Fundamental research in technologies is making larger contribution in our plans, including advanced tightly integrated positioning algorithms, IoT, cloud-based solutions and simplification of data acquisition workflow processes with carefully designed man-to-machine interface.

Technology should remain affordable

From its foundation in 2003, CHCNAV has always been aiming at developing technology with high-standards but always keeping in mind two major factors - the initial investment cost and cost-of-ownership for our users. Technology should remain affordable. CHCNAV is a technology enabler for a growing number of geospatial professionals, in many countries.

Make Your Work More Efficient

CHCNAV's slogan perfectly summarizes the way our GNSS Positioning and integrated Navigation Solutions are designed to dramatically improve productivity and provide outstanding return on investment for our customers and business partners.

CHCNAV

Make your work more efficient

CHC Navigation Technology Ltd
599 Gaojing Road, Building D
Shanghai
China

Phone:
+86 21 5426 0273

Fax:
+86 21 64950963

Email:
sales@chcnav.com

Web:
www.chcnav.com

EndRun Technologies
2270 Northpoint Pkwy.
Santa Rosa, CA 95407
707-573-8633
sales@endruntechnologies.com
www.endruntechnologies.com

EndRun Technologies
2270 Northpoint Pkwy.
Santa Rosa, CA 95407
707-573-8633, 877-849-3878
sales@endruntechnologies.com
www.endruntechnologies.com

Eos Positioning Systems
1160 Rue Levis
suite 100
Terrebonne, Quebec J6W 5S6 Canada
450-824-3325
info@eos-gnss.com
www.eos-gnss.com
See our ad on pages 9 and 51

Epson America Inc.
3840 Kilroy Airport Way
Long Beach, CA 90806
800-873-7766
www.epson.com

ESE
142 Sierra St.
El Segundo, CA 90245
310-322-2136
ese@ese-web.com
www.ese-web.com

Esterline CMC Electronics
600 Dr. Frederik Philips Blvd.
Ville Saint-Laurent, Quebec H4M 2S9 Canada
514-748-3034
www.cmcelectronics.ca

Eve Energy
Park Xikeng IND
Zone Huihuan Town,
Huizhou City, Guang Dong, 516006 China
86-1-350-228-0305
kevin.huang@evebattery.com
www.evebattery.com

F

F4 Tech
3059 Highland Oaks Ter.
Tallahassee, FL 32301
850-385-3667
www.thinkf4.com

Falcom USA
30497 Canwood St.
Suite 104
Agoura Hills, CA 91301
818-874-9226
mukund@falcomusa.com
www.falcomusa.com

FEI-Zyfer Inc.
7321 Lincoln Way
Garden Grove, CA 92841
714-933-4000
sales@fei-zyfer.com
www.fei-zyfer.com

FIRST RF Corporation
5340 Airport Blvd.
Boulder, CO 80301
303-449-5211-x100
inquiries@firstrf.com
www.firstrf.com

Forsberg Services
Richmond House
White Cross
Lancaster, LA1 4XF United Kingdom
44-1524-983320
info@forsbergservices.co.uk
www.forsbergservices.co.uk

Foxcom
16 Hataasia St.
Har Tuv Industrial Zone, 99052 Israel
609-228-8104
allenw@foxcom.com
www.foxcom.com

ftech Corporation
355 YuXin Rd.
East Sec.
Tainan, Taiwan
886-6-600-8999
sales@f-tech.com.tw
www.f-tech.com.tw

Furuno USA Inc.
GPS/OEM Timing Division
70 Engerman Ave.
Denton, MD 21629
410-479-4420
www.furunogps.us.com

G

Galileo Satellite Navigation
20 Eliyahu Eitan St.
Rishon le zion, 69363 Israel
97-23-966-4499
uri@galileo-nav.com
www.galileo-nav.com

Garmin International
1200 East 151st St.
Olathe, KS 66062
913-397-8200
sales@garmin.com
www.garmin.com

Geneq Inc.
10700 Secant St.
Montreal, Quebec H1J 1S5 Canada
514-354-2511, 800-463-4363
info@sxbluegps.com
www.sxbluegps.com
See our ad on page 48

Geodetics Inc.
2649 Ariane Dr.
San Diego, CA 92117
858-729-0872
info@geodetics.com
www.geodetics.com

Geomatics USA
2019 NW 21st Ln.
Gainesville, FL 32605
352-226-9564
amohamed@geomatics.us
www.geomatics.us

GEOsat GmbH
Loehberg 78
Muelheim an der Ruhr, 45468 Germany
49-208-45000-0
info@geosat.de
www.geosat.de

GEOSTAR NAVIGATION LTD.
Cherepanovykh proezd, 54
Moscow, 125183 Russia
495-662-7217
info@geostar-navi.com
http://geostar-navi.com/en/index/

Geotab
1081 South Service Rd. West
Oakville, Ontario L6L 6K3 Canada
416-434-4309
marias@geotab.com
www.geotab.com

GigOptix Inc.
130 Baytech Dr.
San Jose, CA 95134
408-522-3100
sales@gigoptix.com
www.gigoptix.com

Gladiator Technologies
8022 Bracken Pl. SE
Snoqualmie, WA 98065
425-396-0829
sales@gladiatortechnologies.com
www.gladiatortechnologies.com

Global Navigation Software Co.
5026 West Point Loma Blvd.
San Diego, CA 92107-1313
619-735-0380
globenav@aol.com
www.globenav.com

Globalsat Technology Corporation
16F, No.186, Jian-Yi Rd.
Chung Ho City, Taipei Hsien Taiwan
886-2-822-63799
service@globalsat.com.tw
www.globalsat.com.tw

GlobalTop Technology Inc.
No. 16, Nan-Ke 9th Rd.
Science-Based Industrial Park
Tainan City, Tainan 741 Taiwan
886-6-5051268
sales@gtop-tech.com
www.gtop-tech.com

GPS Antennas.com
17900 Crusader Ave.
Cerritos, CA 90703
818-414-8200
info@GPSantennas.com
www.GPSantennas.com

EMCORE Corporation

EMCORE Corporation (NASDAQ: EMKR) is a vertically-integrated, ISO 9001 certified manufacturer based in Alhambra, California and a leading provider of advanced Mixed-Signal Optics products for cutting-edge aerospace & defense systems. EMCORE designs and manufactures highly-advanced navigation products based on our closed-loop Fiber Optic Gyroscope (FOG) technology. These products, including single-axis FOGs, and three-axis Inertial Measurement Units (IMU) and Inertial Navigation Systems (INS) achieve high performance with lower CSWaP (Cost, Size, Weight and Power). All EMCORE's navigation products feature high-bandwidth, high input rate and low-noise making them ideal inertial navigation devices for platform stabilization in Unmanned Aerial Vehicles (UAV), missiles systems, gun targeting systems, dismounted soldier north finding and navigation, Unmanned Underwater Vehicles (UUV) and more.

EMCORE-Hawkeye™ EG-120 FOG

The EMCORE-Hawkeye™ Series EG-120 FOG module is an ultra-compact, state-of-the-art design that is a small, affordable closed-loop FOG. The EG-120 delivers advantageous Size, Weight and Power (SWaP) and is 35% smaller than EMCORE's previous generation FOGs. The EMCORE-Hawkeye™ EG-120 incorporates advanced, next-generation Field Programmable Gate Array (FPGA) electronics that deliver increased performance and reliability combined with low cost.

EMCORE EN-300 Inertial Measurement/Navigation Unit

EMCORE has developed the EN-300 Precision Fiber Optic Inertial Measurement/Navigation Unit as a higher accuracy inertial system to be form, fit and function compatible with a legacy equivalent, but with better performance needed for GPS denied navigation, precise targeting and line-of-sight stabilization. The EMCORE EN-300 is a state-of-the-art design incorporating EMCORE's proprietary integrated optics devices to enhance performance. The internal signal processing provides full stand-alone or aided navigation, and as an option can provide standard IMU delta velocity and delta theta.

EMCORE-Orion™ Series Micro Inertial Navigation System (MINAV)

The EMCORE-Orion™ series high-precision Micro Inertial Navigation System (MINAV) is developed primarily for applications where navigation aids such as GPS are unavailable or denied. EMCORE's advanced technology has enabled the unit to provide standalone aircraft grade navigator performance at 1/3 the Size, Weight and Power (SWaP) of competing systems. This state-of-the-art, fiber optic gyro-based MINAV incorporates EMCORE's proprietary integrated optics devices to enhance performance. There is an option for internal or external GPS. In a GPS denied environment the unit will gyrocompass to approximately 0.7 milliradian.

emcore®

EMCORE Corporation
2015 Chestnut Street
Alhambra, CA 91803 USA

Phone:
+1 626 293 3400

Fax:
+1 626 293 3428

Email:
navigation-sales@emcore.com

Web:
www.emcore.com/navigation

Key Contact:
David Faulkner
Vice President and General Manager of Aerospace & Defense

For the EMCORE

GPS Flight
1279 - 120th Ave. NE
Bellevue, WA 98005
425-653-2477
support@gpsflight.com
www.gpsflight.com

GPS Insight LLC
21803 N Scottsdale Rd.
Suite 220
Scottsdale, AZ 85255
866-477-4321
sales@gpsinsight.com
www.gpsinsight.com

GPS Networking Inc.
373 E. Industrial Blvd.
Pueblo West, CO 81008
719-595-9880, 800-463-3063
salesinfo@gpsnetworking.com
www.gpsnetworking.com

GPS Networking Inc.
373 E. Industrial Blvd.
Pueblo West, CO 81007
800-463-3063
salestech@gpsnetworking.com
www.gpsnetworking.com

GPS Source Inc.
64 N. Mission Dr.
Pueblo West, CO 81007
719-561-9520, 866-289-4777
sales@gpssource.com
www.gpssource.com

GPS Source Inc.
64 N. Mission Drive
Pueblo, CO 81007
719-561-9520, 866-289-0890
sales@gpssource.com
www.gpssource.com

GPS2CAD
4109 W. Laurel Ln.
Phoenix, AZ 85029
602-978-0720
support@gps2cad.com
www.gps2cad.com

GPSTrackit.com
27244 Via Industria
Temecula, CA 92590
951-296-1316
rrail@gpstrackit.net
www.gpstrackit.com

Greenray Industries
840 West Church Rd.
Mechanicsburg, PA 17055
717-766-0223
sales@greenrayindustries.com
www.greenrayindustries.com

Gutec AB
Industrigatan 21c
Lomma, SE-234 35 Sweden
46-40-416681
info@gutec.se
www.gutec.se

H

Handheld USA Inc.
33870 SE Eastgate Cr.
Corvallis, OR 97333
541-752-0313
info@handheld-us.com
www.handheldgroup.com

Harris Corporation
1025 W. NASA Blvd
Melbourne, FL 32919
321727-9100
antenna.info@harris.com
www.harris.com

Harxon Corporation
No. 1001 Zhongshanyuan Rd.
6/F, Block B, Bldg D3, TCL International E City
Nanshan District, Shenzen China
008-675-526989948
sales@harxon.com
www.harxon.com

Hemisphere GNSS
8515 E. Anderson Dr.
Scottsdale, AZ 85255
480-348-6380, 855-203-1770
GGrenier-Baird@HGNSS.com
www.HGNSS.com

Hirschmann Car Communication
1116 Centre Rd.
Auburn Hills, MI 48326
248-373-7150
sales@hirschmann-mi.com
www.hirschmann-car.com

Honeywell
12001 Hwy. 55
Plymouth, MN 55441
800-323-8295
www.honeywell.com

I

iCONN Systems
1110 N. Garfield St.
Lombard, IL 60101
630-709-1825
knovak@iconnsystems.com
www.iconnsystems.com

i-cubed LLC
1600 Prospect Pkwy.
Fort Collins, CO 80525
970-482-4400
sales@i3.com
www.i3.com

IFEN GmbH
Alte Gruber Str. 6
Poing, 85586 Germany
49-8121-22-38-20
sales@ifen.com
www.ifen.com

ikeGPS Inc.
350 Interlocken Blvd.
Suite 250
Broomfield, CO 80021
1-844-4-IKEGPS
info@ikegps.com
www.ikeGPS.com

Impact Power Inc.
12655 W. Jefferson Blvd., 4th Floor
Los Angeles, CA 90066
949-477-9198
sales@impactpower.com
www.impactpower.com

Industrial SkyWorks
50A Beth Nelson Dr.
Toronto, Ontario M4H 1G8 Canada
647-923-9962
info@industrialskyworks.com
www.industrialskyworks.com

Inertial Sense INC.
72 N 720 E
Salem, UT 84653
801-610-6771
sales@inertialsense.com
http://inertialsense.com

Infospectrum
30497 Canwood St.
Suite 104
Agoura Hills, CA 91301
818-874-9226
sales@info-spectrum.com
www.info-spectrum.com

Institute of Navigation (ION)
8551 Rixlew Ln.
Suite 360
Manassas, VA 20109
703-366-2723
membership@ion.org
www.ion.org
See our ad on page 18

INSTOCK Wireless Components Inc.
50 Intervale Road
Boonton, NJ 07005
973-335-6550
sales@instockwireless.com
www.instockwireless.com/

Inventek Systems
2 Republic Rd.
Billerica, MA 01862
978-667-1962
sales@inventeksys.com
www.inventeksys.com

iP-Solutions, Japan
Level 9, Ariake Frontier Building Tower B
3-7-26 Ariake, Koto-ku
Tokyo, 135-0063 Japan
81-3-5530-8667
info@ip-solutions.jp
www.ip-solutions.jp

ISA Telematics GmbH
Hauptsitz
Brünnsteinstraße 7
Grafing, 85567 Germany
49-89-74-94-68-48
info@isatelematics.de
www.isatelematics.de

ITRAK Corporation
800 Research Dr.
Suite 240
Woodland Park, CO 80863
866-MYiTRAK
itrak.sales@itrak.com
www.itrak.com/EN

J

Jackson Labs Technologies Inc.
10191 Park Run Dr.
Suite 100
Las Vegas, NV 89145
702-233-1334
info@jackson-labs.com
www.jackson-labs.com
See our ad on page 29

Janus Remote Communications
2111 Comprehensive Dr.
Aurora, IL 60505
630-499-2121
sales@janus-rc.com
www.janus-rc.com

Japan Radio Co. Ltd.
1 Bridge Plaza North
Suite 275
Fort Lee, NJ 07024
201-242-1882
peterkito@jrcamerica.com
www.jrc.co.jp/eng

JAVAD

JAVAD GNSS Inc.
900 Rock Ave.
San Jose, CA 95131
408-770-1770
sales@javad.com
www.javad.com; javad.com/jgnss/index.html
See our ad on pages 19-26 and 53

Jiashan Jinchang Electronics
398 Zhenye Rd.
South St.
Jiaxing, Zhejiang 314001 China
86-0573-83692157
jack@jinchanggps.com
www.jinchanggps.com

John Deere AMS
4140 NW 114th St.
Urbandale, IA 50322
888-GRN-STAR
www.johndeereag.com

Juniper Systems Limited
4 The Courtyard
Buntsford Gate
Bromsgrove, B60 3DJ United Kingdom
44-0-1527-870773
infoEMEA@junipersys.com
www.junipersys.com

Eos Positioning Systems

Eos Positioning Systems, Inc.®, (Eos) designs and manufactures advanced high-accuracy GNSS receivers for mobile data collection. In 2014, a technical team with more than two decades of GNSS experience founded Eos near Montreal. The team is credited with creating a submeter Bluetooth GPS receiver (2001) and also an RTK GNSS receiver for any device (e.g., iOS, Android). Today, the Eos Arrow Series™ GNSS receivers provide submeter and centimeter accuracy directly into any mobile app, including popular data-collection software such as Esri's Collector for ArcGIS®.

Corporate Mission

Eos has a simple mission: To provide the GIS and mapping community with affordable, high-accuracy GNSS receivers that are easy to use and flexible. Eos Arrow GNSS receivers all provide high-accuracy locations with minimal training on commercial mobile devices (iOS, Android, Windows) and access to a positive customer experience.

Product Innovation

The Eos Arrow Series™ of GNSS receivers offer a unique balance of accuracy, affordability, flexibility, and simplicity. Arrow receivers are flexible (any device, any app) and future-proof (support all new GNSS frequencies and all four global GNSS constellations). They are known for their superior tracking capability and accuracy under dense canopy, thanks to both patented technologies and the ability to maintain lock with free SBAS signals like WAAS, EGNOS, MSAS and GAGAN. In addition, the Arrow Gold RTK receiver can be turned into a base station when private RTK networks are not available or too onerous.

Client Base

Arrow GNSS receivers are popular among utilities, government / municipalities, forestry and park divisions, environmental groups, petroleum professionals, engineering firms, and many other organizations. Common uses include using high-accuracy field mapping to improve asset management, routine field work, regulatory compliance, customer service, outage management, work order management, as-builts, 811 calls, internal/external information sharing, and more. Arrow Gold receivers are also a preferred choice for setting drone/UAV ground control.

Future Outlook

Eos leadership is constantly learning about customer needs from the source and continuously innovating to provide solutions that optimize field work. Learn more at www.eos-gnss.com.

