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# Coordinates

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THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

## "There is a serious threat to GPS"

*–Prof Bradford Parkinson*

## Navigation: Trends and Challenges

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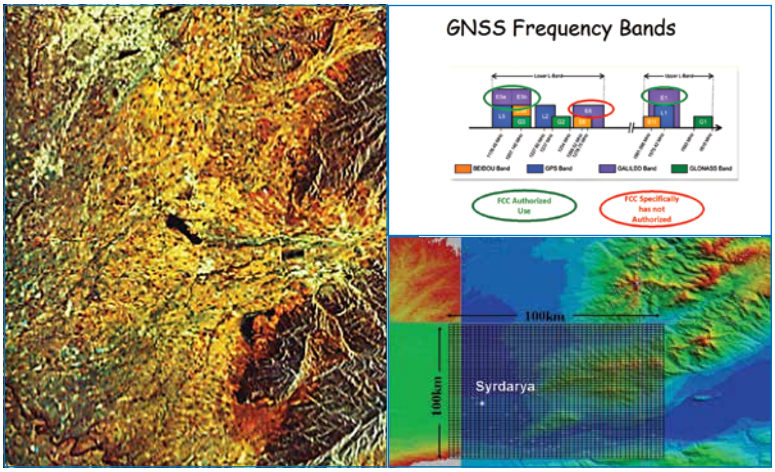


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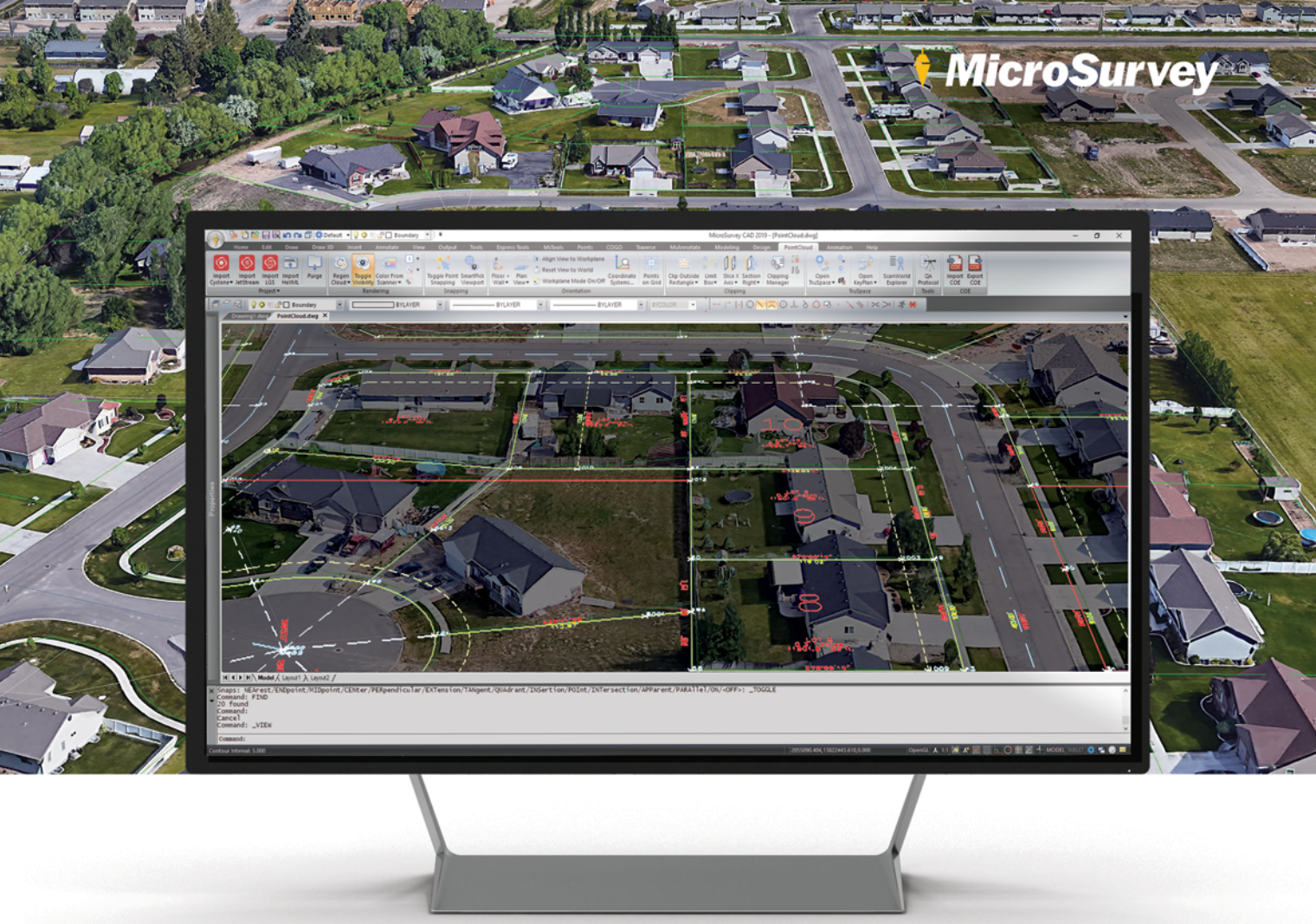


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# Mission Possible!

India gears up for Gaganyaan,

India's manned mission to space.

With the approval of the Government funding

Indian Space Research Organisation (ISRO) targets the manned space mission by December 2021.

Before this, it plans two non-crew flights in December 2020 and July 2021.

The mission will be capable of carrying three Indian astronauts and will orbit the Earth for seven days.

This ambitious plan is a matter of pride and highly laudable.

It will also be important to create an eco-system

By identifying and engaging various stakeholders

In academia and industry

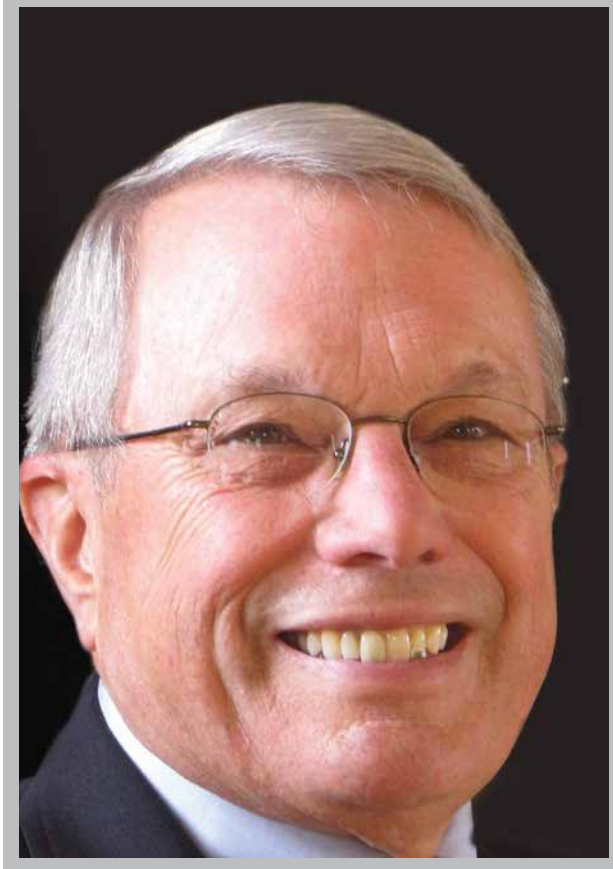
So that the capacities are built

As well as larger benefits of such missions could be leveraged.

**Bal Krishna, Editor**
**bal@mycoordinates.org**

# "There is a serious threat to GPS"

***Says Prof Bradford Parkinson, Chief Architect for GPS and PNT Advisory Board 1st Vice Chair while discussing the Ligado proposal. He shares his views on the wide range of issues related to GNSS in an interview with Coordinates magazine***



**Bradford Parkinson**

*Dr. Bradford Parkinson is a Professor Emeritus (recalled) in the Aeronautics and Astronautics Department of Stanford University.*

*He was the Chief Architect for GPS and led the original advocacy for the system in 1973 as an Air Force Colonel. Gaining approval, he became the first Director of the GPS Joint Program Office and led the original development of the GPS spacecraft, Master Control Station, and eight types of user equipment.*

*He continued leadership of the program through the extensive test validation program, including being the Launch Commander for the first GPS satellite launches. This original deployment of GPS demonstrated comfortable margins against all positioning, navigation, and timing requirements.*

*Earlier in his career, Dr. Parkinson was a key developer of a modernized AC-130 Gunship, introduction of which included 160 hours of combat missions. He was an instructor at the USAF Test Pilot School. In addition, he led the Department of Astronautics and Computer Science at the U.S. Air Force Academy. He retired from the U.S. Air Force as a Colonel.*

*Dr. Parkinson was appointed a Professor at Stanford University in 1984, after six years of experience in industry. At Stanford University, he led the development of many innovative applications of GPS, including:*

*First Commercial aircraft (Boeing 737) blind landing using GPS alone,*

*First fully automatic GPS control of Farm Tractors on a rough field to an accuracy of 2 inches,*

*Pioneering the augmentation to GPS (WAAS) that allows any user to achieve accuracies of 2 feet and very high levels of integrity assurance.*

*Dr. Parkinson has been the CEO of two companies and serves on many boards. He is the editor/author of the AIAA Award winning two-volume set Global Positioning System: Theory and Applications and is author or coauthor of over 50 technical papers.*

*Among his many awards are the IEEE Medal of Honor and the Draper Prize of the National Academy of Engineering, considered by some to be the "Engineering Nobel."*

## You recently opined that the GPS and GNSS are under serious threat in context of Ligado. Could you please explain what exactly you meant?

Let me give an update. We recently had an unusual PNT Advisory Board (PNTAB) telephonic meeting regarding the latest Ligado proposal for using 9.8-Watt transmitters in a radio band near GPS. We, the Advisory Board, sent the ExCom (National Executive Committee for Space-based Positioning, Navigation and Timing) a unanimous letter that strongly recommended disapproval of the Ligado proposal. There were many reasons for this. Most important, that the proposed transmitter density is not known. Ligado has refused to tell us what the tower spacing is going to be. And it is my belief that they're trying to deploy a 5G communication system. Many smartphone users are familiar with 4G. We know 5G is quite different. 5G will use much more powerful transmitters, with much closer spacing. For example, they call for picocells - at the smallest deployment, maybe 100 meters spacing or less. The US government testing has shown that 10 watt Ligado transmitters, spaced about 20 km apart, would still degrade 10% of certain high-performance GPS receivers in that region. Earlier, with powerful transmitters, Ligado had proposed 400 metre spacing. This reveals a fundamental incompatibility. As a result, many US organizations have filed strong opposition to their proposal.

## When all this started? Is it something to do with LightSquared?

Ligado is a successor to LightSquared. LightSquared came out of bankruptcy and its successor company is Ligado. They claim that they have a new plan but frankly speaking their new plan was not a lot different than their old plan, in terms of GPS interference.

It all started in 2011 when LightSquared proposed that the FCC restrictions on its existing frequency authorization in the Mobile Satellite Service (MSS) band (a faint signal, satellite-to-ground) be waived. This would allow the license to effectively be repurposed, allowing high-power terrestrial transmissions. The company has two space-to-ground authorizations in the 1525–1559 MHz band (1526–1536 MHz and 1545–1555 MHz) very close to the GPS primary frequency (L1 at 1575 MHz). Initially, it requested repurposing to ground transmission of 42 dBW (15.8 kW).

We realized, on the basis of extensive tests and analysis, that this would be very destructive to GPS and protested. Next, they proposed to abandon the closer band and reduce power in the further band to 32 dBW, or 1580 Watts. Even more recently they proposed to reduce the transmission power to 9.8 Watts, but were evasive regarding the density of transmitter deployment,

For Ligado, this is a great opportunity if they have the authorization to repurpose their existing license. Some believe that the value of their license might increase by over 20 billion USD.