EOS Positioning Systems

Eos Positioning Systems
1160 Rue Lévis, Suite 100
Terrebonne QC, J6W 5S6
Canada

Phone:
+1 (450) 824-3325 (CAN)

Email:
Info@eos-gnss.com

Web:
www.eos-gnss.com

K

Karel Electronics
Cyberpark B
Blok Kat:3
Ankara, 06800 Turkey
90-312-265-0290
int.sales@karel.com.tr
www.karel-electronics.com

KCS BV
Kuipershaven 22
3311 Al Dordrecht, Netherlands
317-863-12659
kcs@kcs.tv
www.trace.me

KVH Industries
50 Enterprise Ctr.
Middletown, RI 02842
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jay.napoli@kvh.com
www.kvh.com

L

L-3 Interstate Electronics Corporation
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Anaheim, CA 92803-3117
714-758-0500
Greg.Martz@L-3com.com
www.iechome.com

L3 Technologies
602 E. Vermont Ave.
Anaheim, CA 92803
714-758-4011
greg.martz@L3T.com
www2.l3t.com/iec/

Laipac Technology Inc.
20 Mural St.
Unit 5
Richmond Hill, Ontario L4B 1K3 Canada
905-762-1228
sales@laipac.com
www.laipac.com

Laird Technologies
16401 Swingley Ridge Rd.
Suite 700
Chesterfield, MO 63017
636-898-6000
Telematics.NA.Sales@lairdtech.com
www.lairdtech.com

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Vancouver, WA 98682
360-944-7551
info@larsen.pulseeng.com
www.pulseelectronics.com

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6912 S. Quentin St.
Centennial, CO 80112
303-649-1000, 877-696-2584
atibljas@lasertech.com
www.lasertech.com

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Heerbrugg, CH-9435 Switzerland
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www.leica-geosystems.com

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Hartselle, AL 35640
256-274-1616
sales@lidarusa.com
www.lidarusa.com
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Merlin, OR 97532
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info@linxtechnologies.com
www.linxtechnologies.com

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111 Canberra Ave.
Griffith, ACT 2603 Australia
61-2-6126-5700
enquiry@locatacorp.com
www.locatacorp.com

Lockheed Martin
6801 Rockledge Dr.
Bethesda, MD 20817
301-897-6000
www.lockheedmartin.com

Loctronix Corp.
18115 139th NE Ave.
Suite A-1
Woodinville, WA 98972
425-307-3485
info@loctronix.com
www.loctronix.com

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Williston, VT 05495
802-862-6629
sensing_sales@lord.com
www.microstrain.com

M

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Lavernose-Lacasse, 31410 France
335-622-31380
tmproducts@m3systems.eu
www.m3systems.eu

JAVAD GNSS

Inseparably uniting the two continents of America and Europe, JAVAD GNSS Inc represents a dynamic and respected brand in the industry. The creative potential of two great countries has found its manifestation in JAVAD products. Since its inception, JAVAD GNSS has been focused on developing and manufacturing the newest generation of GNSS receivers for high precision/high performance applications. The primary products marketed under this brand name are GNSS receivers and OEM boards based on its 'Triumph' technology. The unmistakable lime-green JAVAD GNSS receivers are known to surveyors the world over. With its J-Shield technology, JAVAD GNSS currently has protection against interferences. J-Shield is a robust filter in the antenna that blocks out-of-band interference. It also provides GNSS receivers with built-in detailed interference awareness features and with a Spoofing Detection option: there is absolutely no way that JAVAD GNSS receivers can be spoofed or jammed without the users' knowledge. JAVAD GNSS receivers will immediately recognize spoofers and jammers and take corrective action.

One recent and revolutionary innovation from JAVAD GNSS is the J-Mate "Total Solution" coupled with the TRIUMPH-LS RTK receiver that 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.

JAVAD GNSS has its own manufacturing facilities in San Jose, California. Four continuous flow SMT lines are highly flexible allowing for diverse and complex products utilizing the latest in component packaging technologies to be assembled and with quick changeover between products enabling high mix, low to medium volume production.

The company's online store allows the customer to calculate project costs and place orders on the same day a purchasing decision is made. Highly qualified staff members operate from two hemispheres via more than a hundred international dealers, to provide high-performance GNSS devices, components, technology and software for professional end-users in the navigation, survey, GIS, agricultural, and OEM-board markets. As a manufacturer, JAVAD GNSS can afford to maintain attractive prices for its customers thanks to complete control of the manufacturing process managed by experts with more than twenty years' experience in the industry. As the sun goes down in San Jose, day is breaking over Moscow; a 24/7 free technical support system provides support by phone, email and interactively online, to customers no matter where are they located on the globe.

The JAVAD GNSS mission is to continue to be at the cutting edge of GNSS technology. The last word is left to Marc Cheves, editor of *The American Surveyor*: "By creating affordable, portable GPS devices for the past nearly thirty years, surveyors all over the world have benefitted from JAVAD's passion for precise positioning. The company is in it for the long run. It's hard to even imagine how far the GNSS envelope may be pushed in the future, but wherever it is, no doubt JAVAD will be there."

JAVAD GNSS
900 Rock Avenue,
San Jose, CA 95131
USA

Phone:
+1 (408) 770-1770

Fax:
+1 (408) 770-1799

Email Sales:
sales@javad.com

Email Dealers:
friends@javad.com

Web:
www.javad.com

Maruwa America Corporation
200 E. Sandpointe Ave.
Suite 525
Santa Ana, CA 92707
714-668-0400
sales@maruwa-america.com
www.maruwa-g.com

Maxim Integrated Products
120 San Gabriel Dr.
Sunnyvale, CA 94086
408-737-7600
www.maxim-ic.com

Maxtena
7361 Calhoun Pl.
Suite 102
Rockville, MD 20855
877-629-8362
info@maxtena.com
www.maxtena.com

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31812 Bad Pyrmont
Germany
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info@meinberg.de
www.meinbergglobal.com
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Meitrack Group
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Suite 180
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626-448-8787
juan.jimenez@meitrackusa.com
www.meitrackusa.com

Micro Engineering Tech
1716-16 Ave. NW
Suite 400
Calgary, Alberta T2M 0L7 Canada
403-457-3112
services@meng-tech.com
www.meng-tech.com

Micro Modular Technologies
17011 Beach Blvd.
Suite 900
Huntington Beach, CA 92647
949-336-7850
sales@micro-modular.com
www.micro-modular.com

Micro-Ant LLC
4722 Wesconnett Blvd.
Jacksonville, FL 32210-7315
904-683-8394
jfrancis@micro-ant.com
www.micro-ant.com

Microlab

Microlab
25 Eastmans Road
Parsippany, NJ 07054
973-386-9696
sales@microlabtech.com
https://microlabtech.com/; https://microlabtech.com/active-solution.html; https://wirelesstelecomgroup.com/

Microsemi Corporation
One Enterprise
Aliso Viejo, CA 92656
800-713-4113, 800-713-4113
farhad.mafie@microsemi.com
www.microsemi.com

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1155 Phoenixville Pike
Suite 106
West Chester, PA 19380
610-344-7676
info@b2bphotonics.com
www.b2bphotonics.com

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Hednesford, Staffordshire WS12 2FS United Kingdom
44-1543-459555
enquiries@mobilemarkeurope.co.uk
www.mobilemark.com

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1140 W. Thorndale Ave.
Itasca, IL 60143
847-671-6690
info@mobilemark.com
www.mobilemark.com

Motorola
2900 South Diablo Way
Tempe, AZ 85282
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Oncore1@Motorola.com
www.motorola.com/gps

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1076 Florida Central Pkwy.
Longwood, FL 32750
47-331-7779, 800-423-2594
matt@multicominc.com
www.multicominc.com

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Austin, TX 78759-3504
800-531-5066
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www.ni.com

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Aurora, IL 60505
630-236-3026
djahr@navsync.com
www.navsync.com

NavSys Corporation
14960 Woodcarver Rd.
Colorado Springs, CO 80921
866-462-8797
info@navsys.com
www.navsys.com

NavtechGPS
5501 Backlick Rd.
Suite 230
Springfield, VA 22151
703-256-8900
info@navtechgps.com
www.navtechgps.com

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www.northropgrumman.com

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enquiries@nsl.eu.com
www.nsl.eu.com

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Fremont, CA 94538
510-933-4800
info@novariant.com
www.novariant.com

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NVS Technologies AG
Letzaustrasse 1
9462 Montlingen, Switzerland
41-71-760-0736
info@nvs-gnss.com
www.nvs-gnss.com

O

Omnetics Connector Corporation
7260 Commerce Cir. East
Minneapolis, MN 55432
763-572-0656
sales@omnetics.com
www.omnetics.com

OmniSTAR
Vlietweg 17h
Leidschendam, 2266 KA Netherlands
31-70-3170900
eu_corrections@omnistar.com
www.omnistar.com

Optical Zonu Corp.
7510 Hazeltine Ave
Los Angeles, CA 91405
818-780-9701
judec@opticalzonu.com
www.opticalzonu.com

Orca Technologies LLC
934 Calle Negocio
Suite B
San Clemente, CA 92673
949-361-0212
sales@orcatechnologies.com
www.orcatechnologies.com

OriginGPS
2 Negev St.
Airport City, 7015002 Israel
972-3-6737010
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Orolia
1565 Jefferson Rd.
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Rochester, NY 14623
585-321-5800
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www.orolia.com
See our ad on pages 17 and 59

Oscilloquartz SA
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Future-proof GNSS Solutions

In the 21st century, where technological change and automation dominate our major industries, more and more industries and services count on reliable, precisely timed networks. Since 1979 Meinberg offers their customers and partners innovative and accurate time and frequency synchronization solutions in order to keep networks operating flawlessly.

Coming Soon: microSync Product Family

Leveraging the expertise of its in-house engineers, Meinberg set out to design a cost-efficient, compact, high-performing device flexible enough to meet the unique needs of a range of different industries. The result is an innovative, multipurpose synchronization solution offering a variety of outstanding features. Available as DIN rail and half rack solution for a space efficient design and in a 19 inch rackmount case.

IMS - Intelligent Modular Synchronization

Versatile and Modular Solutions for Time and Frequency Synchronization in various housing types. Its modularity supports forming highly customized synchronization systems by combining standard building blocks, resulting in one of the most cost-effective and flexible synchronization solutions on the market.

About Meinberg

One of the leading manufacturers of time and frequency synchronization equipment. Meinberg designs and produces Network Time Servers (running NTP and IEEE 1588), PCI and PCI Express Slot Cards, USB connected devices and Industrial Synchronization Systems used in a wide range of applications. The core strength of this highly specialized solutions provider is flexibility. Meinberg offers built-to-order systems which exactly fit into your environment and which fulfill your specific requirements.

EXPERTISE & PRODUCTS

- Leading edge synchronization solutions
- High end PTP and NTP time server products
- GPS, GLONASS and DCF77/WWVB/MSF receivers
- PCI Express Computer Clocks (GPS, GLONASS and DCF77)
- IRIG/AFNOR time code generators/readers
- A large variety of accessories like antennas, diplexers, converters and signal distribution systems

MEINBERG
The Synchronization Experts.

Meinberg Funkuhren GmbH & Co. KG
Lange Wand 9
31812 Bad Pyrmont, Germany

Phone:
+49 (0)5281 9309-0

Fax:
+49 (0)5281 9309-230

Email:
info@meinberg.de

Web:
www.mbg.link/gpsworld

Oxford Technical Solutions
Park Farm Business Centre
PO Box OX25 4AL
Middleton Stoney Bicester, Oxfordshire United Kingdom
01869-238015
+44 (0) 1869-814-250
paustin@oxts.com
www.oxts.com

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Panasonic

Panasonic Canada Inc.
5770 Ambler Dr.
Mississauga, ON L4W 2T3 Canada
416-459-1111
VIP@ca.panasonic.com
www.business.panasonic.ca; https://na.panasonic.com/ca/industrial-devices
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Panorama Antennas Ltd.
61 Frogmore Wandsworth
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Parsec Technologies Inc.
701 East Plano Pkwy.
Suite 300
Plano, TX 75074
972-804-4600
sales@parsec-t.com
www.parsec-t.com

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Phase One Industrial
11755 Airport Way, Rocky Mountain Airport
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Broomfield, CO 80021
303-469-6657
industrial@phaseone.com
https://industrial.phaseone.com

Physical Logic
Lindenstrasse 26
8008
Zurich, Switzerland
41-43-508-3716
info@physical-logic.com
www.physical-logic.com

PNI Sensor Corporation
133 Aviation Blvd.
Suite 101
Santa Rosa, CA 95403
707-566-2260
customerservice@pnicorp.com
www.pnicorp.com

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301 North Whisman St.
Mountain View, CA 94043
408-492-8900
products@polariswireless.com
www.polariswireless.com

Polynesian Exploration Inc.
2210 O'Toole Ave
#240
San Jose, CA 95131
408-500-9716
gene@polyexplore.com
www.polyexplore.com

Position Logic
4522 Executive Dr.
2nd Floor
Naples, FL 34119
866-676-2372
sales@positionlogic.com
www.positionlogic.com

Precise Time and Frequency LLC
50L Audubon Rd.
Wakefield, MA 01880
781-245-9090
dbriggs@ptf-llc.com
www.ptf-llc.com

Propeller Aero
251 Riley St.
Surry Hills, 2010 Australia
041-545-8089
kateryna@propelleraero.com.au
www.propelleraero.com

Q

QinetiQ Ltd.
Cody Technology Park
Ively Rd.
Farnborough, Hampshire GU14 0LX United Kingdom
44-0-8700-100-942
gpssales@qinetiq.com
www.qinetiq.com

NovAtel

NovAtel®, part of Hexagon Positioning Intelligence, is a global technology leader, pioneering end-to-end solutions for assured positioning for land, sea, and air. NovAtel designs, manufactures and sells high precision positioning technology developed for efficient and rapid integration. Our solutions empower the advancement of autonomy and intelligent positioning ecosystems in vital industries that depend on the ability to tackle the most complex challenges in the most demanding environments.

AUTONOMY & POSITIONING - ASSURED

Precise GNSS Receivers

Our OEM7® family of receivers features technology that incorporates innovative capabilities that enhance GNSS-based positioning reliability, accuracy and availability. Our Interference Toolkit (ITK) technology on the OEM7 receivers works to detect sources of interference and intentional or unintentional jamming; it mitigates those occurrences using proprietary NovAtel filters. The ITK also detects electromagnetic interference caused by other components in an integration project. Our technology works together to provide the assured positioning required for the application.

SPAN® GNSS + Inertial Systems

SPAN tightly couples NovAtel's GNSS receivers with Inertial Measurement Units (IMUs) for reliable, continuously available 3D position, velocity and attitude – even during periods of satellite signal unavailability.

Correction Services

NovAtel's Precise Point Positioning (PPP) utilizes TerraStar's premium correction data delivery to provide solutions with high accuracy and instant re-convergence. A variety of levels of accuracy are available from 40 cm to 2.5 cm. For receivers operating in RTK mode, an RTK ASSIST™ subscription ensures the receiver maintains centimetre-level positioning accuracy during periods of outages in RTK radio or cellular network connectivity. Our Oceanix nearshore correction service delivers sub-decimetre positioning for various marine applications.

NavWar

NovAtel's GNSS technology addresses the needs of Navigation Warfare (NAVWAR). Our OEM components and military off-the-shelf products are engineered to ensure continuous positioning and detect, locate and characterize interference sources. NovAtel's GPS Anti-Jam Technology (GAJT®) is a null-forming antenna system that ensures necessary satellite signals are available to compute position and time.

GNSS ANTENNAS

The right antenna maximizes your system's performance. Our extensive GNSS antenna product line delivers many options, from compact, lightweight, low profile GNSS antennas for aviation applications to robust options for agricultural or machine control applications. NovAtel offers SMART antennas which integrate a GNSS receiver card and a high performance antenna element in a single compact enclosure.

GNSS POST-PROCESSING SOFTWARE

Waypoint® post-processing software (GrafNav/GrafNet® and Inertial Explorer®) is market leading software that provides accurate post-mission position, velocity or attitude. It is a popular tool for calculating a truth solution when evaluating positioning or navigation performance.

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NovAtel

NovAtel
10921 14th Street NE
Calgary, Alberta
Canada T3K 2L5

Phone:
1-403-295-4900
1-800-NOVATEL
(1-800-668-2835)

Email:
sales@novatel.com

Web:
www.novatel.com

QUALCOMM Inc.
5775 Morehouse Dr.
San Diego, CA 92121
858-587-1121
www.qualcomm.com

R

Racelogic Labsat
Unit 10, Swan Business Ctr.
Osier Way
Buckingham, Bucks MK18 1TB
United Kingdom
44-1280-825-988
labsat@racelogic.co.uk
www.labsat.co.uk
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8 Sylvia Park Rd.
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www.raytheon.com

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The Pinnacles
Elizabeth Way
Harlow, Essex CM19 5BB
United Kingdom
44-1592-754311
corporatecommunications@raytheon.co.uk
www.raytheon.co.uk

Ready Track Pty Ltd.
32 Victoria St.
Smithfield, New South Wales
2164 Australia
130-076-6703
sales@readytrack.com.au
www.readytrack.com.au

Reelektronika B.V.
Nieuwenbroeksedijk 6
Reeuwijk, 2811 NJ Netherlands
31-182-300-150
info@reelektronika.nl
www.reelektronika.nl

Remote GeoSystems Inc.
3307 South College Ave.
P.O. Box 271292
Suite 211
Fort Collins, CO
970-367-7808
info@remotegeo.com
www.remotegeo.com

Retail Secure
Stee 11, Penistone 1
Regent Court, St Mary's St.
Sheffield, S36 6DT United Kingdom
0333-320-8848
retailsecureuk@gmail.com
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Chandos Rd.
Bristol, BS66PF United Kingdom
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info@rewiresecurity.co.uk
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Einat, 4880500 Israel
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sandee@aims.co.il
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242 E Airport Dr.
Suite 112
San Bernardino, CA 92408
909-890-9040
dynamic.capture@ricoh-usa.com
www.RicohDC.com

RIEGL Laser Measurement Systems GmbH
Riedenburgstrasse 48
Horn, 3580 Austria
0043-2982-4211
office@riegl.com
www.riegl.com

Rockwell Collins
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Cedar Rapids, IA 52498
319-295-8163
kim.betterton@rockwellcollins.com
www.rockwellcollins.com

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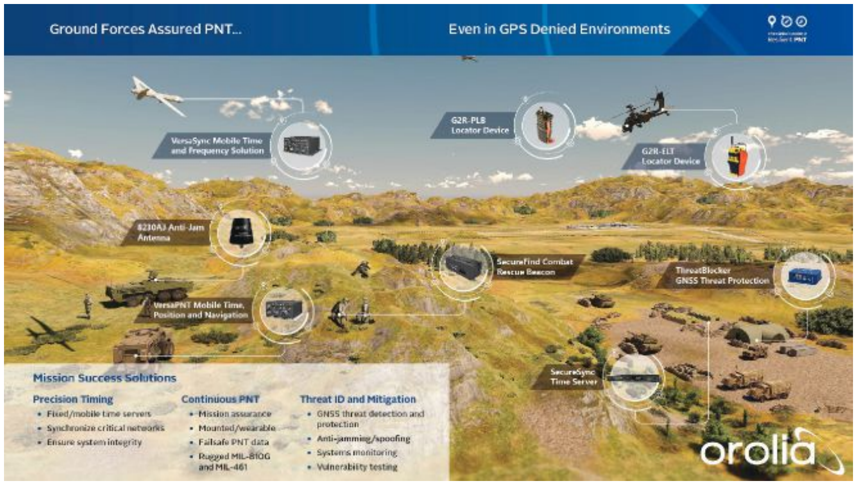

Resilient PNT, Even in GPS Denied Environments

Orolia is a leader in Resilient Positioning, Navigation and Timing (PNT) solutions that improve the reliability, performance and safety of critical, remote or high-risk operations. With locations in more than 100 countries, Orolia provides virtually failsafe GPS/GNSS and PNT solutions to support military and commercial applications worldwide. *Orolia: Time and Location You Can Trust.™*

Assured PNT: Threat ID, Detection and Mitigation

Today's military forces rely on continuous and accurate PNT signals to make timely and effective decisions, even in GPS denied environments. Whether from unintentional interference, or intentional jamming and spoofing, the need for continuous, trusted PNT data is critical for military operations worldwide.

Critical Infrastructure: Essential Systems and Automation

PNT solutions protect essential systems and enable automation in critical sectors such as finance, data centers, e-commerce, process control, telecom, healthcare, utilities and transportation. These industries cannot afford to risk network failure, where even a microsecond delay can mean loss of revenue, loss of service or even loss of life.

The Orolia Resilient PNT Advantage

Orolia delivers comprehensive, proven Resilient PNT solutions from testing and simulation to alternate signals and PNT data sources.

- Interference detection and monitoring
- Threat mitigation and countermeasures
- Testing and simulation
- Timing and synchronization
- Precise PNT data references
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- Signal distribution and wireless networking
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The world's most PNT-reliant systems rely on Orolia.

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Orolia US Headquarters
1565 Jefferson Road
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Phone:
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Email:
info@orolia.com

Web:
www.orolia.com

Rohde & Schwarz
Muehldorfstrasse 15
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Barcelona, 08018 Spain
349-355-11490
info@rokubun.cat
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Rx Networks
1201 W. Pender St.
Suite 800
Vancouver, British Columbia V6E 2V2 Canada
604-685-8988
sales@rxnetworks.com
www.rxnetworks.com

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Satel Oy
Meriniitynkatu 17
P.O. Box 142 FI-24101
Salo, 24100 Finland
358-2-777-7800
info@satel.com
www.satel.com

Satel Survey USA
10680 S. De Anza Blvd.
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Cupertino, CA 95014
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Schweitzer Engineering Laboratories Inc.
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www.selinc.com

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LabSat by Racelogic

LabSat, a division of Racelogic Limited, are experts in the field of GPS testing and data logging. With offices in the UK, US, China and Germany, the company supplies specialised GNSS based test equipment to well-known corporations, in over 80 countries around the world.

Small, light-weight and battery powered, LabSat GNSS simulators allow users to quickly gather detailed, real-world satellite data and replay these signals within a test environment.

The cost effective LabSat 3 is the most affordable, full constellation single GPS or multi-GNSS simulator range on the market, making GPS, GLONASS and BeiDou simulation accessible for any company involved in GNSS design, test or production.

By contrast the LabSat 3 Wideband can handle almost any combination of constellation and signal that exists today, as well as future satellite signals.

LabSat's SatGen software is a user-defined trajectory file generator that can be used to simulate almost any kind of test at a set time and date, anywhere in the world. SatGen files can then be replayed by a LabSat unit directly into GNSS devices for testing.

All LabSat's have the ability to play back other data formats such as CAN, digital and serial streams. With high fidelity 2 bit or 4 bit sampling (6 bit sampling for LabSat 3 Wideband), LabSat's are ideal for testing GPS receiver sensitivity.

The following signals can be recorded and replayed:

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

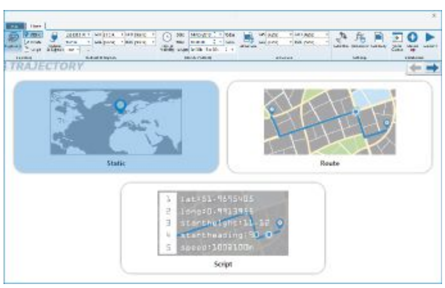
L-band GNSS correction services: Terrastar, Veripos, OmniSTAR, StarFire

Additional signals from dual-CAN, RS232, and digital inputs simultaneously recorded and replayed with GNSS.

Coming in 2019

An update to SatGen will see the addition of the Galileo constellation and a complete overhaul of the simulation software's UI making it easier than ever to create complex test scenarios for all current GNSS constellations at any time or place around the world.

Development continues on LabSat's Almanac Download Server, a portal from which LabSat devices and software can instantly download and update almanacs for every GNSS constellation. Benefits include more timely updates, improved data integrity and the elimination of regional download issues.



The new and improved SatGen simulation software interface (set for release 2019)

LabSat 3 Wideband records and replays up to 4 constellations simultaneously

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Unit 10, Swan Business Centre, Osier Way, Buckingham, Bucks MK18 1TB, United Kingdom

Phone:
+44 1280 823 803

Email:
info@labsat.co.uk

Web:
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From the sky to the lab: GNSS simulators from the T&M expert

Constant innovations and disruptive technologies are the key element of success in various industries - aerospace and defense included. To ensure flawless levels of functionality, strict requirements need to be met during design, verification and testing of electronic systems.

As a recognized industry partner with more than 80 years of expertise in the test and measurement field, Rohde & Schwarz provides market-leading solutions for radar, electronic warfare, satellite, navigation, guidance, communications and radio monitoring systems.

Global navigation satellite system (GNSS) based location services are an essential part of various industries, crucial defense and security applications and our everyday lives, making the compliance and performance of GNSS enabled devices an extremely important task.

Rohde & Schwarz offers a variety of signal generator solutions that are fully capable of replaying GNSS waveforms. Together with available software upgrades, they are able to generate them as well, making them perfect for early stages of receiver development and testing of basic signal acquisition and tracking capabilities. The R&S SMBV100B, R&S SGT100A, R&S SMW200A vector signal generators and the R&S CMA180 and R&S CMW500 communication testers provide receiver testing solutions on every level and for every application.

The solutions based on the R&S SMBV100B perfectly address chipset and end-of-line production testing and are ideal for reliable signal dynamic verification, receiver characterization and basic interference testing.

R&D or military applications require a more advanced solution based on the high performance R&S SMW200A vector signal generator (see fig. 1), ideal for simulating even the most complex real-life scenarios with different requirements.

With this deep expertise across the industries and an extensive solution portfolio, Rohde & Schwarz is a partner of choice for reliable GNSS receiver testing.

ROHDE&SCHWARZ

Phone:
+49 89 4129 12345

Email:
customersupport@rohde-schwarz.com

Web:
www.rohde-schwarz.com/ad/GNSS-solutions

Microwave Photonic Systems
NavCom, A John Deere Company
Novariant
NovAtel
NVS Technologies AG
PCTEL
Racelogic Labsat
Rx Networks
Syntony
Topcon Positioning Systems
Trimble

DIGITAL COMPASSES

Advanced Navigation
Borealis Precision
ComNav
DataGrid Inc.
Furuno USA Inc.
Garmin International
Globalsat Technology Corporation
GlobalTop Technology Inc.
Hemisphere GNSS
Honeywell
ikeGPS Inc.
KCS BV
Leica Geosystems AG
PNI Sensor Corporation
Racelogic Labsat
Silicom
STMicroelectronics
Topcon Positioning Systems
Trimble
USGlobalsat Inc.
ZMicro

ELECTRONIC CHARTS/ MAPS

DeLorme
DigitalGlobe
Furuno USA Inc.
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Global Navigation Software Co.
John Deere AMS
KCS BV
Leica Geosystems AG
Novariant
Racelogic Labsat
Rockwell Collins
Silicom
TomTom
Topcon Positioning Systems
Trimble
ZMicro

Geophysical

Emlid Ltd.
L3 Technologies
Polynesian Exploration Inc
The Fredericks Company
ZMicro

GLONASS HARDWARE/ SOFTWARE

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ALLSAT GmbH
Antenova Ltd.
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Baseband Technologies Inc.
Brandywine Communications
Broadcom Corporation
CAST Navigation LLC
CellGuide Ltd.
CHC Navigation
C-Nav
ComNav Technology
CSR plc
DataGrid Inc.
Galileo Satellite Navigation
GEOSTAR NAVIGATION LTD.
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Janus Remote Communications
JAVAD GNSS Inc.
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Juniper Systems Limited
KCS BV
Leica Geosystems AG
M3 Systems
Maxtena
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NovAtel
NVS Technologies AG
Orolia
Oscilloquartz SA
Oxford Technical Solutions
PCTEL
Polynesian Exploration Inc
Precise Time and Frequency LLC
Racelogic Labsat
Rakon
Rewire Security
Rockwell Collins
Rohde & Schwarz
Skydel
SkyTraq Technology Inc.
Sokkia Corporation
Spirent Communications
Spirent Federal Systems
STMicroelectronics
Swift Navigation
Talen-X
Tallysman Wireless
TeleOrbit GmbH
Telit
Tersus GNSS
Thales
Topcon Positioning Systems
Trimble
Trimble Integrated Technologies
u-blox AG
USGlobalsat Inc.
Xsens

INTEGRATED INSTRUMENTATION WITH GPS

Altus Positioning Systems
Baseband Technologies Inc.
CHC Navigation
Falcom USA
Galileo Satellite Navigation
Geodetics Inc.
Geomatics USA
GPS Antennas.com
GPS Source Inc.
Handheld USA Inc.
Hemisphere GNSS
Infospectrum
JAVAD GNSS Inc.
Juniper Systems Limited
KCS BV
Laser Technology Inc.
Lockheed Martin
M3 Systems
Meitrack Group
Microlab
NavCom, A John Deere Company
NextNav
Orolia
Oscilloquartz SA
Oxford Technical Solutions
Polynesian Exploration Inc
Precise Time and Frequency LLC
Rakon
RIEGL Laser Measurement Systems GmbH
Rockwell Collins
Skyworks Solutions Inc.
Spectratime
Stanford Research Systems
Talen-X
Telit
Tersus GNSS
Trimble
UTC Aerospace Systems
ZMicro

Automated machine control

Applanix
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Communication & Navigation (C&N)
ComNav Technology
DataGrid Inc.
Geodetics Inc.
Harxon Corporation
Hemisphere GNSS
Infospectrum
Japan Radio Co. Ltd.
JAVAD GNSS Inc.
John Deere AMS
KCS BV
Leica Geosystems AG
NavCom, A John Deere Company
Novariant
Topcon Positioning Systems
Trimble

Bar-code scanner

Falcom USA
Infospectrum
Juniper Systems Limited
KCS BV
Ricoh Americas Corporation
Topcon Positioning Systems
Trimble

Camera

Applanix
Baseband Technologies Inc.
Falcom USA
ftech Corporation
ikeGPS Inc.
Infospectrum
JAVAD GNSS Inc.
Juniper Systems Limited
KCS BV
NavSys Corporation
Racelogic Labsat
Remote GeoSystems Inc.
Ricoh Americas Corporation
Topcon Positioning Systems
Trimble

Datalogger

Applanix
Baseband Technologies Inc.
Cobham AvComm (formerly Aeroflex)
Communication & Navigation (C&N)
ComNav Technology
DataGrid Inc.
DeLorme
ftech Corporation
Geomatics USA
GlobalTop Technology Inc.
Handheld USA Inc.
Hemisphere GNSS
ikeGPS Inc.
Infospectrum
Janus Remote Communications
JAVAD GNSS Inc.
John Deere AMS
Juniper Systems Limited
KCS BV
Laipac Technology Inc.
Leica Geosystems AG
M3 Systems
NavSys Corporation
Novariant
Racelogic Labsat
Remote GeoSystems Inc.
Rojone Pty. Ltd.
Topcon Positioning Systems
Trimble
u-blox AG
USGlobalsat Inc.

Infrared/multispectral sensors

Applanix
DigitalGlobe
Falcom USA
Remote GeoSystems Inc.
Trimble

Integrity monitoring

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Broadcom Corporation
CHC Navigation
Geodetics Inc.
ikeGPS Inc.
JAVAD GNSS Inc.
KCS BV
Leica Geosystems AG
M3 Systems
NavCom, A John Deere Company
Racelogic Labsat
Remote GeoSystems Inc.
Spirent Communications
Thales
Topcon Positioning Systems
Trimble

Ionospheric calibrators

C-Nav
Geodetics Inc.

Laser rangefinders

Applanix
ikeGPS Inc.
KCS BV
Laser Technology Inc.
Leica Geosystems AG
RIEGL Laser Measurement Systems GmbH
Topcon Positioning Systems
Trimble

PC/laptop/handheld computer

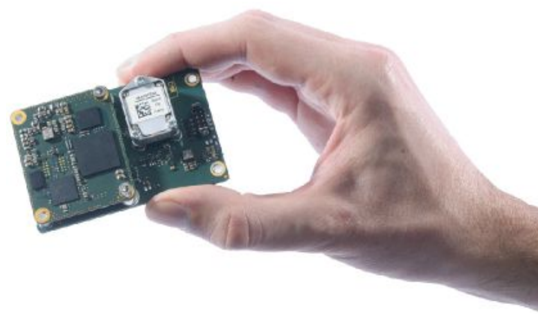
4P Mobile Data Processing
Applanix
Baseband Technologies Inc.
Beijng UniStrong Science & Technology
ComNav Technology
DataGrid Inc.
DeLorme
Furuno USA Inc.
Garmin International
Geodetics Inc.
Global Navigation Software

SBG Systems

SBG Systems is a leading manufacturer of Inertial Measurement Units (IMU), Attitude and Heading Reference Systems (AHRS), and Inertial Navigation Systems coupled with GNSS (INS/GNSS). With more than 10 years of experience in inertial navigation, the company has recently completed its offer with Qinertia, the in-house INS/GNSS post-processing software.

New Solution: Quanta UAV

Quanta UAV is the result of SBG's expertise in both miniaturized technology for drone navigation and high end sensors for mobile mapping. Designed as a geo-referencing solution for UAV, it can also be used as a high-end navigation solution to feed the UAV autopilot. Quanta is available at two different level of accuracy and comes with a 1-year free license of Qinertia post-processing software.



New solution within the Advanced Inertial Navigation Systems

SBG Systems offers two integrated survey-grade INS/GNSS product lines: the Ekinox and the Apogee Series. If the Ekinox offers a smart size/price/performance ratio, the Apogee is highly versatile and fits multiple applications. With a 8GB datalogger, these inertial navigation systems are ideal for surveying applications. The modern and intuitive embedded web interface guides the operator in the simplest way using 3D view.

The brand new Navsight Marine Solution has been designed to make hydrographers' life easier. It consists in an Inertial Measurement Unit available as Ekinox or Apogee grade and connects to Navsight, a rugged processing unit embedding the fusion intelligence and the GNSS receiver.

INS/GNSS Post-processing with Qinertia

Last year, SBG Systems took a major step in the surveying industry by unveiling Qinertia , its in-house post-processing software. After the survey, this full-feature software gives access to offline RTK corrections, and process inertial and GNSS raw data to further enhance accuracy and secure the survey.