## You mentioned that Ligado may try to push for 5G allocation. Can you elaborate on the likely consequences of this?

Our belief is that they are probably trying to develop some form of a 5G network, which is a much more capable than the existing 4G. 5G advocates claim that their maximum data rate is 20Gbit per sec. At that rate, a single user should be able to achieve a gigabit of data connectivity. 5G plans call for frequencies anywhere from 600 MHz to 14 GHz. Increased capacity is not free. Advocates also state that the received wireless power from a 5G network will be 30 times stronger than 4G LTE systems. The only way they're going to achieve that is through much greater tower density and/or higher power. And 5G wireless calls for the construction of smaller cells, not much larger than a football field, going

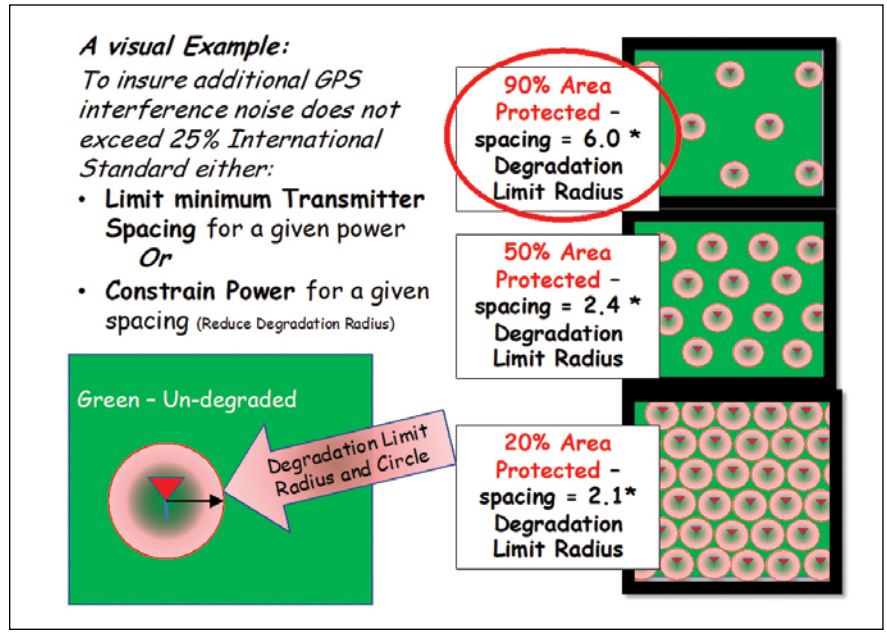



*Chart 1*

down to the micro cells whose coverage radii might look more like your Wi-Fi. That sort of sets the scene.

Chart 1 provides a visual example to understand this. The small green square, lower left, illustrates the GNSS degradation limit radius. Interference noise will not exceed the 25% International Standard (technically the "1 dB standard") outside that radius. Inside that radius, it does. We call that the degradation limit. If the GNSS community accepts even a 10 percent area degradation, so that 90 percent is protected, the radius or spacing between those transmitters has to be at least 6 times that degradation radius. It's clear geometry, and easily calculated. If the GNSS community wants to protect half of area region, the spacing then will have to be 2.4 and so on and so forth. For GPS and GNSS, we believe that at least 90 percent of the area should be protected. That means that the minimum spacing between transmitters must be 6 times the degradation radius. The situation would be as shown in the upper right rectangle.

For GPS/GNSS transmissions at 1575 MHz ("L1") this has strong implications. If the GNSS community accepts 90 percent protected coverage area, the latest Ligado 10-watt transmitters would have to be spaced at least 18 kilometers apart to protect High-Performance GNSS Receivers.

If you view it another way, with their earlier-proposed 400 m spacing, Ligado power would have to be further reduced from 10 watts to 0.036 Watts (2500 times lower) to protect all tested High Performance Receivers, even if only protecting 90% of coverage region.

From PNTAB Letter to ExCom

| Class of GPS Receiver | Bounding Degradation Radius for Receiver Class (with 10W Transmitter from ABC report – Appendix I) | Minimum Separation Between Ligado 10-Watt Transmitters (Meters) | | |
|---|---|---|---|---|
| | | % Region Protected | | |
| | | 90% | 50% | 10% |
| High Performance/ High Productivity (HPR) | 3400 meters | 20,481 | 8190 | 6104 |
| Emergency Vehicles and General Navigation (GLN) | 1045 meters | 6295 | 2815 | 2098 |
| General Aviation and Helicopters (GAV) | 1040 meters | 6265 | 2802 | 2088 |
| Timing (TIM) | 293 meters | 1765 | 789 | 588 |
| Cell (CEL) | 9.5 meters | 57 | 26 | 19 |

*Chart 2*

Ligado also continues to ignore emerging use of modernized GPS and GNSS signals (e.g. L1C). Impacts to receivers tracking these wider bandwidth signals could be worse than that for the current GPS signals

There is another issue in the Ligado filings. They stated that, for any GNSS user experiencing interference, they can just call Ligado. Asking the High-Performance GPS Users, for example the survey community, to monitor the interference is totally unrealistic – they would not know how to do it and would have no means to trace the problem to Ligado.

Ligado also continues to ignore emerging use of modernized GPS and GNSS signals (e.g. L1C). Impacts to receivers tracking these wider bandwidth signals could be worse than that for the current GPS signals.

If Ligado's current license is approved, their spokesperson, in a public meeting about a year ago, implied that, over time, they would expect to be allowed power increases. Their temporary power reductions offer is only to gain regulatory approval and it must also be recognized and rejected as a "nose under the tent"..

To repeat, their proposal is deliberately vague on geometry and spacing of towers. Ligado has steadfastly declined to provide critical technical details to PNTAB to enable full and accurate assessment of interference. They have addressed Aviation (433m) and ignored High Performance Uses that have shown to be much more sensitive to degradation.

## Can you explain the probable degradation in performance of GPS/ GNSS receivers?

Our letter from PNTAB to ExCom (available at https://www.gps.gov/governance/advisory/recommendations/2018-08-letter-to-excom.pdf) clearly explains the bounding degradation radius for five different classes of GPS receivers for a 10-watt transmitter. The letter is based on the extensive Adjacent Band Compatibility (ABC) Testing performed by the US Department

For GPS/GNSS transmissions at 1575 MHz ("L1") this has strong implications. If the GNSS community accepts 90 percent protected coverage area, the latest Legado 10-watt transmitters would have to be spaced at least 18 kilometers apart to protect High-Performance GNSS Receivers

of Transportation. High performance receivers, will begin to degrade at 3400 metres. So that is the degradation radius. To insure 90 percent of the region is not degraded, the Ligado spacing has to be over 20 kilometers (6 times the degradation radius as discussed earlier). The DOT considered other classes of receivers that are not high precision and (and have narrower bandwidth). For example, considering General Aviation (GA), the degradation radius is 1040 meters (see chart below) To protect 90 percent of the area for GA, the tests show that transmitters can be no closer than 6 kilometers. Unfortunately, 6 kilometers-spacing is never going to support 5G data bandwidths with a 10 watt transmitter (Chart 2).

**GPS in 2020 will be transmitting signals L1C/A, L2. L5 and L1C. Given this, do you think that 1dB protection debate is exaggerated? Can the power of L1 GPS C/A transmission be increased to L2?**

First of all, the 1 dB (a 25% increase in noise floor) is a long established and accepted international interference standard. It is an allowance based on the expectation that there are many other sources of interference. In the case of Ligado, the tests are based on a single transmitter, not an aggregate of all transmitters in a region. They are therefore a "best case" for Ligado.

Further, I believe the problem is not exaggerated. We are trying to protect all existing users. GPS was deliberately placed in the quiet, MSS portion of the spectrum, which recognizes that high power, ground transmitters can overpower weaker signals in a very non-linear way. As a reminder: the GNSS received power is on the order of a tenth of a millionth of a billionth of a watt. An adjacent band is not a proper location for high power transmitters.

We believe that the threat of higher power, nearby transmitters can be somewhat alleviated with advanced GNSS receiver designs. The costs of doing so, and the impact on high accuracy remains to be seen. In any case retrofitting various classes of GNSS receivers requires long lead times. An example is commercial aircraft, where retrofitting takes, say 15 to 20 years. If you're going to change your frequency allocation table in such a way that you degrade aircraft or helicopter equipment, it's not like your cell phone; they don't buy a new one every year. So, the protection that we are trying to give to the existing community is for all classes of users and types of equipment.

To solve interference issues by increasing satellite transmitter power is extremely expensive and would require 10s of years to retrofit the whole constellation (if the decision were made today). GPS averages about 2 launches a year. From a first launch, in 6 years or so, it would take another 12 to achieve any new capability.

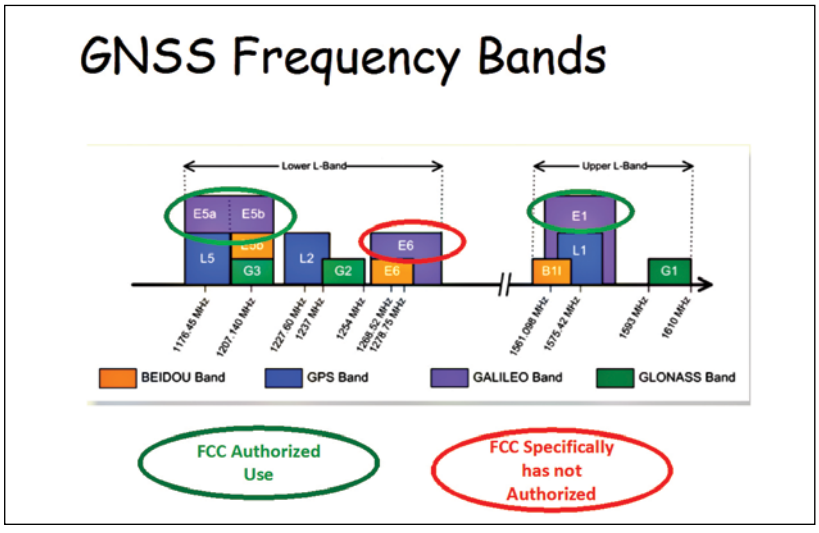



*Chart 3*

So, the point I'm making is that there would not be an easy transition. The additional frequencies are absolutely going to help but that is not a complete solution. So why would you seriously impair the existing users' capability because somebody wants to watch a movie! There are many other frequency bands that 5G can and will use.

**What is the status of the GPS modernization programme?**

We're have just launched the first GPS III and signals should be available this year. An additional 11 are on contract and another contract for 22 GPS IIIs has been signed,

the largest contract the United States Government has ever penned. Part of this, which I find very interesting, is that the latest contract includes continual upgrades and improvements in clocks and signal structures. So this is embedded as the part of the procurement.

**Recently, the Federal Communication Commission, (FCC) has approved the use of Galileo in the US. What is your opinion on this?**

Yes, the FCC has authorized the use of E1 and E5 frequency bands as they are in the same bands effectively as GPS L1 and L5. However, they did not authorize E6. The reason they said is that E6 band is not allocated for navigation purpose in the US (Chart 3). Though in my opinion the users would be better off if they could use the E6 but that is the decision that the FCC has taken.

**Would you like to comment on the clock failures that some of the GNSS systems had to go through?**

If you look at any of the GNSS satellites, they are really synchronized clocks. That's the essence. So we want a clock that has good long-range stability. When I first led the system design, we recognized that a huge challenge was to make an atomic clock that was robust. We had to make it resistant to failures. It is not easy to do that. I might seem bragging a little, but we have had GPS satellites that are 25 years old and are still working. I think that's a tribute to a very rigorous development program. We ran some very harsh tests on the ground to make certain we knew that they would survive.

**Any research going on in the domain of clock development?**

Absolutely, there are. As a matter of fact, the Jet Propulsion Laboratory (JPL) is putting together a really interesting new clock, based on mercury ions. I think it's going to fly sometime in the next six months. Of course, the Europeans are working on a hydrogen maser. I have to tell you, we also had hydrogen maser but had to cancel the program because we could not see a completion date. And you know this was 34 years ago. We could not see any way to get the development clock small enough and low enough in power. Hydrogen masers at that time had a history of early failures.

So, I think the hydrogen maser is a good candidate if it can be made small. Apparently, the mercury ion clock can be made small and might have improved stability by a factor of 10.

Much will continue to happen in sensor technology. Sensors in cell phones will continue to get more and more capable. RTK was not normally used in a cell phone. But all of a sudden, a number of GNSS chips are measuring carrier wave cycles and providing that to application developers. That is one piece of a new wave of "system of systems" designs and opportunities

**Interference has been one issue that has been highlighted. Along with spoofing and jamming are also discussed as threats to GNSS. What is your take on this?**

Our advisory board is addressing this with a Program. The fundamental purpose was assuring PNT. Again PNT, not GPS, but PNT. The Program has three aspects. We call it PTA for Protect, Toughen, and Augment. In terms of protecting, toughening, and augmenting, the major threats are either jamming, which could be inadvertent or deliberate, or spoofing. Of those two threats, I consider jamming much more serious. And the reason is very simple. If you are looking in detail at the techniques for spoofing, by and large a smart receiver should be able to find out when that's happening. So in that case, spoofing would not give a wrong answer. Instead, the receiver understands that there are two alternatives -- that it can use techniques to operate correctly in spite of the spoofing or it has to declare that it no longer has a good solution. It's either of them. And the net result is not a misleading position.

I believe a much more serious problem is jamming. It turns out that there are many techniques that work against jamming. The ones I really like are the phased array antennas that use beam-forming. This makes it difficult to jam. If we go to modern signals and go to multiple constellations, you also have a lot of jamming resistance through redundancy. So I'm not trivializing the problem. It's a serious problem. But the point I'm making is: the T stands for making the receiver resistant to all of those inadvertent or deliberate interferences. And there are ways to do that.

**What is your take on eLoran as a back up to GPS?**

I think it's the most viable backup. Yes it's clearly a long way from the capability of GPS. It's not three-dimensional. It's in essence a regional system. It does not have the accuracy even with the differential correction that its design offers. But it's a much more powerful, less jammable system. I think it should be possible to build a Loran receiver on the same chip as a GNSS receiver. The antenna would be quite different, but well understood. And if you can do that and have a full backup, then the person who thinks they can jam you, suddenly has a much more severe problem. I think that's the essence of the argument and I don't see any other systems having that capability. And the cost, relative to GNSS, is very small.

**In 2010 in an interview with us, you spoke about robotic automation. That was the key trend you predicted. You mentioned about driverless cars in one your presentations in Kyoto three years before. What trends you see in next few years?**

The driverless car is certainly one form of automation. While it isn't going to be accepted suddenly, is already being demonstrated as a series of steps. In part, acceptance is going to be driven by convenience. But perhaps stronger drivers are going to be the safety and economics. For example, in the US, the people who operate large trucking firms have difficulty finding drivers. Driving trucks is grueling work. Now at least two manufacturers have demonstrated driverless trucks. And think about it - normally truck driving in this country is limited to 12 hours a day. If you go driverless, truck use can be extended to 24 hours, and add to that, owners won't have to pay retirement and health benefits. If you go through the economics and a probable case, it will be safer and a lot easier to use robotic automation for driverless trucks. We are also going to see automation in driverless airplanes. Not in the people-carrying planes, but in the cargo. Since airplanes take much longer to upgrade and manufacture, we might also eventually see specialized designs for cargo airplanes that do not have some of the refinements that are in current aircraft. In fact, there is a whole wave of such vehicles already in use – we call them UAVs.

**What else you would like to predict?**

My belief is that much will continue to happen in sensor technology. Sensors in cell phones will continue to get more and more capable. RTK was not normally used in a

cell phone. But all of a sudden, a number of GNSS chips are measuring carrier wave cycles and providing that to application developers. That is one piece of a new wave of "system of systems" designs and opportunities. And application developers will exploit that capability, which is virtually free. They are also going to add chip scale atomic clocks, lidars and radars. They are going to make a driverless car or a driverless truck much safer. So what I see, in terms of technologies, is the integration of a lot of devices that are continuing to advance.

### What could be the advantages and disadvantages of the multi-GNSS scenario?

Well, within limits, the more the merrier. It's an expensive game for the provider! The question is how many constellations does the user need. There is a technical concern and that is if we get too many, all broadcasting on L1C, and we will start to raise the noise floor. It'll become like the tragedy of the commons, which is when too many sheep graze on the grass and pretty soon you don't have any grass. There could be an issue like that, but I don't have any concerns about that right now. Instead, I see enormous benefits in having multiple providers in the GNSS scenario and I'll explain why I see such enormous benefits in this. It's because when you are controlling your own integrity channel (say EGNOS or GAGAN), you are measuring satellites that you may not normally trust, but you're also measuring them often enough, so that if they were to try to do something that's misleading, you can pinpoint the problem. And for the Indian user of GAGAN, or EGNOS for European users, or in the case of WAAS for a US user, you instantly can tell the user in your country and your sovereign nation or in your group of nations that there's something wrong with a certain constellation or satellite. And you can resolve it. You are taking control. You no longer have the dependency that's risky. For example, in the USA, in my opinion, we should authorize the use of GLONASS provided we measure its integrity. Yet the larger problem is that that it is politically difficult. But in my opinion, if we measure the integrity, the user will know within six seconds whether each satellite is usable. When that is done, the WAAS-like provider has total control of accuracy and integrity. And in that sense, anyone could, with a WAAS-type system, use all constellations. So, I don't think there's any significant risk in multi-GNSS.

I think eLoran is the most viable backup. Yes it's clearly a long way from the capability of GPS. It's not three-dimensional. It's in essence a regional system. It does not have the accuracy even with the differential correction that its design offers. But it's a much more powerful, less jammable system

**Word of advice to the countries who are striving to come up with their own GNSS systems?**

They will need a lot of money. It's not easy! If they have ambitions to put up a worldwide system, I guess I can't for the life of me envisage that there is need for yet another. So, all I can say is it's very expensive and it takes much longer than you think. We launched our first GPS satellites forty-four months after we got approval. After the first launch, we quickly launched the other 11 that were available. But it still took us almost 20 years to get an operational system. The problems were mostly money and will. But in part the question was: why you are launching satellites if you don't have any users out there? The satellites must come first, and then the user will come.

**Your comments on Indian System IRNSS and its signal allocation?**

There is an international recognition and entusiasm for IRNSS as a regional system. The second point is where to put any augmenting signal. The US placed it at 1575 MHz. Now we've got one at 1227 MHz. The question is the ease of use. For well-known technical reasons, L-band is the sweet spot, and using GNSS allocation bands makes a lot of sense. If corrections are broadcast on higher frequencies, the user will probably require beam antennas, or the provider would have to significantly increase the satellite power. So those trade-offs can be made the way we made them on GPS to ensure that we had global coverage. And in the case of India or Japan, your trade-offs may be quite different.

**It has been an intriguing journey for you? If you would like share some high points and low points in addition to that you have been a great leader in terms of getting the entire project from the word go. What is your leadership advice?**

The high point was actually launching the first GPS satellite which worked flawlessly. After four were launched, our testing verified our claim; we were easily beating 10 meters accuracy. All of that was very much a high point.

The low point occurred in a situation where we experienced a nagging ground test failure in first GPS satellite's earth sensor. We couldn't figure out what it was. I thought we were going to miss the launch. We finally made it. But the reason for this failure was that one of the manufacturing people had put in an extra cleaning step that was not called for. He did it with good intentions, but in the process he destroyed the coating on the sensors and it took us months to figure that out. But that was certainly one of the low points.

Credit for the success of GPS belongs to many fine engineers. While I understood the project well, including the keys to make it work, I was able to hire some of the greatest engineers in the US.

Frankly, I was in awe of their knowledge and dedication. They were technically as good as I was or better. And the nice part of that is I could assign a purpose, describing what we're trying to do. And then tell them to run with that purpose. And to tell them: "If you run into a brick wall, I can help you. Keep me informed. Tell me what you're doing. I'm counting on you to do it."

It is a joy to run an organization that is populated by people like that. And so I've received a lot of awards, many more than I deserve. But what I'm fond of doing, at any acceptance, is showing pictures and names of many of those heroic engineers lest they be forgotten.

The real success that GPS has enjoyed is a tribute to their dedication. They would not let us fail. It was like combat. It was like bloody combat ensuring that all the features were working. So, the answer is that choosing outstanding people is the key to solving hard problems.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# Navigation: Trends and challenges

Experts share their opinion on the trends and challenges in satellite navigation at 16th International Association of Institutes of Navigation (IAIN) World Congress 2018, Chiba Japan during 28 November – 1 December. Some of the views are presented here

## Ground wave radio navigation system will be developed

**Prof Yasuo ARAI**
Immediate Past President of International Assoication of Institutes of Navigation (IAIN)

Navigation should be de defined not only "to move from point to point decided" but also "entirely to establish the decided Mission including moving", so almost of vehicles should accomplish their missions such as transportation of passengers or/and cargos with one of the most important missions to observe surroundings, to detect hazards and/or to avoid them in order to move to destination with safety, security and efficiency navigation.

Bringing an end to navigation for manned/unmanned vehicles, the technology on the Positioning, Timing, Sensing and Communication should be essential. Though, first of all the latest trends on these technologies will be mentioned, and the challenges to new generation will be done.

> It will be possible to wireless control in large vehicle. So, next generation of network construction should be fused 4G and 5G (low latency system), and be applied to autonomous/ manned vehicle navigation

**Positioning and Timing** Today it has been past quarter centuries since starting GPS operation in full running in 1990s. Now, GPS (USA): GLONASS (Russia): CDMA, GALILEO (EU): FOC and Bei Dou (China) are running as GNSS, and IRNSS (India) and QZSS (Japan) as RNSSs. Almost entirely prospects that until 2020 these all systems will be operating in full running would be done, and it would be coming into the Navigation era when it would be said not possible to navigate without GNSS. Increasing infrastructures on G/RNSS in intensity, GNSS receivers also have been changed to multi-GNSS and multi-Sensors in an attempt to improve the vulnerability of G/RNSS.

**G/RNSS** will be available in the area of outdoor positioning including urban, and positioning accuracy will be sub-meters or cm order from traditional positioning accuracy 10 meters adding application of QZSS.

**Ground wave Radio Navigation** In case of G/RNSS, it is not possible to apply the Positioning and Timing under the ground such as subway or tube and tunnel. Though, it will be difficult to apply the traditional Ground wave Radio Navigation even such as eLoran or Loran C for land navigation. ELoran will be applied to Marine Navigation and Aviation for back up of GNSS vulnerability such as jamming and spoofing.

**Multi-Sensors** IMU is applied to GNSS receiver for automobile navigation according to anti-vulnerability of GNSS, but at present it is just difficult to keep required accuracy for long time depending of GNSS positioning accuracy. Error is affected by the time, so it will enlarge in case of stopping or very slow speed in long time.

**Anti-Jamming/Spoofing** In aviation, the development of phased array GNSS antenna is advanced for not only anti-Jamming/Spoofing but also stable platform to protect the missing satellites due to changing vehicle's attitude.

**Indoor Positioning** Recently, Indoor Positioning System has been applied with WiFi System of which positioning would be done by the measuring the receiving signals' level and several referring markers set up at known fixed points. The accuracy is said 1 meter or sub-meters at present and apply the human being movement in the building or so. Moving robots and small indoor drone will be able to contribute the safety evacuation system indoor field and advance toward seamless navigation indoor from/to outdoor.

**Sensing** Navigation system presents not only Positioning and Timing but also a lot of data or information related navigation for own and others, such as heading, altitudes, 2/3D velocities, yaw/roll/pitch and others' information. The most important information is Radar and Visual information. These systems present circumstances but the performances just also presents navigation information, so these information should be fused and

introduce the solution of surrounding condition just same as expert of navigation would use any kind of information which he or she is able to make up as possible.

**Communication** The communication system is also most important function. 4G is fruitful mobile data communication, and presents IoT not only to fixed points but also mobile vehicles. But latency of 4G or internet is not stable, so it is difficult to apply control network system.

Next generation 5G has low latency such as 0.1 ms which is same as able to control actuators and all of functions in a car. This performance will be able to synchronize a lot of video channels at once and apply the video from desired eye points just same as moving audiences.

The limited performance of 5G is the valid area calculated by range less than latency x radio wave velocity. So, it will be possible to wireless control in large vehicle. So, next generation of network construction should be fused 4G and 5G (low latency system), and be applied to autonomous/manned vehicle navigation.

Closing this article, challenges to nest future are described as follows;

- Ground wave radio navigation system for land navigation will be developed, and GNSS receiver will be covered all radio navigation system, so jump to Multi-RNS (Radio Navigation System) from Multi-GNSS, and proceed Seamless Navigation.
- Application of 3d Velocities by PPP receiver to gain the performance of vehicle control system. Feedback system is essential velocities (time-rate of position) information.
- To gain the accuracy of position (velocities also), using QZSS in each region and instead Geo stationary satellite as SBAS especially at high latitudes.
- Development of downsizing radar for drone and automobile, and fusion of radar, visual and navigation information by sensor to increase not only accuracy but also responsibility for safety, security and economical manned/unmanned/autonomous navigation.

# Societal benefits from positioning, navigation and timing

**John Pottle**
Director, Royal Institute of Navigation, London
President, International Assoication of Institutes of Navigation (IAIN)

We live in a fast-changing world. In the past, success was to get a position fix on a navigation receiver; then an accurate position became the goal. Now resilience is receiving attention: there is a call for continuity and integrity as well as accuracy. The routes to achieving resilience are still maturing. This is evidenced by the multiple approaches to rationalising the risks and mitigating them. Risk assessment frameworks are being developed and starting to be used more regularly, helping to rationalise the likelihood, or sometimes ease, of disruption against the severity of impact. Having rationalised the risk, appropriate mitigation choices can more readily be made.

Mitigating the risks presented by the vulnerabilities of satellite navigation systems does not always have to be complex. A directional antenna provides jamming protection; augmentation with Inertial and/or Wi-Fi improves resilience (though not necessarily accuracy); multi-frequency receivers are less susceptible to jamming and spoofing risks. Many who rely on position, or time, are beginning to design-in security and resilience to their systems. Sophisticated approaches can sometimes be needed. But the 80/20 rule can be applied and some initial steps can deliver a major improvement.

Looking to the future, I submit that what we are seeing here is but the beginning of a revolution: more autonomy, collaborative systems, data analytics, artificial intelligence, augmented reality. We are seeing already the first steps on each of these but the revolution they can enable is to come.

At two recent conferences I have heard multiple mentions of paradigm shift.

It is a beginning of a revolution: more autonomy, collaborative systems, data analytics, artificial intelligence, augmented reality

New paradigms are ahead, where the assumptions of the past and the present should not be relied upon. The basis of success for careers, companies, even nations, is shifting. We all need to change, to adapt, to remain strong and to thrive.