SBG Systems
1, avenue Eiffel
78420 Carrières-sur-Seine
France

Phone:
+33180884500

Fax:
+33180884501

Email:
contact@sbg-systems.com

Web:
www.sbg-systems.com

Co.
Handheld USA Inc.
ikeGPS Inc.
John Deere AMS
Juniper Systems Limited
KCS BV
Leica Geosystems AG
Maxim Integrated Products
Novariant
PCTEL
Racelogic Labsat
TomTom
Topcon Positioning Systems
Trimble

Sonar
Applanix
Furuno USA Inc.
Garmin International

Time and frequency stability
GPS Source Inc.
Orolia
Oscilloquartz SA
Rakon
Spectratime

Variable-rate controllers
GPS Source Inc.
John Deere AMS
NavCom, A John Deere Company
Topcon Positioning Systems
Trimble

Videography (including time/position captioning)
Applanix
Harxon Corporation
ikeGPS Inc.
JAVAD GNSS Inc.
PCTEL
Remote GeoSystems Inc.
Topcon Positioning Systems
Trimble

Wireless communications
Allis Communications Co., Ltd.
Applanix
Beijer Electronics
Beijng UniStrong Science & Technology
Broadcom Corporation
ComNav Technology
DeLorme
Falcom USA
FEI-Zyfer Inc.
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Globalsat Technology Corporation
GPS Antennas.com
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Satel Survey USA
Skyworks Solutions Inc.
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Spectrum Instruments Inc.
Tallysman Wireless
Telit
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TRAK Microwave
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INTEGRATED NAVIGATION EQUIPMENT
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Swift Navigation
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TeleOrbit GmbH
Tersus GNSS
Trimble
UTC Aerospace Systems
VectorNav Technologies
Xsens
ZMicro

Dead reckoning
Advanced Navigation
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Broadcom Corporation
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Garmin International
GlobalTop Technology Inc.
Honeywell
IFEN GmbH
Inertial Sense INC.
KCS BV
M3 Systems
Motorola
NavSys Corporation
NovAtel
NVS Technologies AG
Racelogic Labsat
Systron Donner Inertial
TeleOrbit GmbH
Thales
TomTom
Trimble
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Geodetics Inc.
GlobalTop Technology Inc.
Harris Corporation
Honeywell
IFEN GmbH
Inertial Sense INC.
KCS BV
KVH Industries
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NavSys Corporation
NovAtel
Orolia
Physical Logic
PNI Sensor Corporation
Racelogic Labsat
Reelektronika B.V.
SBG Systems
Sensonor
Sparton
Spirent Communications
Spirent Federal Systems
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UTC Aerospace Systems
VectorNav Technologies
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Microwave Photonic Systems
NVS Technologies AG
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MAPPING
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Juniper Systems Limited
Laser Technology Inc.
Lidar USA
NavCom, A John Deere Company
Nearmap
Oxford Technical Solutions
Phase One Industrial
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Propeller Aero
Remote GeoSystems Inc.
RIEGL Laser Measurement Systems GmbH
Rockwell Collins
SoftNav Systems Inc.
Spectra Precision
Tersus GNSS
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Janus Remote Communications
John Deere AMS
Leica Geosystems AG
Rojone Pty. Ltd.
Topcon Positioning Systems
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Digital mapbases
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Applanix
Azimap
C-Nav
deCarta
DeLorme
DigitalGlobe
Furuno USA Inc.
Garmin International
Global Navigation Software Co.
i-cubed LLC
ikeGPS Inc.
Trimble

Geographic information systems (GIS)
ALLSAT GmbH
AMC Inc.
Applanix
Azimap
CHC Navigation
ComNav
DeLorme
Eos Positioning Systems
Geodetics Inc.
Global Navigation Software Co.
i-cubed LLC
ikeGPS Inc.
John Deere AMS

Skydel

An Orolia Company

Skydel brings a new paradigm to the market for GNSS simulations. At Skydel, we firmly believe that our products, which combine innovative software algorithms and COTS hardware, create the best GNSS simulation solutions for engineers and scientists.

Skydel's team of GNSS experts aim to provide the absolute best customer experience coupled with innovative solutions. Thus, each new project starts with a thorough understanding of the client's business objectives, simulation needs, and technical challenges. With Orolia, Skydel covers a wide range of markets worldwide, and possesses a network of partners and value-added resellers that enhances its simulation offering.

Combining GPU-accelerated computing, field-upgradable software-defined radios (SDR), and COTS hardware, our simulation products generate signals in real-time, with uncompromising performance for the most demanding use cases. This approach provides our clients with a multitude of benefits: easy upgrades, COTS-based scalability, and hardware repurposing to share with other RF applications, to name but a few.

SDX: Software-Defined GNSS Simulator

SDX is our multi-frequency, multi-constellation GNSS simulator. With a 1000 Hz simulation iteration rate, SDX delivers the industry's highest performance in terms of precision, resolution, and ultra-high dynamic motion. The software-defined architecture of SDX offers massive signal simulation capabilities. For example, hundreds of satellites can be simulated in real-time using a COTS graphic card.

SDX features differential GNSS, integrated dynamic interference generation, intuitive automation tools, military codes, a powerful API (Python, C# and C++ open source client), on-the-fly scenario re-configuration, 6DoF receiver trajectories, and much more.

The unique architecture of SDX enables many possible configurations. The simulator is available as a software-only, as one of many turnkey configurations, and adaptive antenna (CRPA) test systems. SDX-based solutions are scalable and easily upgraded.

Skydel believes that being responsive when clients require support or technical assistance is of the utmost importance. Skydel is a modern and agile company that constantly improves its products and services. Our solutions are designed to be intuitive, flexible, and user-centered.

SKYDEL

Skydel
WeWork 5th Floor
(Orolia Canada)
1275 Av des Canadiens-de-Montréal
Montréal (Québec)
H3B 0G4

Phone:
+1 438 239 7924

Email:
sales@skydelsolutions.com

Web:
www.skydelsolutions.com

Juniper Systems Limited
Laipac Technology Inc.
Laser Technology Inc.
Leica Geosystems AG
Lidar USA
Nearmap
Novariant
Remote GeoSystems Inc.
Silicom
Sokkia Corporation
Spectra Precision
TeleType GPS
Topcon Positioning Systems
Trimble

Imagery
AMC Inc.
Applanix
Azimap
ComNav
deCarta
DeLorme
DigitalGlobe
Geodetics Inc.
Global Navigation Software Co.
i-cubed LLC
ikeGPS Inc.
John Deere AMS
Leica Geosystems AG
Lidar USA
Nearmap
Racelogic Labsat
SoftNav Systems Inc.
Topcon Positioning Systems
Trimble

Interfaces
ALLSAT GmbH
Applanix
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Remote GeoSystems Inc.
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SoftNav Systems Inc.
Topcon Positioning Systems
Trimble

Market analyses/reports
Azimap
Racelogic Labsat

Systems
ALLSAT GmbH
Applanix
Azimap
DeLorme
Geodetics Inc.
Global Navigation Software Co.
ikeGPS Inc.
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Juniper Systems Limited
NavCom, A John Deere Company
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Remote GeoSystems Inc.
RIEGL Laser Measurement Systems GmbH
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Travel information databases
AMC Inc.
DeLorme
ITRAK Corporation
TeleType GPS

PHOTOGRAMMETRY/GPS INTEGRATED SYSTEMS
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DeLorme
DigitalGlobe
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KVH Industries
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Oxford Technical Solutions
Phase One Industrial
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Ricoh Americas Corporation
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UTC Aerospace Systems

PRECISE EPHEMERIS INFORMATION
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Topcon Positioning Systems
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PUBLICATIONS, GUIDES, VIDEOS, TRAINING SOFTWARE, ETC.
Artech House Publishers
ComNav
i-cubed LLC
Institute of Navigation (ION)
iP-Solutions, Japan
John Deere AMS
Leica Geosystems AG
Rockwell Collins
Spirent Communications
Topcon Positioning Systems
Trimble
ZMicro

RECEIVER COMPONENTS
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Borealis Precision
GPS Networking Inc.
GPS Source Inc.
Greenray Industries
Hemisphere GNSS
iCONN Systems
INSTOCK Wireless Components Inc.
KCS BV
Microwave Photonic Systems
NavCom, A John Deere Company
Orolia
Oscilloquartz SA
Parsec Technologies Inc.
Polynesian Exploration Inc
Rakon
Satel Oy
SkyTraq Technology Inc.
STMicroelectronics
Telit
Tersus GNSS
Trimble

Alphanumeric displays
Furuno USA Inc.
ikeGPS Inc.
John Deere AMS
Topcon Positioning Systems
Trimble

Bandpass filters
Broadcom Corporation
GPS Networking Inc.
Maxim Integrated Products
Microwave Photonic Systems
Reelektronika B.V.
Rojone Pty. Ltd.
Silicom

Chips/ICs
Antenova Ltd.
Baseband Technologies Inc.
Broadcom Corporation
CellGuide Ltd.
CSR plc
Furuno USA Inc.
Janus Remote Communications
Japan Radio Co. Ltd.
Linx Technologies
Maxim Integrated Products
Motorola
NavCom, A John Deere Company
Parsec Technologies Inc.
QUALCOMM Inc.
Racelogic Labsat
Reelektronika B.V.
SigNav Pty. Ltd.
SkyTraq Technology Inc.
STMicroelectronics
Topcon Positioning Systems
Trimble
u-blox AG

Graphical displays
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Geodetics Inc.
ikeGPS Inc.
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Novariant
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Topcon Positioning Systems
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Interfaces
Baseband Technologies Inc.
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ComNav Technology
Furuno USA Inc.
Geodetics Inc.
Harxon Corporation
ikeGPS Inc.
Maxim Integrated Products
NavCom, A John Deere Company
Racelogic Labsat
Topcon Positioning Systems
Trimble
Trimble Integrated Technologies

Modules
Allis Communications Co., Ltd.
Baseband Technologies Inc.
Broadcom Corporation
CellGuide Ltd.
ComNav Technology
DeLorme
Falcom USA
FEI-Zyfer Inc.
Furuno USA Inc.
Geodetics Inc.
Globalsat Technology Corporation
Gutec AB
Hemisphere GNSS
Honeywell
Impact Power Inc.
Inventek Systems
Jackson Labs Technologies Inc.
Japan Radio Co. Ltd.
John Deere AMS
KCS BV
Laipac Technology Inc.
Linx Technologies
Maxim Integrated Products
Micro Modular Technologies
Microwave Photonic Systems
Motorola
NavCom, A John Deere Company
NVS Technologies AG
OriginGPS
Oscilloquartz SA
Parsec Technologies Inc.
Racelogic Labsat
Raytheon Space and Airborne Systems
Rojone Pty. Ltd.
Satel Oy
SigNav Pty. Ltd.
SkyTraq Technology Inc.
Spectratime
TeleOrbit GmbH
Telit
Thales
Topcon Positioning Systems
TRAK Microwave
Trimble
Trimble Integrated Technologies
u-blox AG

Quartz crystals
FEI-Zyfer Inc.
Greenray Industries
Janus Remote Communications
Maxim Integrated Products
Oscilloquartz SA
Rakon
Spectratime
Time & Frequency Solutions Ltd.

RF amplifiers/preamplifiers
Allis Communications Co., Ltd.
Broadcom Corporation
EndRun Technologies
GPS Networking Inc.
GPS Networking Inc.
GPS Source Inc.
Harxon Corporation

Spirent Federal

GNSS Simulators

With 30+ years of GPS/GNSS simulation experience, Spirent provides simulators that incorporate the high levels of quality, accuracy, fidelity, and reliability with unparalleled performance and customer support. Spirent Federal continues to support US Government and its contractors by being the first to provide new GPS/GNSS signals as they become available. Our dedication to being the first to deliver innovative products and services that meet our customers' needs is why Spirent is the world's leading provider of GPS/GNSS test equipment.

GSS9000

The Spirent GSS9000 Multi-Frequency, Multi-GNSS RF Constellation Simulator is Spirent's most comprehensive simulation solution. It can simulate signals from all GNSS and regional navigation systems and has a system iteration rate (SIR) of 1000 Hz (1 ms), enabling higher dynamic simulations with more accuracy and fidelity. The GSS9000 supports restricted/classified signals. Users can evaluate the resilience of navigation systems to interference and spoofing attacks, and have the flexibility to reconfigure constellations, channels, and frequencies between test runs or test cases.

SimMNSA

SimMNSA allows authorized users to simulate true M-code for the first time ever. SimMNSA has been successfully delivered to users for the GSS9000 series simulator. SimMNSA has been granted Security Approval by the Global Positioning System Directorate.

CRPA Test System

Spirent's Controlled Reception Pattern Antenna (CRPA) Test System generates both GNSS and interference signals. Users can control multiple antenna elements. Null-steering and space/time adaptive CRPA testing are both supported by this comprehensive approach.

Anechoic Chamber Testing

Spirent's GSS9790 Multi-Output, Multi-GNSS RF Constellation Wave-Front Simulator System is a development of the GSS9000. The GSS9790 is a unique solution providing the core element for GNSS applications that require a test system that can be used in both conducted (lab) and radiated (chamber) conditions.

Mid-Range Solutions

Spirent also offers solutions that cater to intermediate GPS/GNSS testing needs. The GSS7000 multi-constellation simulator provides an easy-to-use solution for GNSS testing that can grow with users' requirements. The GSS6450 RF record & playback system enables replay of a real-world GNSS/GPS test repeatedly in the lab.

Spirent Federal Systems
1402 W. State Rd
Pleasant Grove, UT 84062

Phone:
801-785-1448

Fax:
801-785-1294

Email:
gnssinfo@spirentfederal.com

Web:
www.spirentfederal.com

Key contacts:

Jeff Martin
VP Sales
Jeff.Martin@spirentfederal.com
801-523-5991

Kalani Needham
Sales West
Kalani.Needham@spirentfederal.com
801-987-3450

Tyson Gurney
Sales East
Tyson.Gurney@spirentfederal.com
801-678-0276

Jeff Jordan
Sales West
Jeff.Jordan@spirentfederal.com
949-885-6010

Impact Power Inc.
Maxim Integrated Products
Microwave Photonic Systems
NavCom, A John Deere Company
Parsec Technologies Inc.
PCTEL
Rakon
Reelektronika B.V.
Rojone Pty. Ltd.
Silicom
STMicroelectronics
Tallysman Wireless
Topcon Positioning Systems

Rubidium oscillators
Orolia
Oscilloquartz SA
Rakon
Spectratime

RECEIVER PERFORMANCE ANALYSIS
Averna
Baseband Technologies Inc.
Borealis Precision
Broadcom Corporation
CAST Navigation LLC
Geodetics Inc.
ikeGPS Inc.
Janus Remote Communications
Leica Geosystems AG
M3 Systems
NavSys Corporation
Rohde & Schwarz
Silicom
Spirent Communications
Spirent Federal Systems
Talen-X
TeleOrbit GmbH
Topcon Positioning Systems
Trimble

RECEIVERS
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Baseband Technologies Inc.
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CHC Navigation
ComNav
ComNav Technology
Effigis Geo Solutions Inc.
Emlid Ltd.
Eos Positioning Systems
F4 Tech
Foxcom
Galileo Satellite Navigation
Geneq Inc.
Geodetics Inc.
GEOsat GmbH
GEOSTAR NAVIGATION LTD.
GPS Source Inc.
Greenray Industries
Hemisphere GNSS
Inertial Sense INC.
Infospectrum
iP-Solutions, Japan
Jackson Labs Technologies Inc.
JAVAD GNSS Inc.
Juniper Systems Limited
KCS BV
Lockheed Martin
M3 Systems
Microlab
Multicom Inc.
NavCom, A John Deere Company
NovAtel
NVS Technologies AG
Optical Zonu Corp.
Orolia
Oscilloquartz SA
Precise Time and Frequency LLC
Rakon
RFOptic
RIEGL Laser Measurement Systems GmbH
Rockwell Collins
Rokubun S.L.
Satel Oy
Satlab Geosolutions
Septentrio Satellite Navigation
SkyTraq Technology Inc.
Skyworks Solutions Inc.
STMicroelectronics
Suzhou Foif Co. Ltd.
Swift Navigation
Synergy Systems LLC
Syntony
TeleOrbit GmbH
Telit
Tersus GNSS
Trimble
Unicore Communications Inc.

Attitude/direction finding
Applanix
ComNav
DataGrid Inc.
DeLorme
Falcom USA
ftech Corporation
Furuno USA Inc.
Geodetics Inc.
Globalsat Technology Corporation
GlobalTop Technology Inc.
Harxon Corporation
Hemisphere GNSS
ikeGPS Inc.
Inertial Sense INC.
Inventek Systems
JAVAD GNSS Inc.
KCS BV
NavCom, A John Deere Company
NavSync Ltd.
NavSys Corporation
Novariant
NovAtel
Orolia
PNI Sensor Corporation
Rojone Pty. Ltd.
Septentrio Satellite Navigation
SkyTraq Technology Inc.
Surrey Satellite Technology Ltd.
Swift Navigation
TeleOrbit GmbH
Trimble
Trimble Integrated Technologies
Unicore Communications Inc.

Automatic vehicle location
Applanix
Broadcom Corporation
Communication & Navigation (C&N)
ComNav
Falcom USA
ftech Corporation
Geodetics Inc.
GlobalTop Technology Inc.
GPS Insight LLC
Infospectrum
Inventek Systems
ITRAK Corporation
Japan Radio Co. Ltd.
John Deere AMS
KCS BV
Laipac Technology Inc.
M3 Systems
Maxim Integrated Products
Motorola
Novariant
NVS Technologies AG
QinetiQ Ltd.
Rojone Pty. Ltd.
Swift Navigation
Topcon Positioning Systems
Trimble
u-blox AG
Unicore Communications Inc.

Aviation
BAE Systems Rokar
Communication & Navigation (C&N)
ComNav
Esterline CMC Electronics
Falcom USA
FEI-Zyfer Inc.
Garmin International
Geodetics Inc.
Harris Corporation
Harxon Corporation
Honeywell
Infospectrum
Jackson Labs Technologies Inc.
JAVAD GNSS Inc.
KCS BV
Maxim Integrated Products
Microsemi Corporation
Multicom Inc.
NavCom, A John Deere Company
NovAtel
NVS Technologies AG
Racelogic Labsat
Raytheon Space and Airborne Systems
Rojone Pty. Ltd.
Septentrio Satellite Navigation
Swift Navigation
Thales
Topcon Positioning Systems
Trimble Integrated Technologies
Unicore Communications Inc.