So how to rationalise, in this context, the value of our work? At the recent International Navigation Conference (INC2018, Bristol, UK 12-15 November) we explored the benefits to society from application of knowledge and expertise in navigation, positioning and timing. Think of the benefits that come from seismic and bridge monitoring for example; efficiency improvements from smart logistics; safety benefits from automation; the communications revolution enabled through position and precise time.

The World Trade Organisation has published 17 sustainable development goals – the blueprint to achieve a better and more sustainable future for all. Please go online and take a look at them. When you are there, consider how you can measure the impact of your next project? Perhaps you can measure benefit towards one or more sustainable development goals? If you do, I suggest that you will be more successful as you will be creating tangible societal benefit. I also see great value in sharing perspectives and insights between like-minded individuals, organisations, institutions. Together we are can do more, delivering more meaningful benefits, more quickly and more sustainably.

# Civil and Commercial Aviation affected by GPS jamming

**Steve Hickling**
Director Marketing & Sales Enablement, Spirent

**Guy Buesnel**
PNT Security Technologist, Spirent

As modern civil and commercial aircraft become more reliant on GPS, it is perhaps not surprising that there has been significant increase in the number of reported incidents of systems being affected by GPS jamming.

It's important to note that modern airliners retain legacy navigation systems that pilots can use in the event of GPS disruption caused by intentional or unintentional RF jamming. This means that the loss or degradation GNSS signals is not normally a safety-critical issue on the flight deck, but it is an operational issue as flights could be diverted, rerouted or delayed during episodes of interference that preclude the use of modern air traffic methods such as RNAV approaches.

## Number of incident reports on the rise according to Eurocontrol figures

To fully appreciate that GPS interference has the potential to cause significant impact to commercial aviation an examination of recent reports of real-world disruption is helpful. In a presentation in September 2018 setting out its recommendations for protecting aviation from radio frequency interference, Eurocontrol said it had received 815 reports of GPS outages to-date in 2018 – nearly double the number experienced in 2016, the next most-disrupted year.

## GPS interference causes disruption at Ninoy Aquino International Airport

A recently released report from the International Civil Aviation Organisation (ICAO) has revealed that a single airport saw over 50 incidents of GPS interference in just one 3-month period in 2016.

According to the report, flight crews reported more than 50 incidents of harmful GPS interference at Ninoy Aquino International Airport in Manila, Philippines, between March and May 2016.

Flights coming in to land on Runway 24 frequently experienced total loss of GNSS reception in the critical instrument approach phase. According to the report, this "sometimes led to missed approaches", forcing flight crews to go around and re-approach the runway using back-up navigation systems.

What's more, interference to the GPS signal meant incoming aircraft couldn't accurately broadcast their position to air traffic control via the global ADS-B aircraft position identification system. Sometimes the onboard ADS-B couldn't report a position at all, and sometimes the position it reported was massively at odds with the aircraft's true position. Similarly, pilots reported issues with their ground proximity warning systems (GPWS) once location awareness was lost by the automated system.

## Individual Pilot Reports highlight on-board operational issues

Some reported incidents of GPS disruption contain a lot of information about the impact of the problems. Whilst its not certain that the incident below was caused by GPS interference, the symptoms that the flight crew experienced are certainly very suggestive of an interference event

*"An Air France Airbus A319-100, registration F-GRHB performing flight AF-1123 from Munich (Germany) to Paris Charles de Gaulle (France), was in the initial climb out of Munich's runway 26L when the crew reported they had lost their positioning system, they were maintaining runway heading and needed radar vectors to return to Munich. The aircraft stopped the climb at 5000 feet, was vectored for the approach and landed safely back on runway 26L about 20 minutes after departure.*

*According to information The Aviation Herald received both GPS systems showed a fault.*

*The aircraft remained on the ground for about 2:45 hours, then was able to depart and reached Paris with a delay of 3.5 hours.* "

In the USA, NASA administers a voluntary Aviation Safety Reporting System (ASRS). The ASRS collects reports of aviation incidents or situation reports from pilots, controllers or others. Since 2013, there have been more than 250 incidents reported to ASRS relating to GPS disruption.

In one such incident, documented in 2017, a pilot reports that the GPS signal is briefly lost (for around 30 seconds). The pilot wonders whether it was interference caused by a Personal Protection Device (Cigarette Lighter type jammer). The pilot continues into rain, clouds and turbulence but once again encounters GPS signal failure. The pilot report continues, "*then all hell broke loose, GPS signal failure, ADSB failure, multiple cascading messages on the GTN.*" It's a very graphic report and details the impact of what probably was GPS interference, on multiple on-board aircraft systems.

## GPS jamming exercises highlight system issues

Often, pilot reports of incidents most likely caused by GPS interference, coincide

with GPS jamming exercises conducted by the military. A report from the Radio Technical Commission for Aeronautics (RTCA) highlights the worsening impact of military GPS jamming exercises on commercial aviation in the US, due in part to a sharp increase, from 43 exercises in 2012 to 127 in 2017, with the number of affected locations increasing from 16 to 37.

The report identifies 13 different potential impacts on commercial aircraft systems, ranging from loss of GPS-based navigation, which can result in missed runway approaches, to impairment of the ADS-B system, which reports an aircraft's location to air traffic control and other aircraft nearby.

In several cases (24 in 2017), air traffic controllers have had to activate a so-called "stop buzzer" – a request to the organisers of the military exercise to pause the jamming to allow a particular aircraft, such as an air ambulance, to operate unimpeded.

The RTCA report highlights the needs for the whole aviation industry to understand the risks associated with GPS-based navigation, and to address any shortcomings in systems and procedures.

## Mitigation

GPS interference detectors exist that if deployed around airports could lead to operational improvements and mitigations. Also, the frequency of interventions would suggest that better co-ordination between the military and ATC during GPS jamming exercises would be helpful.

Commercial aviation already has legacy networks of conventional radio navigation aids and ILS landing systems, a worldwide infrastructure that can be used alongside GPS to provide assured navigation and this has prevented GPS disruption from becoming a major Safety of Life Issue.

However, reliance on these systems prevents use of modern techniques required to obtain much needed improvements in capacity and efficiency and designed to exploit GNSS accuracy and ubiquity.

# We would do well to not ignore legacy technologies

**Simon Gaskin**
Secretary General,
International Association
of Institutes of Navigation

Ever since mankind started developing means of transport there has been a requirement for the operator to know their present location relative to the destination and hazards or obstacles on the route. Technological developments eventually resulted in a variety of systems by which to achieve that in most environments. Navigators learnt to constantly compare and contrast the outputs of different systems in order to satisfy themselves that those outputs were essentially in agreement or identify whether one (or more) of the systems was in error. Then came the GNSS 'gift' of increasingly accurate absolute position. Overnight, it seems, we unlearnt all the best practices for navigating acquired over centuries and placed our belief in a single method of determining position that is vulnerable to disruption, malicious manipulation, or even denial. Nor has the requirement for quality relative positional information gone away. Could it be that the necessity for autonomous platforms to be permanently certain of the time, their position and attitude without the benefit of a 'person in the loop', will finally be sufficient incentive for the successful introduction of viable alternative systems that will ensure the capability of vehicles to derive that information is resilient?

## Trends

A brief look at the titles of papers recently submitted to the Royal Institute of Navigation's 'Journal of Navigation' reveals some of the methods being examined for their potential to contribute to Resilient Navigation: Visual Shoreline Navigation, Multi-antenna GNSS and INS Integrated Position and Attitude Determination without Base Station for Land Vehicles, Asynchronous Wide Area Multi-Lateration with Irregular Pulse Repetition, A Passive Acoustic Positioning Algorithm Based on Virtual Long Baseline Matrix Window. One of the quests of research is an (almost) error free sensor onboard a vehicle, independent of external signals - the ultimate Inertial Measurement Unit (IMU). But still, the very best are burdened by significant error accumulation and commercially unaffordable price-tags. Much is expected of quantum technology to solve this but a usable solution remains a long-term aspiration. Recently, much navigation was done by eye. Given the developments in imaging, another avenue for determining relative position ought to be the utilisation of cameras (visual spectrum, low-light, Infra-red, thermal - (think the burgeoning, wondrous camera imaging of nature)) - onboard, independent and difficult to mislead, but not infallible.

Another possibility is to make use of 'signals of opportunity' (SOOPs), that is to say, signals transmitted for other purposes but which might be made use of to determine relative position.

However, the very nature of SOOPs is that they may not be the same everywhere a vehicle travels. Thus, either a receiver must be capable of making use of any signal - a big ask, or a suite of receivers will be required in order to enable the continuous determination of position from an ever changing array of signals with concomitant costs. The automotive industry in particular has been developing the Simultaneous Location And Mapping (SLAM) technique of comparing the vehicle's 'sense' of location with a map of its operating area in order to derive where it is on that map. Their objective being to employ both SOOPs and SLAM to locate a vehicle.

We would do well to not ignore legacy technologies, which still have much

to contribute, especially with a little 21st Century make-over. There are ongoing studies into the possibilities for extracting more information from radar, but this is very much in its early stages and not without weaknesses. But every ship (at least) already carries one, or more, radar systems so, if there is added value to be obtained from this tried and tested method, its adoption by just one navigation community should not involve great expense or complex regulation.

There is at least one older, well proven, terrestrial-based radio system capable of providing position and, crucially, time of sufficient accuracy for not only platform navigation but also the operation of regional, national and international networks for which uninterrupted access to continuous and precise time is a fundamental requirement. Unfortunately, much of the infrastructure for one such system in Europe has been dismantled, but it continues to be used in other regions and, indeed, some nations intend to build new systems.

## Challenges

Quite apart from any technical or physical challenge, it is my perception that, whilst the User community has generally begun to recognise the need for resilient navigation, one of the biggest challenges is still that, with some exceptions, owners, operators, Authorities and regulators are reluctant to recognise that multiple GNSS constellations alone do not provide resilient navigation and that it is imperative that alternative, non space-based, positioning and timing systems together with the sensors to utilise them, are developed, adopted and utilised. Beyond that are the more prosaic issues: penalties (financial, both in terms of outlay and who pays; technical, the complexity of installation and operation and regulatory); coverage (local, regional or global); whether to pursue one solution to fit all (easier to regulate and cheaper to install), or a plethora of solutions in different locations, each only appropriate to part of the User community (far more complex, far more difficult to regulate, more expensive for the owner/operator and therefore unlikely to be popular); the preparation of standards for operational performance and means of testing so that manufacturers know what they are attempting to produce; the development of navigation suites which will automatically and continuously compare and contrast the outputs of different positioning systems in order to detect divergence, perhaps utilising machine learning, or maybe under the watchful eye of a remote operator - such systems will be sine qua non in autonomous vehicles and they will ease the mental load on operators in manned platforms.

## Conclusion

Prof. Brad Parkinson advocates that GNSS be Protected, Toughened and Augmented. Only augmentation, by whatever system, or system of systems, industry can deliver, will truly ensure that the navigation of manned or autonomous vehicles, in all environments, is sufficiently resilient to ensure uninterrupted, safe, secure, precise and efficient operations.

# We actually feel the GNSS vulnerability in South Korea and we know it is real

**Jiwon Seo**
Assistant Professor, Yonsei University, South Korea
Member of the eLoran Advisory Committee, Ministry of Oceans and Fisheries (MOF), South Korea

## What is your opinion about GNSS vulnerability especially in the context of South Korea?

It is widely known that GNSS is vulnerable to radio frequency interference, but the large-scale intentional GPS jamming that South Korea has experienced for the past years is not common. The most recent jamming from the North lasted six days and impacted several hundred kilometer areas. During the period, 1,794 cell towers, 1,007 airplanes, and 715 ships experienced GPS disruptions. We actually feel the GNSS vulnerability in South Korea and we know it is real.

## What is your take on GNSS back up?

Because a large-scale GNSS jamming can occur anytime in Korea and its impact is potentially hazardous, it is wise to have a back-up strategy. After realizing the vulnerability of GNSS, the Ministry of Oceans and Fisheries (MOS) of South Korea searched for a proven GNSS back-up technology that is deployable in a short time frame. Among several candidates, enhanced long-range navigation (eLoran) became the winner, and MOF initiated the Korean eLoran program.

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## Please explain the rationale and the objectives of the Korean eLoran Testbed Project?

The Korean eLoran testbed project that is led by the Korea Institute of Ships and Ocean Engineering (KRISO) began in 2016 and intends to demonstrate the maritime navigation capability of eLoran in the northwest area of South Korea by the end of 2020. The original Korean eLoran program that I first announced at the European Navigation Conference 2013 planned to deploy a nationwide eLoran system with three eLoran transmitters in addition to the existing two Loran-C transmitters, but the plan was changed later to a two-phase plan toward a nationwide coverage. The Korean eLoran testbed project is the first phase, which deploys one eLoran transmitter for performance verification.

## What are the key features and the status of the Korean eLoran Testbed Project?

The Korean eLoran testbed constitutes one eLoran transmitter and two differential correction stations (DLoran stations) in addition to the existing two Loran-C transmitters. The project requirement is to demonstrate a 20-m maritime navigation accuracy within a 30-km range from DLoran stations. The contract of procuring an eLoran transmitter was signed last year, and an NL-40 transmitter from UrsaNav and Nautel is expected to be installed in September 2019. The KRISO Consortium also independently develops an eLoran transmitter, which is a part of the project requirement. The performance of a prototype transmitter was demonstrated in December 2018.

The key challenge is not a technology issue. Securing permanent land with a 150-m radius to install a 137-m antenna of the original design is the most difficult task

## What are the challenges you face while implementing the project?

The key challenge is not a technology issue. Securing permanent land with a 150-m radius to install a 137-m antenna of the original design is the most difficult task. Most part of South Korea has mountainous terrain, and large and flat land is very limited and already developed. For the performance verification purpose, a smaller-size antenna will be temporarily installed on a 170-m by 60-m area on the Ara West Sea Lock in Incheon. Because of the reduced antenna size, the effective radiated power will be also reduced.

# Science, technology and practice to resilient navigation

The 16th World Congress of the International Association of Institutes of Navigation (IAIN) was held at Chiba Japan during November 28 – December 1, 2018. The theme was "Science, Technology and Practice to Resilient Navigation". The World Congress is held in different regions every three years to discuss technical navigation issues since 1976.

In his keynote address on Towards Resilient PNT and Intelligent Navigation Dr Hiroyuki Yamato, National Institute of Maritime, Port and Aviation Technology, Japan, highlighted two big challenges in Marine and air transport industries, which bear a heavy responsibility of international trade.

The first challenge is automation or autonomization of navigation which realizes safe and labor-saving transportation and better working environment for watch officers and pilots. The second challenge is the pursuit of the economically effective and energy saving navigation to realize environmentally friendly transportation. Shipping companies and air lines are also making efforts to strengthen their competitiveness in this regard. These challenges require digitalized optimal navigation taking into account of the effect of navigation environment based on real time performance measurement of individual ships and planes. Resilient and accurate Position, Navigation and Timings (PNTs)and intelligent navigation technologies are expected to play a big role in the measures to the two challenges.

Dr Izumi Mikami, Satellite Positioning Research and Application Center made a presentation on"Higher Accuracy Positioning Enabled by GNSS and its Guide toward "New World". He said that the QZSS's service will realize centimeter level accuracy, while the others target about 20 centimeters through 1 meter range accuracy. These services are readily applicable to the autonomous vehicles driving as the most intuitive and straightforward example. These must, however, incubate countless and inconceivable applications in our daily life, should the services be suitably combined with other new technologies such as AI, 5G, IoT, the robotics, the cloud computing, the big data, and so on. The navigation method itself of any mobile things including space vehicles should also change drastically depending on the GNSS service progress. The concept of "New World" of navigation guided by the GNSS precise positioning services is worth foreseeing.

Mr James Joeseph Miller, NASA Headquarters spoke on International Cooperation in the GNSS Space Service Volume (SSV). He elaborated on a number of on-going efforts to engage GNSS providers and space agencies to pursue compatibility and interoperability among these systems to support space operations.

Dr John Raquet, The Air Force Institute of Technology made a presentation on UAVs vs Natural Autonomous Vehicles (NAVs) — Are We Closing the Gap? In view of many significant advancements in UAV technology over the past 10-15 years, in this presentation, Dr Raquet evaluated on how well we are really doing in this area by comparing performance of UAVs with those of Natural Autonomous Vehicles (NAVs), defined as entities that fly but are not designed, built, or controlled by a humans (birds, for example). Performance was evaluated according to eight different metrics, and the "best in class" UAVs and NAVs for each metric are directly compared. The picture that emerged provided insight into where to put our UAV development efforts as we move toward the future.

Dr Dorota A Grejner-Brzezinska, The Ohio State University in her presentation on PNT in Smart Cities – Are We Ready for Autonomous Driving? introduced the concept of smart and connected communities and smart cities, and discussed the trends that guide the advances in the implementation of these concepts worldwide. She also discussed the various aspects of autonomous driving in a smart city with examples of research performed at The Ohio State University.

Mr Dana A Goward, President, Resilient Navigation and Timing Foundation made a presentation on "Resilient PNT –Protect, Toughen, and Augment GNSS". He said that a holistic approach focusing on user needs and an architecture that is able to reliably fill them is required to achieve resilient navigation. In this light, relying entirely upon weak GNSS signals is insufficient. At the moment the space portion of that architecture is sufficient, though it is being increased regularly. We must do everything we can to protect navigation signals from space, ensure our ability to use them is maximized with toughened receivers, and augment space signals with other signals and autonomous systems. The presentation discusses ways in which efforts to protect, toughen, and augment GNSS are being pursued in various countries and other initiatives that should be undertaken.

In the award ceremony, several awards were presented. The John Harrison Award for outstanding contribution to navigation was presented to Dr Dorota A Grejner-Brzezinska, Ohio State University, and the Necho Award for long term contribution to the field of navigation to given to Prof Bernhard Hofmann-Wellenhof of the Austrian Institute of Navigation. The Honorary Membership was awarded to Capt Rein van Gooswilligen. Taro Suzuki, Assistant Professor, Waseda University received IAIN's Sedak Award for presentation of his paper "Evaluation of Precise Point Positioning of Small UAVs using L6E Signal via QZSS."

There was an interesting and lively discussion in Plenary Panel on Resilient Navigation. The session was chaired by Mr Dana A Goward, President, Resilient Navigation and Timing Foundation. The panelists were Mark Dumville, Nottingham Scientific Ltd (UK); Steve Hickling, Spirent; Michael Jones, Roke Manor; Prof Jiwon Seo, Yonsei University; and Francis Zachariae, International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) General Secretary.

Over 250 delegates attended the congress from 27 countries. The congress had over 100 presentations. The IAIN World Congress 2021 is scheduled to be held at Edinburgh, UK during 15 – 18, November 2021.

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Front

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Based on our third generation a new TRIUMPH chip made in a solid magnesium alloy metal box.


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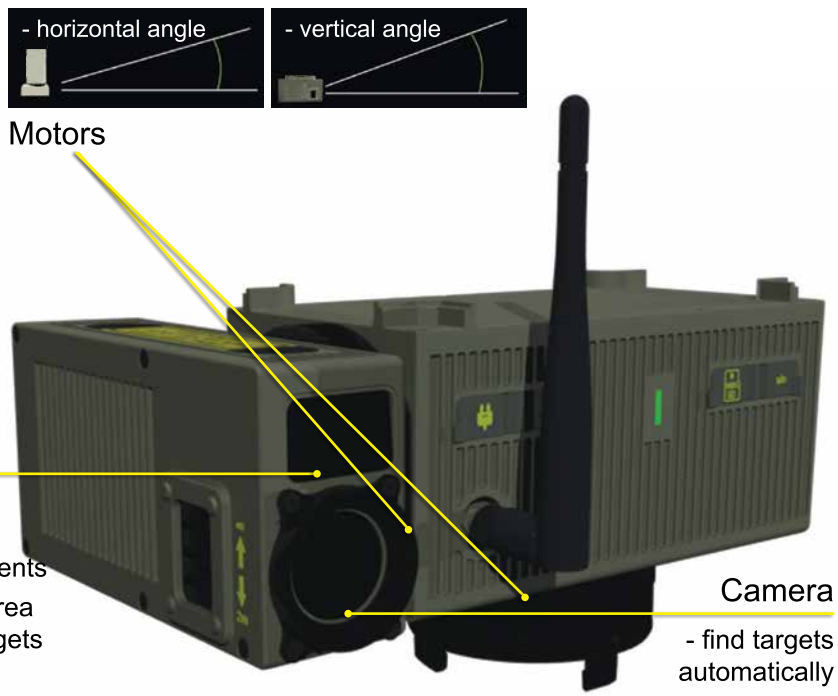
Why follow a workflow designed for yesterday's equipment?

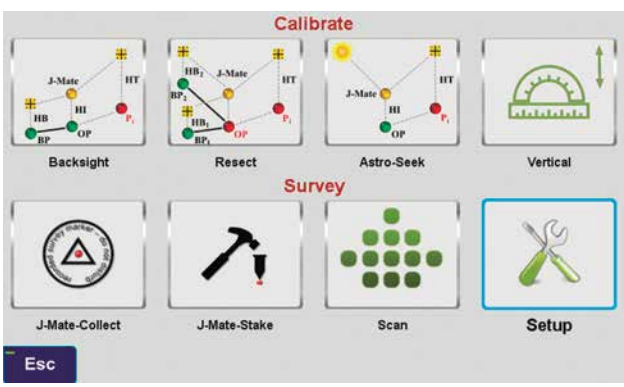
# This is J-Mate

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


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

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



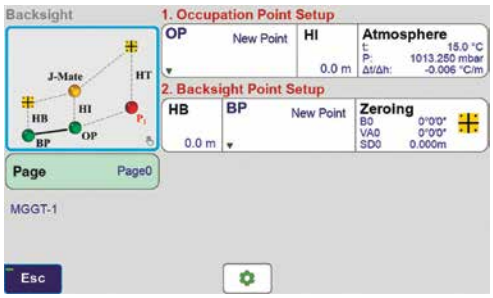

With J-Mate you can establish your occupied position via three different ways: 1) Backsight; 2) Resection; or 3) our new Astro-Seek (more of that later).

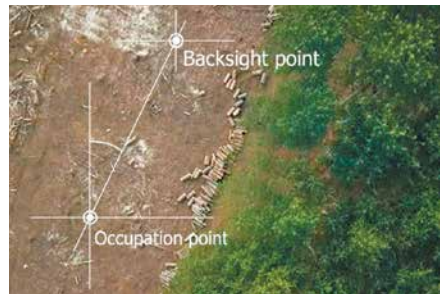
When you click the Setup icon of the J-Mate screen you get access to parameters that tunes J-Mate to your desire.

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

## Backsight icon

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

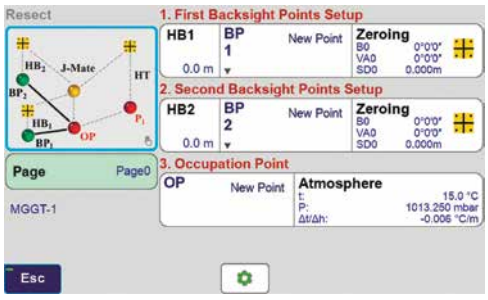


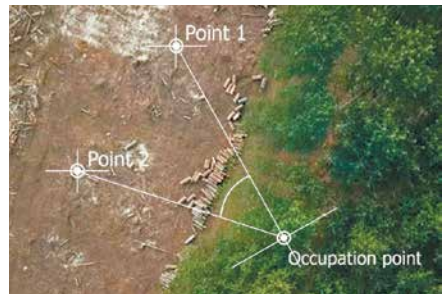




This screen appears which guides you to determine the accurate positions of the Occupation Point and the Backsight Point, to establish an azimuth and calibrate the J-Mate angular encoders.

## Resect icon

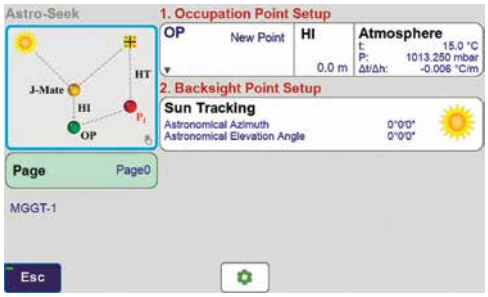
If GNSS signals are not available at the Occupation Point, click the “J-Mate-Resect” icon




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

## Astro-Seek icon

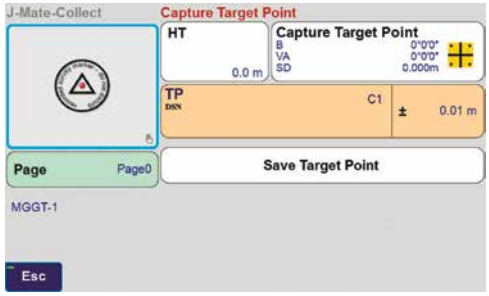



**And now our new feature!**

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

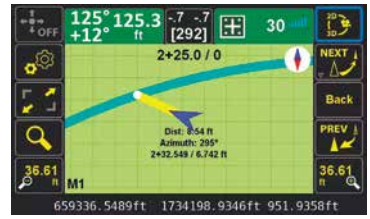
## J-Mate-Collect

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




## J-Mate-Stake

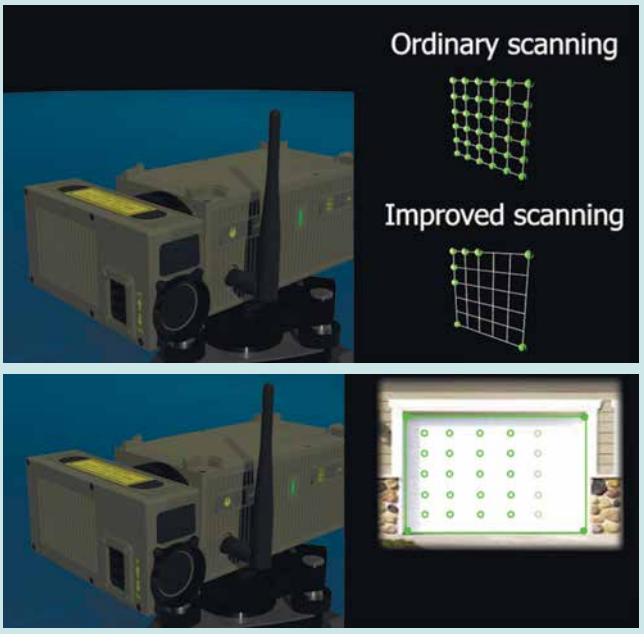
Click the J-Mate-Stake icon to use for stakeout.