Computer GPS cards/ modules
Antenova Ltd.
Baseband Technologies Inc.
Brandywine Communications
Broadcom Corporation
ComNav Technology
DataGrid Inc.
DeLorme
Garmin International
Geodetics Inc.
ikeGPS Inc.
Infospectrum
Inventek Systems
Jackson Labs Technologies Inc.
Juniper Systems Limited
KCS BV
Maxim Integrated Products
NavCom, A John Deere Company
NVS Technologies AG
Orolia
QinetiQ Ltd.
Racelogic Labsat
Raytheon Space and Airborne Systems
Rojone Pty. Ltd.
Telit
TomTom
Trimble
u-blox AG
Unicore Communications Inc.

Digital signal processor integrated chips (DSP-IC)
Baseband Technologies Inc.
CellGuide Ltd.
NavCom, A John Deere Company
QUALCOMM Inc.
Rojone Pty. Ltd.
TeleOrbit GmbH
Trimble

Geodetic/geophysical
Applanix
CHC Navigation
C-Nav
ComNav
ComNav Technology
DataGrid Inc.
Geodetics Inc.
Harris Corporation
IFEN GmbH
JAVAD GNSS Inc.
Leica Geosystems AG
NavCom, A John Deere Company
NavSync Ltd.
NVS Technologies AG
Orolia
Racelogic Labsat
Rojone Pty. Ltd.
Septentrio Satellite Navigation
Sokkia Corporation
Topcon Positioning Systems
Trimble
Unicore Communications Inc.

Handheld
Altus Positioning Systems
Applanix
Beijer Electronics
Beijng UniStrong Science & Technology
Broadcom Corporation
CellGuide Ltd.
CHC Navigation
ComNav
ComNav Technology
DeLorme
Effigis Geo Solutions Inc.
Emlid Ltd.
F4 Tech
Falcom USA
ftech Corporation
Garmin International
Geneq Inc.
Geodetics Inc.
GEOsat GmbH
GlobalTop Technology Inc.
Greenray Industries
Harris Corporation
Hemisphere GNSS
Honeywell
ikeGPS Inc.
Infospectrum

Syntony-GNSS

The Company

Syntony is a company specialized in the design and manufacturing of a full range of positioning, navigation and timing (PNT) products and solutions. Our expertise is evenly used in various scientific domains (labs, universities and research centers worldwide), advanced aeronautic applications, space, defense, telecoms, IoT and transportation.

Syntony has its headquarters in Toulouse (France), offices in New York (NY, USA) and San Francisco (CA, USA) and representation in India, China and South Korea, Japan, Singapore, USA, Israel and Germany (new reps are welcome).

R&D

Syntony's highly innovative products and solutions are inheriting from over 15 years of R&D in radiofrequency, electronics and GNSS signal processing. Because we believe that innovation means nothing if there is no business benefit for our customers, we continuously invest in new developments that will improve our clients' performance and business experience. Since the beginning, Syntony has dramatically improved the design and performance of its original line of products (***Constellator*** and ***Echo***), but also launched fundamentally innovative underground location solutions namely ***SubWave*** and ***SubWave+*** that propose revolutionary and fully deployable underground location solutions for public transport (metros, trains, busses), and infrastructures (tunnels, underground parking, mining…). Syntony is also at the origin of unique GNSS receivers embedded in aerospace vehicles, as in land vehicles.

The products

Our products are already or will soon be part of your daily life, being now core to leading companies' programs and developments, as Syntony will have delivered more than one hundred high performance signal generators over the past 12 months, all over the world:

Echo R&P, our highest fidelity GNSS signal Record and Playback system, is now, for example, on board with the Aeronautics Giants, flight testing with the Single Aisle aircraft program of an industry leader.

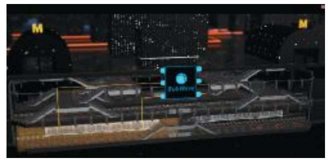
Constellator, our most advanced and versatile GNSS simulator, has been selected to bench test the receivers of the next Giant 900+ satellite constellation launched in the USA, being also (according to one source) the "best value for money" worldwide solution and "highest generated signal fidelity."

SubWave, our GPS zone-based Underground Location Solution, is now the backbone of the largest Scandinavian metro operator's safety environment and is now complemented by SubWave+, the only real-time and high-precision underground location solution offering 100% GPS compatibility.

News of this year

Syntony is now one of the few players recognized worldwide on high-end GNSS simulation, especially in aeronautic and space domain: as an example, in addition to Oneweb (US) and ISRO (India), the 3 European satellite manufacturers have now chosen Syntony's simulator for AIT.

Also, thanks to its exciting perspectives on the deep indoor market, Syntony has finalized in 2019 its last fundraising round: 7M$. This will allow Syntony to invest further into its simulator products, to make new steps towards even more affordable and more versatile products.



Syntony-GNSS
France: 5 Chemin de Chèvrefeuille 31300 Toulouse, France

New York: 1251 Avenue of the Americas, 3rd floor, C/O Pramex, New York, NY 10020, USA

California : 535 Mission St. 14th floor, San Francisco, CA 94105, USA

Phone:
+33 (0) 581 319 919
+1 646 799 0101

Email:
contact@syntony-gnss.com

Web:
syntony-gnss.com

Inventek Systems
Juniper Systems Limited
L-3 Interstate Electronics Corporation
Leica Geosystems AG
Maxim Integrated Products
NVS Technologies AG
QinetiQ Ltd.
Raytheon Space and Airborne Systems
Rojone Pty. Ltd.
Suzhou Foif Co. Ltd.
TomTom
Topcon Positioning Systems
Trimble
Unicore Communications Inc.

Land vehicle navigation/route guidance

Applanix
BAE Systems Rokar
Beijng UniStrong Science & Technology
CellGuide Ltd.
CHC Navigation
Communication & Navigation (C&N)
ComNav Technology
DeLorme
Falcom USA
Furuno USA Inc.
Garmin International
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Inventek Systems
Japan Radio Co. Ltd.
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KCS BV
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Leica Geosystems AG
M3 Systems
Maxim Integrated Products
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Novariant
NovAtel
NVS Technologies AG
PCTEL
Racelogic Labsat
Raytheon Space and Airborne Systems
Rojone Pty. Ltd.
Swift Navigation
TeleOrbit GmbH
TeleType GPS
Telit
TomTom
Topcon Positioning Systems
Trimble
Unicore Communications Inc.
USGlobalsat Inc.

Marine

Allis Communications Co., Ltd.
Altus Positioning Systems
Applanix
Baseband Technologies Inc.
Beijer Electronics
Brandywine Communications
CHC Navigation
C-Nav
ComNav
ComNav Technology
DataGrid Inc.
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QinetiQ Ltd.
Rojone Pty. Ltd.
Septentrio Satellite Navigation
Swift Navigation
Thales
Topcon Positioning Systems
Trimble
Trimble Integrated Technologies
u-blox AG
Unicore Communications Inc.

Military

Applanix
BAE Systems Rokar
Baseband Technologies Inc.
Brandywine Communications
CAST Navigation LLC
EndRun Technologies
Falcom USA
FEI-Zyfer Inc.
Geodetics Inc.
GPS Source Inc.
Greenray Industries
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Juniper Systems Limited
KCS BV
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Lockheed Martin
Maxim Integrated Products
Microsemi Corporation
Multicom Inc.
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NavSys Corporation
Northrop Grumman
NovAtel
QinetiQ Ltd.
Racelogic Labsat
Raytheon Space and Airborne Systems
Raytheon UK
Rojone Pty. Ltd.
Silicom
Spectratime
Spectrum Instruments Inc.
Spirent Federal Systems
Thales
Topcon Positioning Systems
TRAK Microwave
Trimble
Trimble Integrated Technologies
UrsaNav Inc.

OEM modules/engines/chipsets

Antenova Ltd.
Applanix
BAE Systems Rokar
Baseband Technologies Inc.
Borealis Precision
Brandywine Communications
Broadcom Corporation
CellGuide Ltd.
CHC Navigation
ComNav
ComNav Technology
CSR plc
DataGrid Inc.
Esterline CMC Electronics
FEI-Zyfer Inc.
ftech Corporation
Furuno USA Inc.
Garmin International
Geodetics Inc.
GEOSTAR NAVIGATION LTD.
GlobalTop Technology Inc.
Harris Corporation
Hemisphere GNSS
Honeywell
Infospectrum
Inventek Systems
Jackson Labs Technologies Inc.
Janus Remote Communications
Japan Radio Co. Ltd.
JAVAD GNSS Inc.
KCS BV
Laipac Technology Inc.
Leica Geosystems AG
Linx Technologies
Loctronix Corp.
Maxim Integrated Products
Motorola
NavCom, A John Deere Company
NovAtel
NVS Technologies AG
OriginGPS
QinetiQ Ltd.
Raytheon Space and Airborne Systems
Reelektronika B.V.
Rojone Pty. Ltd.
Satel Oy
Septentrio Satellite Navigation
SigNav Pty. Ltd.
SkyTraq Technology Inc.
Spectratime
Spectrum Instruments Inc.
Swift Navigation
Telit
Thales
TomTom
Topcon Positioning Systems
TRAK Microwave
Trimble
Trimble Integrated Technologies
u-blox AG
Unicore Communications Inc.
USGlobalsat Inc.

PCMCIA cards

Furuno USA Inc.
Geodetics Inc.
ikeGPS Inc.
John Deere AMS
Rojone Pty. Ltd.

Radio frequency integrated chip (RF-IC)

Antenova Ltd.
Baseband Technologies Inc.
ComNav
Emlid Ltd.
Greenray Industries
Laipac Technology Inc.
Linx Technologies
Maxim Integrated Products
NavCom, A John Deere Company
QUALCOMM Inc.
Rojone Pty. Ltd.
Satel Oy
Silicom
Skyworks Solutions Inc.
STMicroelectronics
TeleOrbit GmbH
Trimble
u-blox AG

Software receivers

Baseband Technologies Inc.
CHC Navigation

Talen-X

Experts in PNT system performance, GNSS simulation and threat mitigation for NAVWAR applications. Talen-X enhances their customer success by providing high quality products at a great value reducing cost, risk, and schedule.

GNSS Simulation

- **BroadSim** - GNSS simulator and jammer used for lab or field testing
- **BroadSim Anechoic** - GNSS simulation system used for anechoic chamber testing
- **BroadSim Wavefront** - CRPA enabled, phase-coherent GNSS simulation system

Anti-Jam and Spoofing Devices

- **ThreatBlocker** - GPS jamming and spoofing detection and protection device

PNT Testing Tools

- **PANACEA** - Automated PNT performance and vulnerability test suite
- **RxStudio** - Real-time GNSS receiver data collection, control and display
- **Panorama** - Visual analysis and reporting tool for GNSS receiver data
- **Valiant 153M** - GB-GRAM/GB-GRAM-M interface test fixture

Simulation, Scaled for Innovation

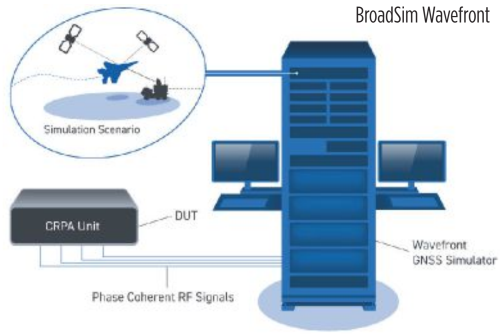
Yesterday's solutions won't fix tomorrow's problems. Our mission is to revolutionize the PNT market through better testing products, providing quicker and more accurate results, which result in the best solutions for our warfighters. With threats growing in complexity and number and our reliance on GNSS signals at an all-time high, there is a need for integrated, automated, and collaborative testing. Thanks to Talen-X's scalable hardware platforms and software-defined architecture, matching these needs has never been easier or more affordable. Talen-X exemplifies this with its most recent achievement, BroadSim Wavefront - a system made to effectively lab test CRPA and multi-element antennas.

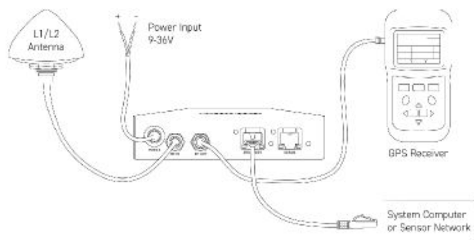
Key features of BroadSim Wavefront include:

- Integrated jamming, spoofing, and repeating
- Scalable architecture from 4 to 16 elements
- Software-defined system using COTS hardware
- Built upon existing SDX GNSS simulation engine
- Real-time continuous phase calibration
- < 1 degree RMS of phase coherency

A BroadSim Wavefront demo system will be exhibited at the 2019 Joint Navigation Conference, July 9-10 in booth #513.

BroadSim Wavefront





ThreatBlocker

BroadSim Anechoic

TALEN-X
COMMUNICATE - NAVIGATE - EXCEL

Talen-X
3916 Dayton Xenia Road
Beavercreek, OH 45432

Phone:
614-246-1077

Email:
sales@talen-x.com

Web:
www.talen-x.com

Galileo Satellite Navigation
Harris Corporation
IFEN GmbH
iP-Solutions, Japan
Loctronix Corp.
M3 Systems
Maxim Integrated Products
NavSys Corporation
Nottingham Scientific Ltd.
NVS Technologies AG
Rojone Pty. Ltd.
Silicom
Swift Navigation
Syntony
TeleOrbit GmbH
Trimble
u-blox AG

Space
BAE Systems Rokar
Baseband Technologies Inc.
Borealis Precision
C-Nav
ComNav Technology
DataGrid Inc.
FEI-Zyfer Inc.
Galileo Satellite Navigation
Geodetics Inc.
Harris Corporation
JAVAD GNSS Inc.
Lockheed Martin
M3 Systems
Microsemi Corporation
NavSys Corporation
NovAtel
Rojone Pty. Ltd.
Silicom
Spectratime
Surrey Satellite Technology Ltd.
Swift Navigation
Syntony
TRAK Microwave
Trimble

Surveying
Allis Communications Co., Ltd.
Applanix
CHC Navigation
C-Nav
ComNav
ComNav Technology
DataGrid Inc.
Emlid Ltd.
Eos Positioning Systems
Geodetics Inc.
Harris Corporation
Harxon Corporation
Hemisphere GNSS
IFEN GmbH
JAVAD GNSS Inc.
Juniper Systems Limited
Leica Geosystems AG
NavCom, A John Deere Company
NovAtel
RIEGL Laser Measurement Systems GmbH
Rojone Pty. Ltd.
Satlab Geosolutions
Septentrio Satellite Navigation
Sokkia Corporation
Spectra Precision
Suzhou Foif Co. Ltd.
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Topcon Positioning Systems
Trimble
u-blox AG
Unicore Communications Inc.

Surveying/GIS
Allis Communications Co., Ltd.
Applanix
Beijng UniStrong Science & Technology
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ComNav
ComNav Technology
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Rojone Pty. Ltd.
Satel Oy
Sokkia Corporation
Spectra Precision
Suzhou Foif Co. Ltd.
Topcon Positioning Systems
Trimble

Surveying/RTK
Allis Communications Co., Ltd.
Applanix
CHC Navigation
C-Nav
ComNav
ComNav Technology
DataGrid Inc.
Emlid Ltd.
Eos Positioning Systems
Geneq Inc.
Geodetics Inc.
Geomatics USA
GEOSTAR NAVIGATION LTD.
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Harxon Corporation
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IFEN GmbH
Inertial Sense INC.
JAVAD GNSS Inc.
John Deere AMS
Leica Geosystems AG
NavCom, A John Deere Company
Novariant
NovAtel
NVS Technologies AG
Racelogic Labsat
Rojone Pty. Ltd.
Satel Oy
SkyTraq Technology Inc.
Sokkia Corporation
Spectra Precision
Suzhou Foif Co. Ltd.
Swift Navigation
Topcon Positioning Systems
Trimble
Trimble Integrated Technologies
Unicore Communications Inc.

Timing
Allis Communications Co., Ltd.
Arbiter Systems Inc.
Brandywine Communications
Broadcom Corporation
ComNav
EndRun Technologies
ESE
FEI-Zyfer Inc.
ftech Corporation
Furuno USA Inc.
GlobalTop Technology Inc.
GPS Source Inc.
Greenray Industries
Harris Corporation
Harxon Corporation
Impact Power Inc.
Jackson Labs Technologies Inc.
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Microlab
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NovAtel
NVS Technologies AG
Orolia
Oscilloquartz SA
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Precise Time and Frequency LLC
QinetiQ Ltd.
Rojone Pty. Ltd.
Septentrio Satellite Navigation
SigNav Pty. Ltd.
SkyTraq Technology Inc.
Spectratime
Spectrum Instruments Inc.
Synergy Systems LLC
Tallysman Wireless
Telit
Thales
Time & Frequency Solutions Ltd.
TRAK Microwave
Trimble
u-blox AG
Unicore Communications Inc.

Tracking
Allis Communications Co., Ltd.
Antenova Ltd.
Applanix
Baseband Technologies Inc.
Blue Sky Network
CellGuide Ltd.
Communication & Navigation (C&N)
ComNav
ComNav Technology
CSR plc
DeLorme
Falcom USA
ftech Corporation
Furuno USA Inc.
Geneq Inc.
Geodetics Inc.
GEOsat GmbH
GEOSTAR NAVIGATION LTD.
Globalsat Technology Corporation
GlobalTop Technology Inc.
GPS Flight
GPSTrackit.com
Harris Corporation
ikeGPS Inc.
Infospectrum
Inventek Systems
Japan Radio Co. Ltd.
JAVAD GNSS Inc.
John Deere AMS
Juniper Systems Limited
KCS BV
L-3 Interstate Electronics Corporation
Laipac Technology Inc.
M3 Systems
Maxim Integrated Products
Microsemi Corporation
NavCom, A John Deere Company
NavSys Corporation
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Raytheon Space and Airborne Systems
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Silicom
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Synergy Systems LLC
Syntony
Tallysman Wireless
TeleOrbit GmbH
Telit
Topcon Positioning Systems
Trimble
u-blox AG
Unicore Communications Inc.