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

## Smart laser scanner

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




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

Seize the day with J-Mate + TRIUMPH-LS


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

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

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# TRIUMPH-1M

Based on our new 864 channel chip, equipped with the internal 4G/LTE/3G card, easy accessible microSD and microSIM cards, includes “Lift & Tilt” technology.

## TRIUMPH-1M


864 channel chip, equipped with the internal 4G/ LTE/3G card, easy accessible microSD and microSIM cards, includes “Lift & Tilt” technology.

## TRIUMPH-2


Total 216 channels: all-in-view (GPS L1/L2, GLONASS L1/L2, SBAS L1) integrated receiver.

## The one and the only Digital Radio Transceiver in the world!

Unique adaptive digital signal processing, which has benefits: the full UHF frequency range and all channel bandwidths worldwide • the best sensitivity, dynamic range, and the highest radio link data throughput • embedded interference scanner and analyzer • compatibility with another protocols. Cable free Bluetooth connectivity with GNSS receivers and Internet RTN/VRS access via embedded LAN, Wi-Fi, and 3.5G

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### HPT435BT/HPT135BT/HPT225BT*


35 W UHF/VHF Transceiver

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1 W UHF/VHF with internal battery

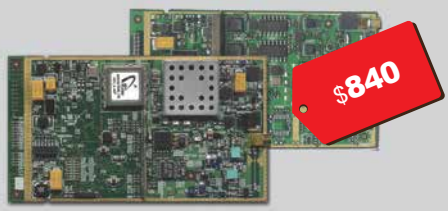
### L-Band/Beacon*


Receivers for multiple applications

### JLink LTE BAT*


Web-interface Wi-Fi, Ethernet, 4G/LTE, UHF/VHF/FH915, internal battery

### OEM Solutions

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*Power, data cables and antenna are included.

# Digital elevation models based on the topographic maps

This article focuses on the technology of creating a digital elevation model (DEM) with the help of the geographic information system (GIS)

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This article focuses on the technology of creating a digital elevation model (DEM) with the help of the geographic information system (GIS). The geodetic measurements, topographic maps at a scale of 1:500 000, remote sensing, GNSS data and Central Asian Tectonic Science (CATS) are used for creating of DEMs. The advantages of the GIS in comparison with traditional methods of creating maps are given in this work. The ways for use of the European Remote-Sensing Satellite (ERS1) and the Synthetic Aperture Radar (SAR) for creating of the digital map of the Tashkent region are described. Development of digital terrain models using GIS PANORAMA for 4 regions of Uzbekistan is described in more detail. The analysis of the trajectory of the ERS1 during the passage to the territory of Uzbekistan was also made.

From the perspective of the development of the Global Geodetic Reference Frame (GGRF) Uzbekistan's commitment envisages the further improvement the national geodetic infrastructure. The goal is to develop spatial data in accordance with required accuracy and to contribute to the development of an accurate, accessible and sustainable GGRF. In this country, the development of homogeneous distribution of geodetic infrastructure is related to the upgrading the reference system and Datum, the cartographic projections for topographic maps. Data sharing is also limited because of not well defined geodetic standards and an absence of open geodetic data. This paper covers only one of the issues of the development GGRF and Global Spatial Data Infrastructure.

From the perspective of the development of the Global Geodetic Reference Frame (GGRF) Uzbekistan's commitment envisages the further improvement national geodetic infrastructure. The goal is to develop spatial data in accordance with required accuracy and to contribute to the development of an accurate, accessible and sustainable GGRF

In 1980-1990, information about the terrain was recorded on the national topographic maps. The information was obtained on the basis of geodetic measurements (triangulation and leveling), aerial surveys and optical remote sensing. Currently, these maps must be corrected and improved because of deformation of the coordinate grid due to global and local plate shifts. First of all, this refers to the mathematical basis of the maps. Accurate topographic maps are in need not only to navigate, but also to indicate geometric relations between points of landmarks depicted on the map, to display information on areal extent of different land use, to design large infrastructure and transportation problems, and so on. They will be in demand for a long time and can be used as an addition to digital maps. A refined rectangular and spatial coordinate system is a base for development of an accurate digital map and a digital elevation model. A spatial reference system defines the coordinate system and Datum in which all landmarks have a unique "address" or position.

Many areas of the world are poorly or insufficiently mapped, and any existing information is often out-of- date. Additionally, the rapidly growing market

for GIS has increased the demand for digital maps. These trends have led to the wide spread use of optical satellite-derived information. With the introduction of the GIS, the foundation of which is software and digital map, the situation has changed significantly due to the use of digital terrain models based on modern imagery, satellite navigation systems. The progress of the development of technology in remote areas of the Earth causes the demand for modern digital maps. Digital elevation models with support of GIS are used to solve applied problems in mapping. In particular, there is the need to assess the accuracy of the model and the choice of the optimal DEM when analyzing the terrain from many digital maps of various scales and methods of obtaining them. GIS takes on special significance, since it is oriented to work with digital cartographic information, which is necessary for coordinate-time binding of objects and used in the planning of construction.
A complete replacement of paper maps with digital ones does not happen despite the growing role of digital maps, which form the basis of GIS. It is only about their joint use and complementation of each other. The capabilities of modern programs allow not only to create a digital map, but to recalculate the coordinates of neighboring states. The construction of a three-dimensional model of relief depends on the accuracy of the heights and the scale of topographic maps.

The main sources of the digital elevation model are geodetic measurements, topographic maps, aerial survey data, laser scanning, the remote sensing and GNSS data. In order to use these data for construction of DEM, it is necessary to have special software or GIS. The GIS is multifunctional and flexible in use, which allows us to create not only 2D, but also three-dimensional models of terrain and topography. The basis for creating a digital elevation model is the values of the heights of contour lines on topographic maps, which are plotted by the photogrammetric method. The accuracy of these contour lines depends on the scale of source-map, the angle of the terrain slope, and the accuracy of the heights of the benchmarks obtained by the triangulation and leveling.

The absolute heights of the surface points on topographic maps are indicated by the benchmarks, town survey marks, the trigonometric beacons. They are the orthometric heights obtained relative to the Baltic sea level (BSL), which has become a classic standard and will probably remain for a long time. These heights are normally obtained through spirit leveling, which is a very tedious and expensive process. Distortions in heights are mostly caused by periodic crustal deformations while the inconsistency between the BSL and geoid.

Since 1977, all heights on topographic maps are normal heights $H\gamma$, which were calculated relative to the Molodensky quasigeoid. The relationship between orthometric height and ellipsoidal height (h) is given by $H = h - N$. Reduction of the normal height $H\gamma$ to the ellipsoidal height h is necessary to calculate the Gauss-Krüger cartesian coordinates in the case of seven transformation parameters determination. The orthometric height should never be given without stating the geoid model used. Different geoid models give different heights for a point, even though the ellipsoid height might be very accurate. The precise geoid model not only enables to convert ellipsoidal heights to leveled heights but also plays an important role in combining leveling data with GPS measurements to study vertical crustal movements for a longer period of time. The determination of heights using GPS is a long-term goal in surveying, in order to substitute time consuming and expensive differential leveling. It is necessary to modify the reference system of topographic maps taking into account modern requirements to accuracy. Another issue is to change the cartographic projection and to improve the origin of the zero point of the vertical component (Datum).

## Additional reference frame

In 2018, Uzbekistan introduced the World Geodetic System 1984 (WGS84) instead of the coordinate system 1942 (SK42) for the geodetic works and town mapping. Due to the lack of digital maps in the new coordinate system, the outdated topographic maps are still in use. As long as the traditional coordinate and reference systems are still used along with the modern systems there will be need for translation of spatial data from traditional systems into the modern coordinate system (Molodensky and Helmert methods). This means that during the transition period there will be a high-volume data processing of geodetic datum shift coordinate transformations from traditional into the modern systems. There are a lot of soft for conversion of spatial data between various coordinate and reference systems. These programs are flexible to use, can perform calculations on large amounts of data quickly and with high accuracy. Users of these programs should be aware of the potential uncertainties, or errors, in computed heights when applying the software to convert values between two systems. If there are accurate initial data, then the results of the calculations will be correct. In the case of approximate parameters between two systems or the absence of them, then the use of the program is not correct. The result is that the relationship between two coordinate systems at the present time must also be observed on the ground, and this observation is subject to error as well. Therefore, only approximate models can ever exist to transform coordinates from one coordinate system to another. All national topographic maps were produced on the basis of SK42 in the Gauss-Krüger projection. As a transitional stage to the international coordinate system, it is possible to use existed topographic maps with the introduction of an additional coordinate network that is shifted by the difference between SK42 and WGS84. There are no digital maps in the new coordinate system, so it is necessary to improve the existed topographic map, taking into account modern requirements for accuracy and efficiency. Modification of the reference frame comprises updating the state vertical network and establishment national GNSS reference station. Additional reference frame based on modified Gauss – Krüger projection is more suitable for topographic maps at a scale of 1 : 25 000 – 1 : 100 000. The transition into the additional reference frame will help the surveyors and geodesists to use the existed and modern

coordinates which are based on the two ellipsoids. Preliminary calculations of the difference in the coordinates of points between the two coordinate systems show that it increases depending on the scale of the map. These topographic maps with an additional coordinate grid will be used until modern digital maps for the whole country are created. Development of high-precision geoid and calculating the exact height on topographic maps is the foundation for the construction of DEM. One of the important construction parameters is the orthometric height on topographic maps obtained with respect to the geoid or BSL.

## Methodology

DEM has three different components: computational model, network connection of nodes, representations with cells and this uses regular matrix of interpolated elevation data, which offers hierarchical classification of information depending on scale. A digital elevation model is a digital representation of a ground surface topography, and it can be represented as a raster (a grid of squares) or as a vector based triangular irregular network (TIN). Contour lines are lines that indicate elevation and the relief, which is in feet above BSL. The contour lines are obtained by cutting the terrain with equipotential surfaces in equal elevation distances and orthogonally projected on the basic equipotential surface. On map, regular contour lines are the thinner brown lines, index contour lines are the thicker brown ones. Creating and analyzing a TIN creates a huge strain on a computer system, and the smaller the area, the faster the processing speed. DEMs are commonly built using remote sensing techniques, but they may also be built from results of land surveying. These are used often in geographic information systems, and they are the most common basis for digitally-produced relief maps. The terrain surface can be described as compromising of two different elements; random and systematic. The stochastic elements are the continuous surfaces with continuously varying relief. It would take an endless number of points to describe exactly the random terrain shapes, but these can be described in practice with a network of point. It is a common approach to use a network that creates sloping triangles or regular quadrants.

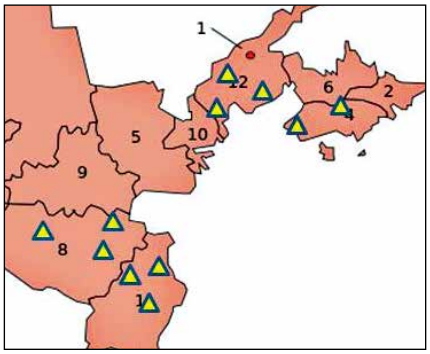


**Figure 1. CATS network in Uzbekistan**

## Observation and measurement

Geo-referencing to the high-altitude coordinate system helps defining coordinates of DEM. The state geodetic coordinate system is outdated and needs to be corrected and modernized. A digital elevation model should be geo-referenced to the international geodetic coordinate system. One of the most significant developments of the past few years has been the establishment of the International GPS Service for Geodynamics.

From 1992 to 1998, GPS measurements were carried out on the CATS project in order to study the distribution and accommodation of intraplate deformation in Central Asia for an improved assessment of geohazard (Fig. 1). The CATS project has a wider coverage and covers the region of Central Asia, although not the entire territory is covered by this network. (Fig.2). GPS receivers can measure ellipsoid height, some receivers use approximations of the geoid height to estimate the orthometric height from the geoid height. As an example, when using GPS receivers in the CATS project, the height of the geoid varied from -37 to -51m depending on the terrain.

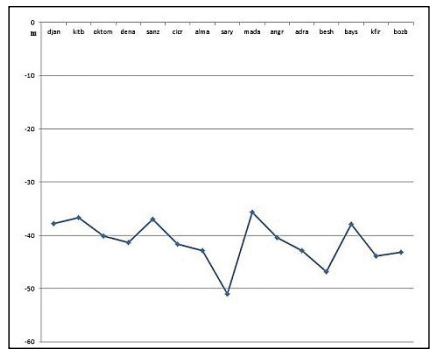


**Figure 2. Geoid deviation for CATS points**

The quality of the network geometry of the CATS network is in the order of 1- 3mm for horizontal components and about 5 mm for the height. This is derived from Helmert transformation between the daily solutions and the campaign solution. The global network accuracy is in the order of 1-2cm. Figure 3 shows the deviation values of the coordinates (in mm.) of the CATS project points on the daily solutions using the Helmert transformation.

The largest deviation in height is obtained for the stations "Angr" and "Adra". This is due primarily to the fact that there are mines in these areas. Repeated measurements on these points will give an answer to the reason for the deviation of coordinates in height. The coordinates of these CATS points will be used to create a high-precision geodetic network. This starting configuration will be augmented by additional GPS stations in those areas where nothing exists, in order to obtain a more or less homogeneous data. Accuracy of computed geoid undulations depends largely on the extent of the terrestrial gravity anomaly data used around the computation point. In any gravimetric geoid computations at a regional or local level the gravity data is used only to a limited extent, therefore Stokes formula in its original form may not provide the desired solution. A precise geoid model is necessary for the establishment of a rigorous orthometric height system and unification of vertical Datum.

In 1996-1999, specialists from the Munich Center for the Study of the Earth implemented a project on remote sensing of Central Asia using the ERS1 and the SAR installed in Kitab, Uzbekistan (Fig.4). ERS1 imagery was used to generate high quality DEM using SAR interferometry; to provide thematic information on land cover including tropical areas; to improve localization of products complementing GPS measurements in remote areas; to

rectify old or inaccurate maps or maps generated using other space data to high localization accuracy. From October 1998 to March 1999, the ERS-1 carried out remote sensing of the country with the help of the RA (Radar Altimeter) and PRARE (Precise Range and Range-rate Equipment). Since the ERS-1 has no receiving equipment, the PRARE receivers were installed on the ground. The ground station operate as `listen-only' stations, using the one-way Doppler signal in S- or S/X-band and the broadcast satellite ephemerides for on-line position determination at the site (Fig.5). The relative positioning in centimeter accuracies which can be derived with help of these stations, in particular when tracking in an interferometric data, will be appropriate for many geodetic and geodynamic applications.

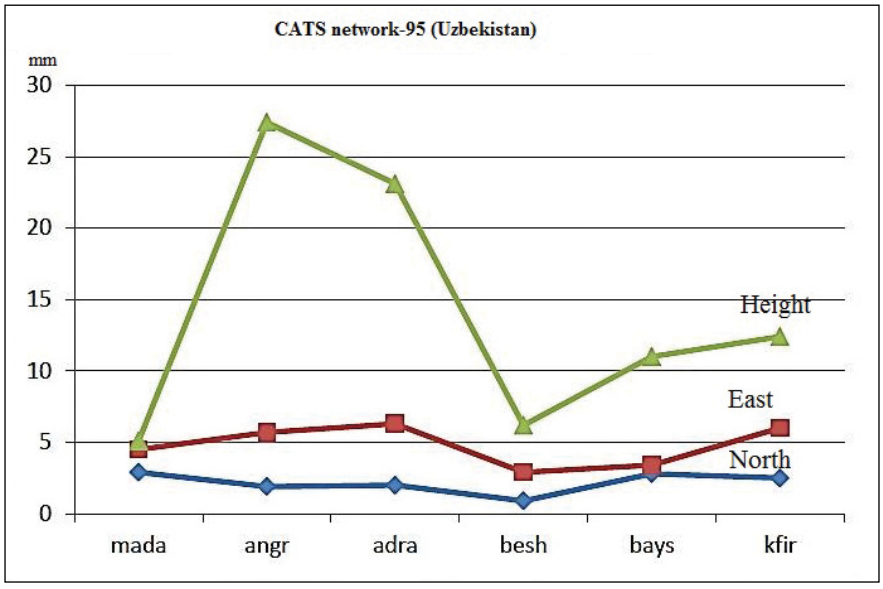


**Figure 3. Repeatability of CATS 95 network**

**Figure 4. SAR, Kitab, Uzbekistan**

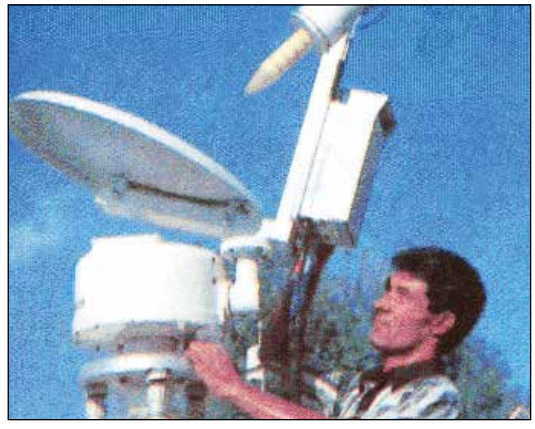

**Figure 5. PRARE, Kitab, Uzbekistan**

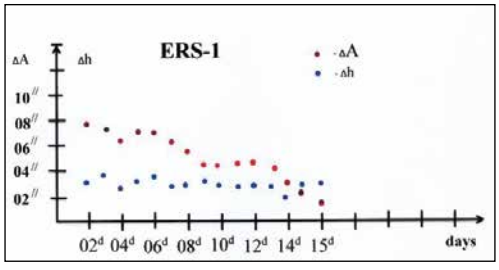


**Figure 6. O-C variation within 2 weeks in ΔA and Δ h for ERS1.**

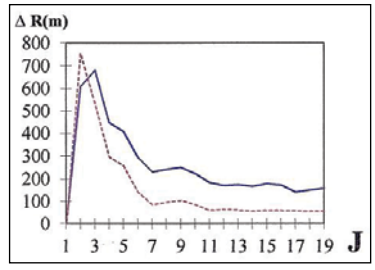


**Figure 7. The change in the difference of distances to the ERS1 with the influence of zonal harmonics and atmosphere**

During the passage of the satellite over the territory, software was developed to predict its trajectory. In order to estimate the effect of Earth's anomalous gravity field on particular satellite orbits, it is often sufficient to determine the accelerations caused by the first zonal harmonics. The dominant perturbing influence on the orbits of low artificial satellites is Earth's noncentral gravitational field. In order to obtain high accuracy in orbit computations, which is necessary for most geodetic applications of satellite observations, it is necessary to estimate also the accelerations caused by atmospheric drag. For low orbiting satellites atmospheric drag also plays an important role. Therefore, there was worked out algorithmic program for calculation of ERS1 trajectory with taking into account of zonal harmonics $J_{19}$ and atmospheric drag. There are calculated values azimuth (A) and elevation (h) of ERS1 trajectory during two weeks. The Figure 6 shows the deviation values in azimuth and altitude between the observation and the calculation $(O\text{-}C)_{\Delta A,\, \Delta h}$ .

Calculation of ERS1 trajectory shows that the developed algorithmic program is correct and it is closed to the theoretical trajectory in short time for optical observation (Fig.7). The results of calculation show that the Earth's geopotential and atmospheric drag significantly affect the satellite motion for altitudes from 200 to 800 km. And also with an increase in the number of zonal harmonics, the distance

**Figure 8.The digital map of Tashkent area**

difference between the perturbed and unperturbed motion decreases.

Preliminary processing of remote sensing of this territory was carried out in Munich. Post- processing of this data was carried out with the help of the ERDAS soft and it is recorded on 83 CD at a scale of 1: 100 000. There is the first digital map of the Tashkent area based on the remote sensing (Fig. 8). Unfortunately, there is no grid system on the digital map.

## Results

In 2000-2002, digital maps of ten regions were built by the MSIAC, USA with the help of GIS TERRA VISTA for maps at a scale of 1: 50 000. Terra Vista has possibility to import DTED0 level elevation data and VPF data from an open NGA data source and to create a Janus Terrain Database. Terra Vista is an advanced terrain modeling software that enables developers to generate correlated visual, sensor, SAF/ CGF, and analytical 3D databases. Providing the industry's highest level of correlation, fastest production times, and most powerful production environment, Terra Vista includes all of the features in Terra Vista Base plus more output options and key integrations with productivity options. Developed digital maps with the help of Terra Vista were adapted for special studies. However, the images of the contours on these models did not correspond to the contours on the topographic maps, and more over they did not reflect the complete picture of the terrain where topography was performed (Fig.9,10). After a detailed analysis of these digital maps, it was suggested to improve the GIS Terra Vista taking into account modern requirements to the terrain.

With the help of these GIS, the digital terrain model is presented in 3D with the ability to export in any format, as well as in the multimedia representation of the surface. Creating a 3D model does not require lengthy preparation; it is enough to have a 2D map and an elevation matrix. From these data, a three-dimensional model of the terrain of the selected terrain may be built. To build a 3D terrain model, one can use: a vector map, a matrix of heights, a triangulation relief model, a map classifier, a library of three-dimensional images of objects, digital photographs of the terrain and digital photographs of terrain objects. The main module for building a digital elevation model is the matrix of heights (Fig.11).

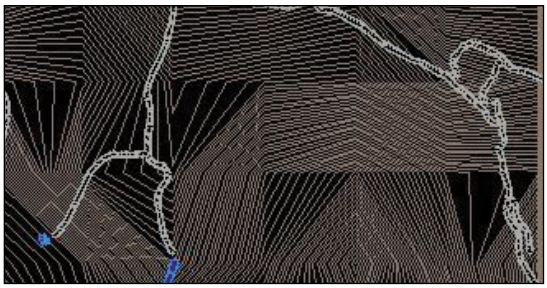

Figure 9. Contour lines (GIS Terra Vista)

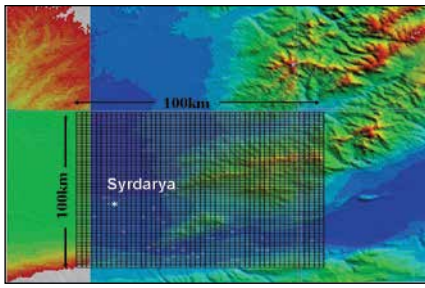


Figure 10. DEM (GIS Terra Vista)

The matrix of the heights of the terrain is based on the information of map objects having an absolute height or a 3D. The matrix of heights is used in relief analysis, building profiles and visibility zones, calculating the length and area of objects with taking into account the characteristics of relief, calculating the volume of earthworks, modeling flood zones, determining the directions of slopes, forming a three-dimensional map of the area and others.

The results of creating a digital terrain model using the GIS PANORAMA are produced in the National University of Uzbekistan ( Fig.12). These areas are placed on topographic maps of 1: 500000 scale, which were scanned in raster format. Before digitizing this raster data, it is necessary to transform the raster image into the mathematical basis of topographic maps, taking into account all accuracy requirements. This procedure is performed more accurately and in detail in the national mapping agencies. In the process of digitization, raster and vector maps of the terrain are created for building DEM of some areas. The elevation were determined using not only contour lines on the topographic maps, but also all the additional information from the maps. The horizontal and vertical Datum of the DEMs is the SK42 and the BSL.

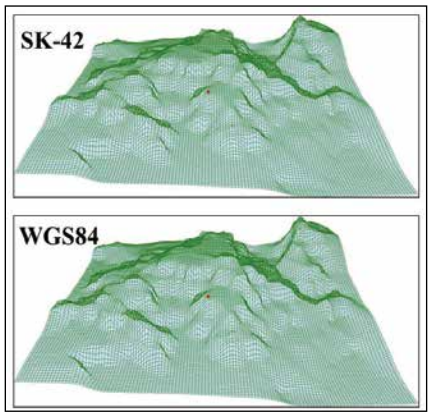


Figure 11. DEMs for two systems

For comparison, digital models were developed in two coordinate systems, SK42 and WGS84. This will allow to analyze the geoid undulation for the gravitational field of the studied area. In the future, these data will be used to improve the digital terrain model and calculate the height of the quasigeoid. There is a slight difference between the two coordinate systems due to the choice of the scale of the topographic map and the terrain relief. The spatial difference of the digital models of the two systems can be obtained using large scale topographic maps.

The relief of Central Asia is heterogeneous and difficult to perform geodetic and cartographic works. Therefore, a digital model of the relief and terrain is only the preliminary information when it is built with the use of topographic maps. This can serve as a guide for reconnaissance of the terrain before creating a national digital model. Preliminary results of digitization of contours showed that the initial data of the topographic map needs to be corrected and edited, both in the situation and in generalization. In addition, it is necessary to use the results of the modern navigation surveys.