SATELLITE SIGNAL SIMULATORS/ PSEUDOLITES
BAE Systems Rokar
Baseband Technologies Inc.
Borealis Precision
Broadcom Corporation
CAST Navigation LLC
Cobham AvComm (formerly Aeroflex)
Galileo Satellite Navigation
Harxon Corporation
IFEN GmbH
iP-Solutions, Japan
Jackson Labs Technologies Inc.
L-3 Interstate Electronics Corporation
Loctronix Corp.
M3 Systems
Microwave Photonic Systems
NavSync Ltd.
Nottingham Scientific Ltd.
Novariant
NVS Technologies AG
Orolia
Racelogic Labsat
Rockwell Collins
Rohde & Schwarz
Silicom
Skydel
Spirent Communications

Tersus GNSS Inc.

Tersus is a leading GNSS RTK solution provider. Our engineers have been pioneers in the design of GNSS products to support high-precision positioning applications. Our products include GNSS RTK & PPK OEM boards and receivers, as well as integrated solutions such as the David GNSS Receiver, Oscar GNSS Receiver, MatrixRTK, and GNSS-aided Inertial Navigation System. Designed for easy and rapid integration, our GNSS solutions offer centimeter-level positioning accuracy and flexible interfaces for a variety of applications including: unmanned aerial vehicle (UAVs), surveying, mapping, construction engineering, and precision agriculture.

Oscar GNSS Receiver

The Oscar GNSS Receiver is a new generation GNSS RTK system. It supports calibration-free tilt compensation function; leveling pole is not required. The calibration-free tilt compensation technology makes surveying easier and improves efficiency for field work. Test and go is realized. Equipped with a built-in high sensitivity tilt sensor and the combination of GNSS and IMU technology, it can eliminate the disadvantages of the cumbersome process of calibration, as well as provide reliability and defense against geomagnetic disturbances.

Easy configuration with a 1.54-inch big interactive screen on Ultimate and Advanced versions. With an internal high-performance multi-constellation and multi-frequency GNSS board, the Oscar GNSS Receiver can provide high accuracy and stable signal detection to ensure centimeter-level positioning. Oscar integrates a GNSS antenna, a Bluetooth module, and a 4G network module. The high-performance antenna can speed up the time to first fix (TTFF) and improve anti-jamming performance.

Oscar equips smart lithium batteries which can detect electricity and display the power level intelligently. The built-in large capacity battery is detachable, two batteries support up to 16 hours of fieldwork in RTK mode.

David GNSS Receiver

The Tersus David is a cost-efficient, palm-sized GNSS receiver designed for surveying UAVs, AGVs and agricultural applications. Working with an external GNSS antenna, the free Tersus Survey App and post-processing software, the David GNSS receiver is a low-cost solution for all survey applications, including real-time RTK positioning and data collection for PPK.

A 4GB onboard embedded multimedia card (eMMC) makes it easy to save data for post processing. The compact size, IP67-rated enclosure and external Bluetooth module alleviates most of the inconveniences encountered in field work.

TERSUS

Tersus GNSS Inc.
Room 210, Building 01, Lane 666, Zhangheng Road, Pudong District, Shanghai, P.R.China.

Phone:
0086 21 58460122

Fax:
0086 21 50803101

Email:
sales@tersus-gnss.com

Web:
www.tersus-gnss.com

Spirent Federal Systems
Syntony
Talen-X
TeleOrbit GmbH
Tersus GNSS

SECURITY CODE DECRYPTION DEVICES
Baseband Technologies Inc.
KCS BV
Raytheon Space and Airborne Systems
Retail Secure
ZMicro

SEMINARS/TRAINING
ALLSAT GmbH
Broadcom Corporation
Communication & Navigation (C&N)
DeLorme
Falcom USA
Furuno USA Inc.
Institute of Navigation (ION)
John Deere AMS
Leica Geosystems AG
NavCom, A John Deere Company
NavtechGPS
Oscilloquartz SA
Satel Oy
Space Foundation
Spectratime
Topcon Positioning Systems
Trimble
u-blox AG

SOFTWARE
Azimap
Baseband Technologies Inc.
CHC Navigation
Clark Labs
ComNav
ComNav Technology
Effigis Geo Solutions Inc.
Forsberg Services
Geodetics Inc.
Geomatics USA
GEOsat GmbH
GPS Antennas.com
Industrial SkyWorks
JAVAD GNSS Inc.
KCS BV
L3 Technologies
Laser Technology Inc.
M3 Systems
NavCom, A John Deere Company
NovAtel
Orolia
Oscilloquartz SA
Phase One Industrial
Propeller Aero
Remote GeoSystems Inc.
Rewire Security
Rockwell Collins
Rokubun S.L.
SBG Systems
Skydel
SoftNav Systems Inc.
Swift Navigation
Syntony
Talen-X
TeleOrbit GmbH
TerraGo
Trimble

Coordinate conversion
ALLSAT GmbH
AMC Inc.
Azimap
Best-Fit Computing Inc.
CHC Navigation
DataGrid Inc.
DeLorme
Effigis Geo Solutions Inc.
Geodetics Inc.
i-cubed LLC
Inventek Systems
JAVAD GNSS Inc.
Leica Geosystems AG
NavCom, A John Deere Company
NovAtel
NVS Technologies AG
Polaris Wireless
Sokkia Corporation
Telogis Fleet Management Software
Topcon Positioning Systems
Trimble

Geodetic surveying
ALLSAT GmbH
AMC Inc.
Applanix
Best-Fit Computing Inc.
CHC Navigation
ComNav Technology
DataGrid Inc.
Effigis Geo Solutions Inc.
Geodetics Inc.
Global Navigation Software Co.
JAVAD GNSS Inc.
Leica Geosystems AG
NavCom, A John Deere Company
Rockwell Collins
Sokkia Corporation
Spectra Precision
Topcon Positioning Systems
Trimble

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Baseband Technologies Inc.
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ikeGPS Inc.
Infospectrum
KCS BV
NavSync Ltd.
NVS Technologies AG
Polaris Wireless
Remote GeoSystems Inc.
Ricoh Americas Corporation
Rockwell Collins
Trimble
u-blox AG

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ALLSAT GmbH
AMC Inc.
Applanix
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CHC Navigation
Clark Labs
C-Nav
Communication & Navigation (C&N)
DeLorme
F4 Tech
Geodetics Inc.
GEOsat GmbH
GPS2CAD
i-cubed LLC
ikeGPS Inc.
JAVAD GNSS Inc.
Laser Technology Inc.
Leica Geosystems AG
NavSync Ltd.
Remote GeoSystems Inc.
Telogis Fleet Management Software
Topcon Positioning Systems
Trimble

GPS-related Internet applications (mapping, navigation, tracking, etc.)
ALLSAT GmbH
AMC Inc.
Applanix
Baseband Technologies Inc.
CHC Navigation
C-Nav
ComNav
ComNav Technology
deCarta
DeLorme
Falcom USA
Geodetics Inc.
Geotab
Global Navigation Software Co.
Globalsat Technology Corporation
GPS Insight LLC
GPSTrackit.com
Harxon Corporation
i-cubed LLC
ikeGPS Inc.
Infospectrum
Inventek Systems
ITRAK Corporation
John Deere AMS
KCS BV
L3 Technologies
Laipac Technology Inc.
Leica Geosystems AG
M3 Systems
NavSync Ltd.
NavSys Corporation
Novariant
Polaris Wireless
Position Logic
QinetiQ Ltd.
Racelogic Labsat
Remote GeoSystems Inc.
Rewire Security
Rockwell Collins
Rojone Pty. Ltd.
Silicom
SoftNav Systems Inc.
TeleOrbit GmbH
TeleType GPS
Telit
Telogis Fleet Management Software
TerraGo
TomTom
Topcon Positioning Systems
Track Your Truck
Trimble
u-blox AG

Mapping
ALLSAT GmbH
AMC Inc.
Applanix
Azimap
Baseband Technologies Inc.
Blue Sky Network
CHC Navigation
C-Nav
Communication & Navigation (C&N)
ComNav
ComNav Technology
deCarta
DeLorme
Furuno USA Inc.
Garmin International
Geodetics Inc.
Global Navigation Software Co.
GPSTrackit.com
i-cubed LLC
ikeGPS Inc.
JAVAD GNSS Inc.
John Deere AMS
Laipac Technology Inc.
Laser Technology Inc.
Leica Geosystems AG
NavSync Ltd.
Novariant
PeopleNet
Polaris Wireless
Remote GeoSystems Inc.
Rewire Security
Rockwell Collins
Rojone Pty. Ltd.
Silicom
SoftNav Systems Inc.
Sokkia Corporation
Spectra Precision
TeleType GPS
Telogis Fleet Management Software
TerraGo
TomTom
Topcon Positioning Systems
Trimble

Mission planning
Applanix
Broadcom Corporation
ComNav
Effigis Geo Solutions Inc.
Esterline CMC Electronics
Global Navigation Software Co.
ikeGPS Inc.
Leica Geosystems AG
NavCom, A John Deere Company
NovAtel
Polaris Wireless
Remote GeoSystems Inc.
Rockwell Collins
Rohde & Schwarz
SoftNav Systems Inc.
Sokkia Corporation
Spirent Communications
Telogis Fleet Management Software
Topcon Positioning Systems
Trimble

Navigation/route guidance
ALLSAT GmbH
AMC Inc.
Applanix
Azimap
Broadcom Corporation
ComNav
ComNav Technology
deCarta
DeLorme
Falcom USA
Furuno USA Inc.
Garmin International
Geodetics Inc.

Topcon Positioning Systems, Inc.

Topcon Positioning Group, is a leading designer, manufacturer and distributor of precision measurement and workflow solutions for the global construction, geospatial and agriculture markets. Topcon has a mission to provide superior end-to-end business solutions by integrating high-precision measurement technology, software and data. Its vision is to improve productivity and workflow to meet global demand for sustainable agriculture and infrastructure.

At the intersection of infrastructure and technology, Topcon provides construction, surveying, engineering and agriculture professionals with the advantages and know-how to be at the forefront of technological innovation to maximize efficiency.

Topcon GNSS receivers fully employ multi-constellation reception and use Universal Tracking channel technology, automatically ensuring optimum reception of all GNSS satellite signals.

Other Topcon groundbreaking technologies include high-speed precision grading, hybrid GNSS positioning systems with sub-centimeter accuracy, and advanced crop sensing and nutrition application control, improving productivity and conservation worldwide.

Construction automation depends upon Topcon high-precision GNSS, total stations, motion sensors and equipment control technology to enable grading and excavation based on pre-configured 3D design data that produces accurate work regardless of the operator's skill level. Automation increases productivity, conserves energy, resolves labor shortages, optimizes costs, and reduces CO2 emissions. The use of IT also enables real-time project management and data sharing at every phase of a project.

The Topcon focus on innovation is not limited to our own engineering and research and development. We have spent decades developing collaborative relationships with other manufacturers that incorporate our technology into their OEM offerings. This puts Topcon at the foundation of mass data capture applications like aerial and road-based mobile mapping, autonomous vehicle development and other applications that will change the way we build, work and live.

Learn more at https://www.topconpositioning.com/

TOPCON

Topcon Positioning Systems, Inc.
7400 National Drive
Livermore, CA 94550
United States

Phone:
925-245-8300

Fax:
925-245-8599

Email:
salesorders@topcon.com

Web:
www.topconpositioning.com

Geotab
Global Navigation Software Co.
John Deere AMS
KCS BV
L-3 Interstate Electronics Corporation
Laipac Technology Inc.
Leica Geosystems AG
Loctronix Corp.
M3 Systems
NavCom, A John Deere Company
NavSync Ltd.
NavSys Corporation
PeopleNet
Polaris Wireless
Racelogic Labsat
Rewire Security
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Silicom
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TeleType GPS
Telogis Fleet Management Software
TerraGo
TomTom
Trimble

Network adjustment

Applanix
Azimap
Best-Fit Computing Inc.
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ComNav Technology
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Geodetics Inc.
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NavCom, A John Deere Company
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Orolia
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Spectra Precision
Topcon Positioning Systems
Trimble

Orbit analysis and simulation

Baseband Technologies Inc.
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NVS Technologies AG
Orolia
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Rohde & Schwarz
Silicom
Skydel
Spirent Communications
TeleOrbit GmbH
Trimble

Pre-/post-processing

ALLSAT GmbH
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AXIO-NET GmbH
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C-Nav
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Forsberg Services
Geodetics Inc.
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Global Navigation Software Co.
i-cubed LLC
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M3 Systems
NavCom, A John Deere Company
NavSys Corporation
NovAtel
Polaris Wireless
QinetiQ Ltd.
Remote GeoSystems Inc.
Rokubun S.L.
Rx Networks
SBG Systems
Septentrio Satellite Navigation
Spectra Precision
Topcon Positioning Systems
Trimble

System performance analysis

Averna
Baseband Technologies Inc.
Broadcom Corporation
CAST Navigation LLC
Chemring Technology Solutions
C-Nav
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ikeGPS Inc.
John Deere AMS
Leica Geosystems AG
Loctronix Corp.
M3 Systems
Nottingham Scientific Ltd.
Oscilloquartz SA
Polaris Wireless
Racelogic Labsat
Rohde & Schwarz
Spectratime
Spirent Communications
Spirent Federal Systems
TeleOrbit GmbH
Telogis Fleet Management Software
Topcon Positioning Systems
Trimble

Vehicle/vessel/asset tracking

Applanix
Baseband Technologies Inc.
Communication & Navigation (C&N)
ComNav
CSR plc
deCarta
Falcom USA
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Geodetics Inc.
GEOsat GmbH
Geotab
Global Navigation Software Co.
Globalsat Technology Corporation
GPS Antennas.com
GPS Flight
GPS Insight LLC
GPSTrackit.com
Infospectrum
Inventek Systems
ITRAK Corporation
John Deere AMS
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Rewire Security
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Syntony
TeleOrbit GmbH
TeleType GPS
Telogis Fleet Management Software
Topcon Positioning Systems
Trimble
u-blox AG
USGlobalsat Inc.

SURVEYING-RELATED EQUIPMENT

Altus Positioning Systems
Azimap
CHC Navigation
Chronos Technology Ltd.
ComNav Technology
F4 Tech
Geodetics Inc.
Geomatics USA
GEOsat GmbH
Juniper Systems Limited
KVH Industries
Lidar USA
M3 Systems
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Polynesian Exploration Inc.
Remote GeoSystems Inc.
Suzhou Foif Co. Ltd.
Tersus GNSS
The Fredericks Company
Trimble
US Radar Inc.

Dataloggers

4P Mobile Data Processing
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Globalsat Technology Corporation
ikeGPS Inc.
Juniper Systems Limited
Leica Geosystems AG
M3 Systems
Novariant
Panasonic Canada Inc.
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Rojone Pty. Ltd.
Silicom
Sokkia Corporation
Spectra Precision
Topcon Positioning Systems
Trimble
USGlobalsat Inc.

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Leica Geosystems AG
Rojone Pty. Ltd.
Silicom
Sokkia Corporation
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Topcon Positioning Systems
Trimble

Pen-based survey/GIS

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F4 Tech
Geodetics Inc.
Leica Geosystems AG
Sokkia Corporation
Trimble

SYSTEM DESIGN/ INTEGRATION

ALLSAT GmbH
Antenova Ltd.
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Beijer Electronics
Braxton Technologies
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ComNav Technology
Eos Positioning Systems
Falcom USA
Geomatics USA
Globalsat Technology Corporation
GPS Source Inc.
ikeGPS Inc.
KVH Industries
Lockheed Martin
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Meitrack Group
Microlab
Microsemi Corporation
Microwave Photonic Systems
NavCom, A John Deere Company
NVS Technologies AG
Orolia
Polynesian Exploration Inc.
QinetiQ Ltd.
Racelogic Labsat
Raytheon Space and Airborne Systems
Remote GeoSystems Inc.
Rohde & Schwarz
Rojone Pty. Ltd.
Satel Oy
SoftNav Systems Inc.
Spirent Communications
Spirent Federal Systems
Talen-X
Trimble

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EndRun Technologies
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Galileo Satellite Navigation
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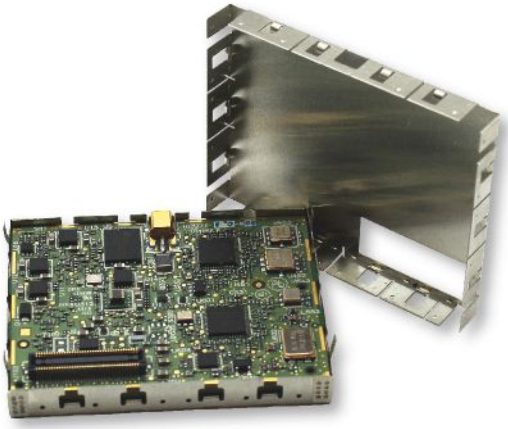
GPS Source Inc.
Greenray Industries
JAVAD GNSS Inc.
L-3 Interstate Electronics Corporation
Microlab
Microsemi Corporation
NovAtel
Optical Zonu Corp.
Orolia
Oscilloquartz SA
Panasonic Canada Inc.
Precise Time and Frequency

Trimble



Trimble is transforming the way the world works by delivering products and services that connect the physical and digital worlds. Core technologies in positioning, modeling, connectivity and data analytics enable customers to improve productivity, quality, safety, and sustainability. From purpose-built products to enterprise lifecycle solutions, Trimble software, hardware and services are transforming a broad range of industries such as agriculture, construction, geospatial, and transportation and logistics.

Trimble's Integrated Technologies Division provides system integrators and OEMs high-precision GNSS modules for positioning and navigation solutions that serve a broad range of applications such as autonomous navigation, agriculture, land & marine surveying, construction, mapping, dredging, meteorology, transportation, asset tracking, oil and gas research, mining and aviation, ground vehicle navigation as well as other geo-positioning/geo-referencing applications. The products utilize a start-to-finish approach that enables integrators to take advantage of a complete technology package that provides robust precision accuracy and fully streamlined integration into applications.

Trimble's innovative GNSS receiver technology is easy to integrate into users' applications, reducing development effort and time to market. Trimble's robust centimeter-level, real-time kinematic (RTK) positioning is achieved through the combination of multi-frequency GNSS—full triple frequency support of all available GNSS satellite constellations—and onboard inertial sensors. By integrating inertial sensors directly into GNSS modules, users can experience more robust performance in a variety of challenging environments, such as urban canyons, tunnels and heavy canopy.

For over 40 years, Trimble has worked on developing technology that delivers multi-constellation support for worldwide scalability and highly accurate position and orientation data. With years of engineering, testing and customer experience, Trimble's technology helps to make our customer's products reach their market potential.

Trimble
10368 Westmoor Drive,
Westminster, CO 80021

Email:
sales-intech@trimble.com

Web:
www.trimble.com/Precision-GNSS

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Rakon
RFOptic
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Schweitzer Engineering Laboratories Inc.
Telit
TimeTools Ltd.
Trimble

Time-code generators
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Orolia
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u-blox AG

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Timing clocks
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Telit
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Brandywine Communications
Connor-Winfield
EndRun Technologies
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Janus Remote Communications
JAVAD GNSS Inc.
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SigNav Pty. Ltd.
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Globalsat Technology Corporation
GlobalTop Technology Inc.
GPS Antennas.com
Infospectrum
iP-Solutions, Japan
ITRAK Corporation
Japan Radio Co. Ltd.
John Deere AMS
KCS BV
M3 Systems
NavCom, A John Deere Company
NavSync Ltd.
PCTEL
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TeleOrbit GmbH
TeleType GPS
Topcon Positioning Systems
Trimble
USGlobalsat Inc.
ZMicro

UNMANNED AERIAL VEHICLES (UAVS)
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Antenova Ltd.
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CHC Navigation
Cobham AvComm (formerly Aeroflex)
ComNav
ComNav Technology
Emlid Ltd.
Geodetics Inc.
Industrial SkyWorks
Inertial Sense Inc.
Jackson Labs Technologies Inc.
JAVAD GNSS Inc.
KVH Industries
L3 Technologies
Laser Technology Inc.
Leica Geosystems AG
Lidar USA
M3 Systems
Maxtena
Microwave Photonic Systems
Orolia
Oxford Technical Solutions
Phase One Industrial
Physical Logic
Propeller Aero
Rakon
Remote GeoSystems Inc.
RIEGL Laser Measurement Systems GmbH
Rockwell Collins
SBG Systems
Sensonor
Telit
Tersus GNSS
Trimble
Trimble Integrated Technologies
Unicore Communications Inc.
Xsens

Components (including software)
Airobot
Antenova Ltd.
Baseband Technologies Inc.
CHC Navigation
Cobham AvComm (formerly Aeroflex)
ComNav
Emlid Ltd.
JAVAD GNSS Inc.
Laser Technology Inc.
Lidar USA
M3 Systems
Maxtena
Microsemi Corporation
Orolia
Physical Logic
Rakon
Remote GeoSystems Inc.
RIEGL Laser Measurement Systems GmbH
Rockwell Collins
SBG Systems
Sensonor
Septentrio Satellite Navigation
Telit
Trimble
Trimble Integrated Technologies
Unicore Communications Inc.
Xsens

Integrated systems
CHC Navigation
Cobham AvComm (formerly Aeroflex)
ComNav
Inertial Sense Inc.
JAVAD GNSS Inc.
Lidar USA
M3 Systems
Microsemi Corporation
Microwave Photonic Systems
Oxford Technical Solutions
Physical Logic
RIEGL Laser Measurement Systems GmbH
Rockwell Collins
Sensonor
Trimble
Trimble Integrated Technologies

VEHICLE LOCATION/ TRACKING WORKSTATIONS AND SYSTEMS (COMPUTER-AIDED DISPATCH)
Broadcom Corporation
Communication & Navigation (C&N)
ComNav Technology
deCarta
Furuno USA Inc.
Geodetics Inc.
Globalsat Technology Corporation
GlobalTop Technology Inc.
GPS Antennas.com
Infospectrum
Janus Remote Communications
Japan Radio Co. Ltd.
John Deere AMS
KCS BV
L3 Technologies
Laipac Technology Inc.
M3 Systems
Meitrack Group
NavSync Ltd.
NVS Technologies AG
Position Logic
Racelogic Labsat
Ready Track Pty Ltd.
Rojone Pty. Ltd.
Spirent Communications
Spirent Federal Systems
TeleOrbit GmbH
TeleType GPS
Topcon Positioning Systems
USGlobalsat Inc.

Unicore Communications

Unicore Communications Inc. is a technology company focused on the design and development of highly integrated ICs, multi-sensor fusion algorithms and GNSS receivers.

With the advantage of talent, management, technology and localization services, Unicore provides advanced time-space sensing/transmission products and services including one-stop SoC chips and GNSS receivers. The accuracy of Unicore GNSS receivers ranges all the way from meter, through sub-meter and centimeter, down to the millimeter level. Applications include CORS, survey and mapping, precision agriculture, intelligent driving, unmanned vehicles, mechanical control, precision timing, IOT and wearable devices — along with a number of other industrial requirements.

HIGH-PRECISION GNSS RECEIVER BOARDS/MODULES

UB4B0M

- GPS L1/L2/L5+ BDS B1/B2/B3+ GLONASS L1/L2+ Galileo E1/E5a/E5b+ QZSS L1/L2/L5
- Compact size, with low power consumption
- Centimeter-level high-precision RTK positioning
- Millimeter-level carrier phase precision
- < 5s RTK initialization time
- 50km baseline RTK
- 20Hz output rate
- Widely adopted by mainstream surveying RTK equipment, UAV base station

(46 x 71 mm)

UM482

- 30 x 40 mm, SMD packaging
- All-constellation multi-frequency dual antenna heading module
- Accurate, reliable centimeter-level RTK positioning
- 0.2°/1 m baseline heading accuracy
- <5s initialization time
- 20 Hz output rate
- <20ms output latency
- On-board 6-axis MEMS

(30 x 40 mm)

UM4B0

- Small footprint (30 x 40 mm)
- All-constellation all-frequency high-precision RTK module
- Supports GPS, BDS, GLONASS, Galileo and QZSS, supports BDS BD3 signal
- Advanced multipath mitigation technology and low elevation tracking technology
- Accurate, reliable centimeter RTK positioning
- 20Hz output rate
- On-board 6-axis MEMS
- Proven-Products have been widely applied in worldwide projects, a leading choice for intelligent drive, robots, UAVs, etc., reliable centimeter-level RTK positioning
- <5s initialization time
- <20ms output latency

(30 x 40 mm)

AUTOMOTIVE-GRADE GNSS+MEMS MODULE

UM220-INS NF

- BDS/GPS+MEMS dual-system module
- Directly outputs inertial navigation data (supports NMEA0183)
- Continuous positioning in GNSS-denied conditions
- ISO/TS-16949 certified product line
- 6-axis MEMS inside, including gyro, accelerator
- Supports speed pulse and map matching feedback input
- -40°C~+85°C operating temperature
- Successfully entered international brand vehicle market

(12.2 x 16 mm)

UNICORE COMMUNICATIONS INC.

F3, No.7, Fengxian East Road, Haidian, Beijing, P.R.China, 100094

Phone:
+86-10-69939800

Sales Phone:
+86-10-69939828

Fax:
+86-10-69939888

Email:
info@unicorecomm.com

Web:
www.unicorecomm.com

AUTONOMOUS DRIVING GUIDANCE

Multi-Band GNSS with Embedded Functional Safety for the Automotive Market

BY FABIO PISONI, DOMENICO DI GRAZIA, GIUSEPPE AVELLONE, LUIS SERRANO, BRETT KRUGER, LAURA NORMAN AND NATASHA WONG KEN

Autonomous driving applications are raising the requirements for onboard GNSS receivers to new highs. Position accuracy, protection levels, high availability, robustness of operation and integrity are the priorities shaping a new class of automotive components and architectures. Autonomous driving deals with life-critical issues: the expectation of reliability and safety for this new generation of receivers, as well as for other sensors and systems, is very high.

The International Organization for Standardization (known by the language-independent short form ISO) has issued documents codifying functional safety (FuSa) for automotive applications: ISO 26262: part 1 to part 11. ISO 26262 complements the well-known automotive reliability standard published by the Automotive Electronics Council, AEC-Q100. With respect to FuSa, a system can be defined as functionally safe if it always operates correctly and predictably. More importantly, in the event of failures, the system must remain safe for people. Lastly, as security is becoming paramount, a new standard for cybersecurity in automotive applications — ISO/SAE 21434 — is in development by ISO and SAE International (initially called the Society of Automotive Engineers) that will require a GNSS receiver to be robust against jamming, spoofing and meaconing attacks.

The Automotive Safety Integrity Level (ASIL) is a key part of ISO 26262 compliance, and the standard specifically identifies the minimum testing requirements depending on the ASIL of the component. The ASIL of a component or system depends on the ASIL of the target application. The ASIL is determined at the beginning of a development process. It varies from ASIL-A to ASIL-D, where A is for less critical applications and D for the most critical ones such as steering and braking systems. ASIL-rated lane-level positioning performance can be demonstrated today by combining an ASIL-B software positioning engine and TerraStar-X correction technology from Hexagon Positioning Intelligence with GNSS measurements from an ASIL-B-rated GNSS chipset.

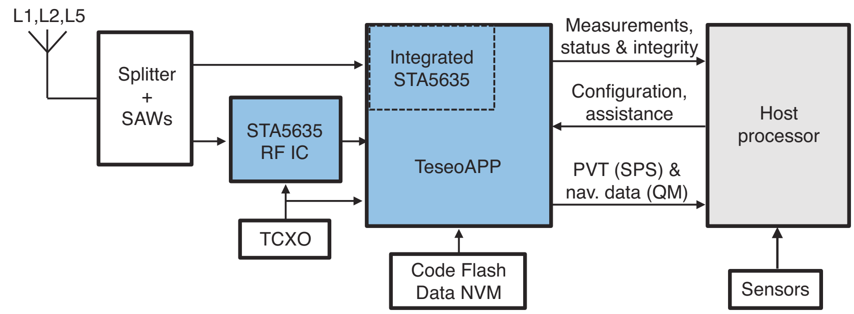

FIGURE 1 Block diagram of the TeseoAPP platform for safety-critical applications, featuring surface-acoustic-wave (SAW) filters, a temperature-compensated crystal oscillator (TXCO), non-volatile memory (NVM) and both internal and external STA5635 tuners. (See text for other initialisms used.)

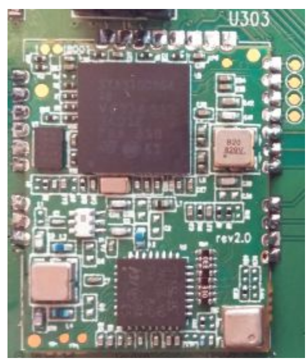

FIGURE 2 The TeseoAPP Evaluation Module, including the STA9100 (TeseoAPP) and STA5635 (external tuner).

To conjugate performance requirements with the demand of embedded functional safety, STMicroelectronics has developed TeseoAPP (STA9100), a next-generation GNSS component, designed to meet an ASIL-B level of safety. TeseoAPP is a multi-band GNSS measurement engine. It outputs all the observables, navigation and integrity data required by a safety-critical precise positioning algorithm, located on a host processor. TeseoAPP also computes a local L1 code-based standard position, velocity and time (PVT) solution (SPS) for monitoring and integrity purposes.

Also part of the baseline features are autonomous satellite acquisition (cold start condition), real-time assistance, data decoding and storage on external non-volatile memory (NVM), accurate timing and pulse-per-second generation under vehicle dynamics.

RECEIVER ARCHITECTURE

The target architecture for a safety-critical platform is sketched in **FIGURE 1**, where a host microprocessor is in charge of collecting GNSS observables and sensor data from the TeseoAPP. The latter includes on the same chip die a first configurable RF chain for the L1 signal ensemble and the baseband part for processing all the signals in the served bands, while the second chip is an RF front end (code-named STA5635), configurable for receiving the other served bands (such as GPS L2 or L5, Galileo E5a or E5b or E6, and so forth). The two chips are clearly visible in the photograph of a TeseoAPP evaluation module of **FIGURE 2**.

The selected frequency plan and constellation configuration depend on the specific autonomous driving scenario and the target geographic area. The TeseoAPP supports a mix of frequencies and signals as shown in **TABLE 1**. The chipset baseband unit can track up to 80 channels. A tracking snapshot from a rooftop antenna (located at the ST office in Naples, Italy) is illustrated in **FIGURE 3**.

Both the TeseoAPP and the STA5635 have been designed

INNOVATION INSIGHTS

BY RICHARD B. LANGLEY

I DRIVE A 10-YEAR OLD KIA SPORTAGE. It is still quite roadworthy despite having to contend with New Brunswick winters. However, it lacks some of the safety features that are present in newer cars. There is no back-up camera, no forward-collision warning, no automatic emergency braking, and no blind-spot warning, for example. These are just some of the safety systems that come as standard or optional on most new cars these days. Still, the driver is responsible for the safety and operation of the car at all times. True, help might be provided for parallel parking and cruise control, but that's about it for automated operation with most vehicles.

But things are changing and changing fast. Real automation is coming to automobiles. Already partial automation is available in some high-end vehicles that can take over steering, braking and acceleration in certain circumstances. The driver is still responsible for other aspects of the vehicle's operation including paying attention to road conditions. Soon, we will have conditional automation where the car can drive itself but the driver must stay alert and be prepared to take over immediately at any time. Next will come high automation where a computer fully drives the car at certain times on certain routes such as a highway. Multiple systems, including back-up systems, will maintain a required safety level and the car will determine if it is safe to operate autonomously. If not, it could pull over to the side of the road and shut down. And finally, we may have full automation of cars. They will be able to drive on any road under virtually any conditions and won't need any controls such as steering wheels or accelerator or brake pedals.

Augmented GNSS guidance will play a major role in the automation of vehicles. As with any navigation or guidance system, there are four important requirements: accuracy, availability, continuity and integrity. Perhaps the most obvious requirement, accuracy describes how well a measured value agrees with a reference value, typically the true value. How well a system accounts for various errors or biases determines the accuracy of corrected measurements and, ultimately, the accuracy of a derived position. A navigation system's availability refers to its ability to provide the required function and performance within the specified coverage area at the start of an intended operation. In many cases, system availability implies signal availability. Environmental factors such as signal attenuation or blockage or the presence of interfering signals might affect availability. Ideally, any navigation system should be continuously available to users. But, because of scheduled maintenance or unpredictable outages, a particular system may be unavailable at a certain time. Continuity, accordingly, is the ability of a navigation system to function without interruption during an intended period of operation.

While accuracy, availability and continuity of a guidance system are all important, it is the integrity or trustworthiness of the system that is paramount. It is why the automotive industry has already developed integrity standards for the automation of vehicles. And it is why GNSS chip manufacturers and positioning systems developers are working on bespoke devices for autonomous driving, whatever the level of automation. In the Innovation column this time around, we'll learn about one such development — one with embedded functional safety.

Color code (*)=CUT2.0 silicon I => internal tuner (TeseoAPP) E => external tuner (STA5635)		GPS / QZSS			GLONASS		BEIDOU			GALILEO			IRNSS
		L1C/A	L2C	L5	G1	G2	B1I	B2I	B2a(*)	E1	E5a	E5b	L5
0	GPS/QZSS L1/L2C + GLO G1/G2 + BeiDou B1I + GAL E1	I	E		I	E	I			I			
1	GPS/QZSS L1/L2C + GLO G1 + BeiDou B1I/B2I + GAL E1	I	E		I		I	E		I			
2	GPS/QZSS L1/L5 + GAL E1/E5a + GLO G1 + BeiDou B1I/B2a + IRNSS	I		E	I		I		E	I	E		E
3	GPS/QZSS L1/L2C + GLO G1 + BeiDou B1I + GAL E1/E5b	I	E		I		I			I		E	
4	reserved for future use												
5	GPS/QZSS L1/L2C + Galileo E1/E5b + BeiDou B1I/B2I	I	E				I	E		I		E	

TABLE 1 **The TeseoAPP (STA5635) supported frequency plans and scenarios.**

for ASIL-B following the concept of "safety element out of context" (SEooC) described in ISO standard ISO 26262:2012. In this context, assumptions have been made for the application (such as on the mission profile), identifying the related safety goals from which functional and technical safety requirements have been derived.

Following the guidelines identified in the ISO 26262 flow for safety-relevant product development, several safety mechanisms have been identified at the hardware, firmware and system/boot level. The microcontroller unit (MCU) supports dual-core operation in a lock-step configuration to verify processor output errors together with a memory built-in self-test (executed at startup) and error correction code on a safety-related embedded random access memory. Other hardware redundancies have been introduced in safety relevant parts such as triple-voted registers for critical configuration parameters. For the real-time operating system (RTOS), an ASIL-D-level product — the highest level — was selected. Functional safety analysis of the GNSS sub-system has produced a dedicated technical safety concept, including aspects such as tuner operation, interference and jamming mitigation, signals and observables quality management (QM), reliable host communication (using generic end-to-end or E2E protocols for data integrity and resilient flow control), and reliable system software. A simplified overview of all these safety mechanisms is outlined in **FIGURE 4**, where the orange-colored blocks are specific for the GNSS sub-system.

Safety Mechanisms. The technical safety concept of the GNSS sub-system is implemented by a security, integrity and safety (SIS) monitoring layer (see **FIGURE 5**). The SIS collects information and metrics from other receiver blocks embedded in the RF/baseband hardware and from different components of the GNSS firmware stack. The SIS internally computes integrity risk estimates, which are delivered to a central intelligence monitor (CIM) capable of switching the receiver into a safe state, within a fault-tolerant time interval, when the overall receiver integrity appears compromised. In its simplest form, the CIM can be represented by a weighted sum of integrity risk inputs, followed by some activation function. During this process, a first layer of logic (CIM-L1) combines a subset of signal quality metrics to decide a priori which observables shall be passed to the host or discarded (not delivered).

The collected signal metrics include quality estimators (based on multi-correlation techniques for example) or classic linear combinations of observables (such as dual-frequency carrier-phase differences or code-minus-carrier). Receiver metrics, on the other hand, have a more global scope and include estimators for inter-frequency biases, system-time cross-checks among constellations, and so on. The fault collection and control unit (FCCU) conveys hardware status flags to the SIS. Typically, an FCCU exception indicates some critical hardware failure and takes a priority path when switching the safe state. For

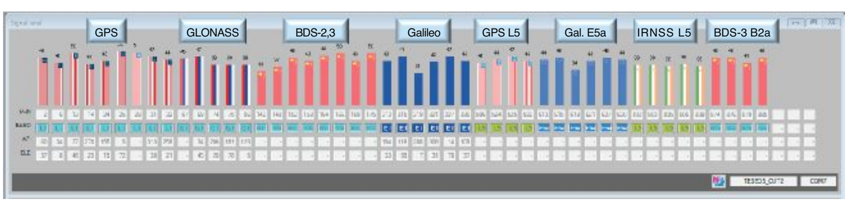

FIGURE 3 **Screenshot of the L1-L5 TeseoAPP configuration, from the ST Teseo-Suite tool (using the Naples rooftop antenna).**

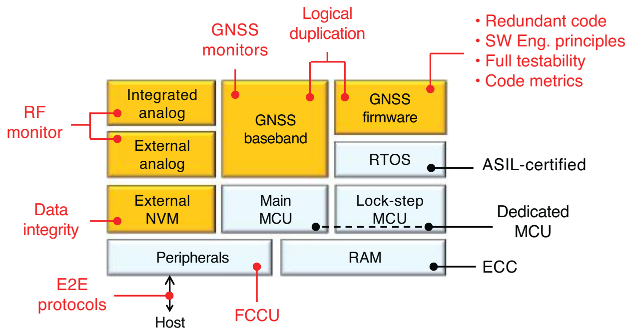

FIGURE 4 Overview of the TeseoAPP safety mechanisms. (See text for acronyms and initialisms used.)

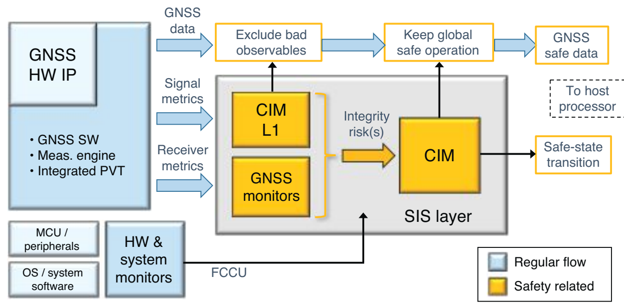

FIGURE 5 Safety information flow through the TeseoAPP security, integrity and safety layer. (IP = intellectual property; other short forms in text.)

example, a fault in the MCU lock-step monitor will trigger an immediate firmware action, mediated by the FCCU.

POSITIONING PERFORMANCE

To demonstrate the performance that can be achieved using the ST TeseoAPP chipset, Hexagon Positioning Intelligence (PI) has combined measurements from the TeseoAPP with an automotive-grade antenna and Terrastar-X correction technology, and processed the data using PI's software positioning engine. Even with a modern receiver supporting dual-frequency, multi-constellation measurements, such as the TeseoAPP, corrections are necessary to deliver decimeter-level performance and safety information required by an autonomous vehicle.

In clear-sky environments, lane-level positioning accuracy is achieved, enabling GNSS as a key input to autonomous systems. **FIGURE 6** shows the horizontal error performance of the combined ST+PI solution in the form of an error time series and an error cumulative distribution function (CDF). The error performance expected from today's single frequency automotive-grade GNSS without corrections and processing is also shown for comparison.

For guidance systems in autonomous applications, the GNSS position must be accompanied by safety information

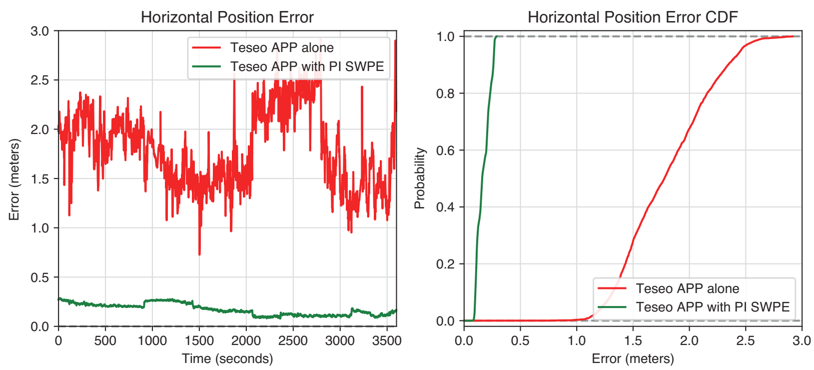

FIGURE 6 Horizontal error time series and cumulative distribution function (CDF) of the TeseoAPP alone and of the TeseoAPP with PI software positioning engine (SWPE) in an open-sky environment.

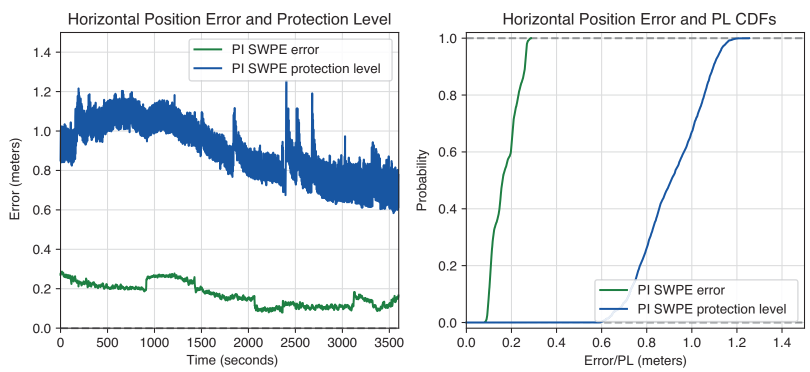

FIGURE 7 Horizontal error and protection level (PL) including cumulative distribution functions (CDFs) of the PI software positioning engine (SWPE) in an open-sky environment.

and integrity guarantees. The concept of protection levels (PLs) has been introduced to provide this. A horizontal protection level defines a circle or ellipse around the reported GNSS position, which will have some error, within which the actual position is guaranteed to fall. The PI software positioning engine is ASIL-B rated, so its position and PL outputs are available for use in safety-related autonomous applications. The autonomous system using the GNSS position is assured that its actual position is within the protection level ellipse. To output ASIL-B-rated positions accompanied by PLs,

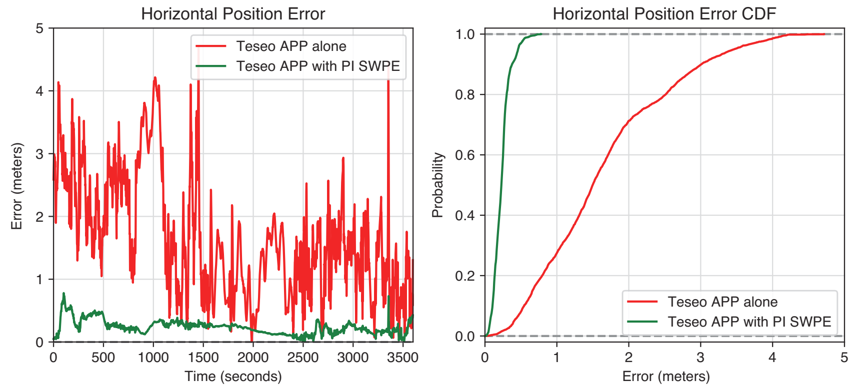

FIGURE 8 **Horizontal error time series and cumulative distribution function (CDF) of the TeseoAPP alone, and of the TeseoAPP with PI software positioning engine (SWPE) in a highway environment.**

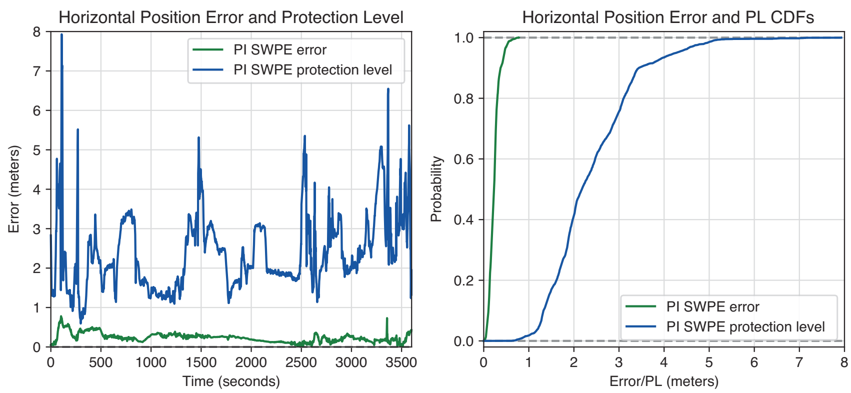

FIGURE 9 **Horizontal error and protection level (PL) including cumulative distribution functions (CDFs) of the PI software positioning engine (SWPE) in a highway environment.**

ASIL-rated GNSS measurement inputs are required.

Using the inputs and techniques described above, the PI software positioning engine calculates PLs for every GNSS position output. The PI data from Figure 6 is shown again in **FIGURE 7** with accompanying PL information. In this case, a PL with integrity risk of 10^{-7} is shown, meaning that the actual position error is expected to exceed the reported PL at a rate less than 10^{-7} per hour.

The PLs shown in Figure 7 are typically much greater than the position error. This is because the protection level calculation must account for a large number of potential faults that are not generally present. For instance, undetectable GNSS satellite faults can occur at rates greater than 10^{-7} per hour, and so must be accounted for in the PL.

In non-clear-sky environments, the GNSS position calculation is complicated by frequent loss of "sight" of the GNSS satellites. This is mitigated by having additional constellations and frequencies. However, for added availability of a precise position in challenging environments, it is necessary to incorporate sensor fusion into the position calculation, typically by using a six degree-of-freedom inertial measurement unit (IMU) as input, which includes three accelerometers and three gyroscopes to measure 3D translational and rotational motion. The IMU can maintain position accuracy for short periods when GNSS is unavailable, such as when driving under an overpass on a highway. The IMU provides a relative positioning output, so the absolute error growth is unconstrained in the absence of GNSS inputs. Therefore, it is important to have the GNSS receiver as the primary sensor in the positioning solution to constrain IMU drift and to reacquire GNSS signals rapidly after emerging from a GNSS outage.

Position error results for a typical highway environment are shown in **FIGURE 8** after adding input from an automotive-quality IMU to the PI software positioning engine. Small spikes in position error are due to short GNSS outages along the test route. However, the error growth due to loss of GNSS is minimal due to the coupling of the IMU data with the GNSS measurements.

FIGURE 9 shows the PI highway data with accompanying PLs. Though the errors are well-constrained through GNSS outages, the PLs typically increase significantly. This is due to the higher noise of low-cost IMUs, and the uncertainty associated with reacquiring GNSS signals. PLs must account for worst-case IMU performance, which can have errors orders of magnitude greater than the nominal performance. During GNSS signal reacquisition, minimizing receiver noise is critical for fast position reconvergence, reinforcing the need for high-quality GNSS in autonomous applications.

CONCLUSION

The TeseoAPP is the first generation of multi-band GNSS chipsets designed by STMicroelectronics to meet the two main requirements of autonomous driving: accuracy and safety-critical operation. The execution of the ISO 26262 standard for TeseoAPP is still a work in progress and encompasses two main aspects: 1) a safety plan implementation, code quality metrics and processes management and 2) the technical safety concept. Both of these aspects presented specific challenges, mainly due to the inherent complexity

of the product and the large amount of firmware involved.

To exploit the maximum benefit of the TeseoAPP in safety-critical automotive applications, a high-accuracy ASIL-B-rated position engine is required. Hexagon PI's software positioning engine is designed to use measurements from an ASIL-rated GNSS receiver, along with GNSS corrections and IMU data, to generate ASIL-rated position outputs, with accompanying integrity guarantees. The PI software positioning engine computes protection levels. The calculation and determination of PLs is required to meet the safety and integrity guarantees necessary in autonomous driving for functionally safe operation. The software positioning engine also outputs ASIL-rated velocity, attitude and absolute time data, although we have not discussed these in this article.

The required high performance and safety expectations suggested, since the early stages of the project, a system composition in which the TeseoAPP was configured as an ASIL-B measurement-engine whereas the ASIL-B software positioning engine algorithms (by Hexagon PI) run on a separate ASIL host processor. We believe this synergy of competencies will represent the key for a successful solution to enable safe and reliable positioning in autonomous driving applications.

ACKNOWLEDGMENTS

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FABIO PISONI leads the GNSS System Architecture and Software Team (Automotive and Discrete Group) at STMicroelectonics Italy in Milan, where he has worked since 2009. He has a degree in electronics from Politecnico di Milano and has previous experience as a GNSS and digital signal processing (DSP) engineer.

DOMENICO DI GRAZIA is a GNSS signal senior staff engineer at STMicroelectronics Italy in Naples, where he has worked since 2003. He has a degree in telecommunication engineering from the University of Naples Federico II, holds patents in the GNSS area, and has previous experience in digital communications.

GIUSEPPE AVELLONE is in the GNSS System Architecture and Software Team (Automotive and Discrete Group) at STMicroelectonics Italy in Catania, where he has worked since 1998. He has a degree in electronics from Università di Palermo and previous experience as a GNSS and DSP engineer.

LUIS SERRANO is a GNSS technical marketing manager with STMicroelectronics based in Munich. He holds a Ph.D. in GNSS from the Department of Geodesy and Geomatics Engineering, University of New Brunswick, Canada. He has been active in the GNSS precise positioning field since 2007, and holds a patent on GNSS.

BRETT KRUGER is a software engineer specializing in GNSS/INS integration in the Safety Critical Systems Group at the Hexagon Positioning Intelligence (PI) NovAtel brand in Calgary, Canada. He holds an M.A.Sc. in electrical engineering from the University of Toronto, Canada.

LAURA NORMAN is a geomatics engineer specializing in GNSS integrity and protection levels in Hexagon PI's Safety Critical Systems Group. She obtained her M.Sc. from the Department of Geomatics Engineering at the University of Calgary, Canada.

NATASHA WONG KEN is the Safety Critical Systems product manager at Hexagon PI. She has worked at PI since 2012 after obtaining a B.Sc. in geomatics engineering from the University of Calgary.

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SEEN & HEARD

GALILEO GUIDES MADRID METRO BUSES

Galileo and EGNOS are helping EMT Madrid to improve its services, reports the European GNSS Agency. Madrid is one of the first cities using Intelligent Transport Systems (ITS) with enhanced positioning services. Positioning units in 2,050 public buses mean customers know exactly where their ride is, and when it will arrive. Receivers in the buses use signals from EGNOS and Galileo.

DROUGHT FIGHTERS

About 3,000 villages in the Karnataka state of India face serious water shortage. More than 2,000 tankers and 1,800 private bore wells have been hired to meet the need. To ensure the water gets to the right place, all tankers supplying water to drought-hit villages and towns are being equipped with GPS to prevent misuse. The trackers will show the movement of the tankers from the water source to the residential areas.

GETAWAY CAR STOPPED IN ITS TRACKS

In March, a Florida Highway Patrol trooper darted a GPS tracker onto the back of a fleeing minivan during a 60 mph chase. As the pursuit carried over county lines, a trooper used his StarChase system to tag the minivan. The FHP used the tracking information to roll out a spike mat to stop the suspected felon. Only a few police agencies in the state have the technology, which is still being tested.

HELP FOR REFUGEES

Between 2013 and 2018, almost 70,000 children in Kenya died of diseases that could have been prevented with vaccines. Two Nairobi teenagers, Kunjal Bharatkumar and Supraja Sayee Srinivasan, paired a health website they created with small GPS devices, tested at Dadaab Refugee Complex. A mother gets a GPS bracelet and her baby a GPS necklace. The trackers turn on when it's time to alert the mother that her child is due for its next vaccine. Then, mom can take her child to get the shots. If they miss their vaccine appointment, the GPS sends a signal to healthcare workers to provide vaccines. The website can create maps of active diseases.

PHOTO CREDITS: Madrid bus/EMT Madrid; Bangalore water jugs/CamBuff/Shutterstock.com; police tracker/StarChase; Dadaab Refugee Complex/iStock.com/sadikgulec

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