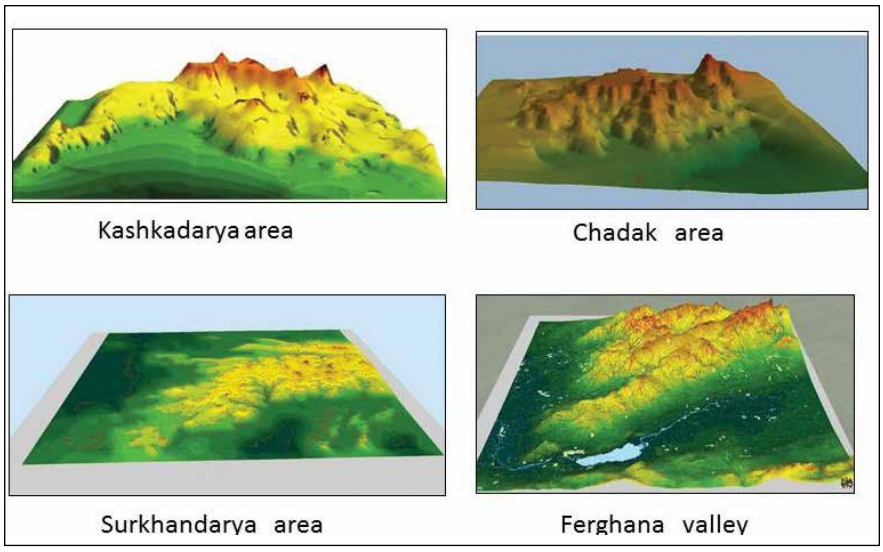


**Figure 12. DEMs of four areas of Uzbekistan**

## Conclusion

Thus, building elevation models by interpolating digital contours from topographic maps has its disadvantages. This is a hard work and this does not have enough satisfactory modeling accuracy. Despite these disadvantages, it is assumed that digitized topographic data will be used for a few more years. Construction a DEM provides an opportunity to create a national model of the relief.

The developed digital terrain models will be an example for building a digital model of the territory as well as detailed information for editing existing topographic maps. In addition, digital models in the border areas lead to the development of a unified system of coordinates for two or more republics. It can also be useful in the design of hydraulic structures and facilities where the mining takes place. This is especially important in areas where there are landslides and flooding. The developed results are used when conducting lectures and practical classes in higher educational institutions. The data can be used by cartographic organizations in the design of building structures near mountainous areas.

In the future, the use of the GOCE satellite data will provide more detailed information on the geoid, relief and water surface of the Aral Sea, as well as on the environmental protection.

Construction a DEM provides an opportunity to create a national model of the relief. The developed digital terrain models will be an example for building a digital model of the territory as well as detailed information for editing existing topographic maps

## Acknowledgement

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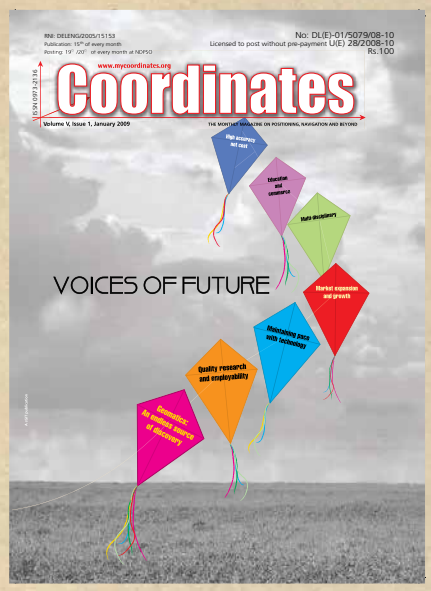
# In Coordinates

## 10 years before...

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## Signal design criteria and parametric analysis

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Current global navigation satellite systems (GNSSs) [1] are based on signals lying within the L-band of the radio-navigation satellite service (RNSS) spectrum. Since the need for more systems and signals is emerging, new alternative frequency resources are needed. In particular, the C-band frequency portion is envisioned as an option for future GNSSs.

## Voices of future

**Prof George Cho**
University of Canberra Australia

In this article students from around the globe were canvassed on their views on their studies in geomatics and GNSS. Interesting commentaries and views were received from twelve students.

### Need to know capabilities of GNSS

**Deok Won Lim**
Chungnam National University, Daejeon, Korea

### Challenge is high cost of equipment

**Ruzinoor Che Mat**
Universiti Putra Malaysia, Malaysia

### There are unlimited opportunities

**Malambo Moonga Lonesome**
University of Applied Sciences Stuttgart, Germany

### A competitive advantage in career

**Adam Yau**
MPhil student The Hong Kong Polytechnic University Hong Kong

### New skills required to exploit spatial data

**Sheelan Sh.Vaez**
PhD student, Melbourne University, Australia

### The challenge is to increase the accuracy

**Xiaofan Li**
University of Colorado at Boulder, USA

### An endless source of discovery

**Chris Goodall**
PhD student University of Calgary, Canada

### Graduates need to "market" themselves strategically

**Karla Edwards**
PhD Candidate Ohio State University, USA

### Economic crisis will lead to innovation

**Simone Savasta**
Ph. D. Student Politecnico di Torino, Italy

### The problems in the dual-use of GPS and GLONASS remain

**Hedeki Yamada**
PhD. Candidate, Tokyo University of Marine Science and Technology, Japan

### Firms to take up a PhD student for meaningful research are highly rare

**Suddhasheel Ghosh**
Indian Institute of Technology Kanpur, India

**Susham Biswas**
**Indian Institute of**
Technology Kanpur, India

### Educational institutions should be in tandem with latest technologies

**Thilantha Lakmal Dammalage**
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# Geospatial industry must focus on making big data more useful

The relevance of geospatial information and technology to continue to build upon its current momentum and grow increasingly relevant to many and varied business processes

**Boris Skopljak**
Marketing Director for Trimble Geospatial strategy and analytics

As we anticipate technology trends unfolding in 2019, the dominant theme for the geospatial industry is the need for precise data and the ability to make that data useful in more workflows and in varying markets around the world.

We predict geospatial technology in the upcoming year will be shaped by cloud computing, artificial intelligence, autonomous vehicles, sensor fusion, ubiquitous use of geospatial data, 3D modeling and other advancements. These innovations can fail if they don't clearly benefit users, so product development needs to be aligned with the work of our customers.

We predict geospatial technology in the upcoming year will be shaped by cloud computing, artificial intelligence, autonomous vehicles, sensor fusion, ubiquitous use of geospatial data, 3D modeling and other advancements

In 2019, here are several technology trends we expect to propel the geospatial industry forward:

## Making more date more useful

While the industry has made great strides when it comes to making mass data collection easier, the real value of data is not in collecting it, but in using it for better decision-making. The geospatial industry must now turn its focus to making big data more useful, and in more meaningful ways. We believe we will see technology providers focus on the advancement of processing tools and software solutions that will help users turn their data into decisions in 2019.

Over the coming months, we also expect to see the continued adoption of a single geospatial data hub that enables users to bring all disparate data to a single department, enabling field-to-finish with more confidence. With the support of a "central hub," geospatial professionals will also be better informed to select the best hardware tool for the job, regardless of whether they walk it, fly it or drive it to gather data.

The ultimate goal is to shift away from siloed collections of data toward more reliable and useful systems of record that can be referenced by multiple users across multiple disciplines. Cloud-based platforms and feature services will play a major role in eliminating unnecessary physical data transfer and enabling easier project collaboration and information exchange, all of which makes it easier to leverage big data to make better business decisions.

## Harnessing the power of sensor fusion

Looking ahead, we expect sensor fusion technologies – which combine multiple different sensor types or technologies in ways that maximize their combined strengths while minimizing their combined weaknesses – to include more IMUs, GNSS and emerging technologies like Solid State Lidar and SLAM processing. These innovations will continue to make it possible to blend multiple disciplines of mass geospatial data capture into one seamless process.

Mobile mapping systems are one example. They combine the various strengths and weaknesses of different types of sensors -- inertial (IMU), wheel speed, GNSS, cameras and LiDAR -- and fuse these sensor outputs, achieving greater level of accuracy and detail enabling detailed engineering, operation and design.

Having different types of sensor data can be extremely powerful, but even more beneficial is fusing that data for analysis and decision making. Supported by the right software, sensor fusion is about getting the most out of various sensors and sensor combinations to solve business problems.

We believe this type of technology integration will remain a priority in 2019 as more geospatial professionals take advantage of unique sensor combinations that provide enhanced geospatial context and understanding.

## Increasing technology access with as-a-service business models

In recent years, enterprise organizations have increasingly adopted the subscription or pay-per-use service model rather than one-time technology purchases. The "As-a-Service" business models offers substantial benefits, including a more predictable cash flow and streamlined workflows, and we expect it to continue to gain in popularity in the coming year.

The As-a-Service approach also results in more people using their smartphones and mobile devices to receive satellite data for a precise position – a technology advancement that will multiply the capability of organizations to increase the adaption of professional grade measurement technology in the coming years.

## Better understanding site conditions with visualization and AR/MR

The use of augmented reality (AR) and mixed reality (MR) tools will increase in the next several years, in part because geospatial data, such as point clouds, complex meshes and terrain models, is often difficult to explain and deliver to clients. AR, MR and other visualization tools make it easy to understand existing site conditions by overlaying models over the existing environment. For example, a user of augmented reality technology could view existing underground services and future landscapes overlaid on a worksite to avoid hitting a utility line during excavation work. Other benefits include collaboration, planning and asset management. Organizations that can offer this functionality to their customers will have an edge on the competition in 2019 and beyond.

## Generating rich data via 3D modeling, bim

The mixed reality solutions mentioned above thrive on accurate and properly attributed 3D models. The design and construction industry is at a tipping point in which Building Information Modeling (BIM) can positively affect geospatial professionals' work the more they embrace it. However, prospective BIM adopters need to realize the technology not only provides intelligent 3D modeling, but it also offers a centralized platform for sharing data to help partners communicate effectively, in real-time.

When surveyors take advantage of BIM holistically, they are both factoring in the traditional aspects of a building's design and generating rich data spanning the range of properties of a structure's components, construction and maintenance.

The increased adoption of BIM technology represents a paradigm shift in the design, build and operate process. At its core, BIM is meant to transform how project teams work together on a job, from start to finish, and we expect to see increased discussion, development and adoption of BIM technology in the coming months and years.

## More widespread reliance on geospatial information

Geospatial data is no longer utilized just by surveyors and those trained in the collection and use of geospatial data. I expect the relevance of geospatial information and technology to continue to build upon its current momentum and grow increasingly relevant to many and varied business processes. As such, barriers that previously segmented functionalities will increasingly dissolve, with further integration driven by innovation. This integration will help reduce the gap between data capture, processing, analysis and delivery of an easy-to-understand, cohesive image of the real world, from surveyor to customer.

### Actifio teams up with Onix

Actifio, enterprise Data-as-a-Service (DaaS) software provider, has announced an alliance with Onix, provider of cloud computing solutions and consulting services. This alliance will provide Onix customers with a powerful cloud infrastructure backed by data replication and disaster recovery services powered by Actifio, allowing enterprises to bring their on-premise environment to the cloud. With this alliance, Onix and Actifio will collaborate to deliver clients powerful infrastructures teamed with data replication and disaster recovery insurance. *www.actifio.com*

### Altran collaborates with Wirepas to develop LBS solutions

Altran, leader in engineering and R&D services, has signed a partnership with Wirepas to extend its range of localization solutions services. As a part of its portfolio, Altran provides solutions to solve asset tracking issues thanks to location-based services leveraging an end-to-end, modular and technology-agnostic architecture, from physical devices to backend platform and applications. *www.wirepas.com*

### FCC to investigate Mobility Fund coverage mapping

With more than $4.5 billion at stake over the next decade, the Federal Communications Commission has launched an investigation into the accuracy of maps representing national carriers' LTE coverage in rural areas that would potentially qualify for federal subsidies.

The accuracy of those maps in representing in granular detail which parts of the country have acceptable LTE coverage and speed is a major factor in determining whether a particular area will receive federal funding as part of Mobility Fund II, which will pump $4.53 billion in subsidies into expanding rural LTE coverage over the next 10 years.

The maps were published in 2018 based on a one-time collection of LTE coverage data and subsidy data from the Universal

Service Administrative Company; commercial mobile network operators contributed their own coverage data to that effort. Initially, the FCC established a 150-day window for interested parties — mostly rural wireless operators who could potentially serve those areas with support from MF-II if the areas are deemed insufficiently served by non-subsidized LTE coverage — to file challenges to those coverage maps, including speed test data to back up their challenges. *www.rcrwireless.com*

## Tesla tests Autopilot navigation for traffic lights and roundabouts

Tesla has teased that Navigate on Autopilot will gradually handle more and more driving responsibilities, but those aren›t just fanciful long-term plans - they're very much on the roadmap for the near future. In the midst of a public pitch for Navigate on Autopilot, Elon Musk mentioned that Tesla is currently testing «traffic lights, stop signs & roundabouts» in pre-release software. It›s hard not to be a bit skeptical of Musk›s claim that you›ll soon travel to work with «no driver input at all,» but this is promising if the very thought of entering a busy roundabout makes you nervous. *www.engadget.com*

## Connected and Autonomous Commercial Vehicles Face Daunting Cyber Threats

New analysis by Frost & Sullivan, "Automotive Cybersecurity Emerges as a Strategic Priority in an Era of Connected and Autonomous Commercial Vehicles," finds that automotive cybersecurity solutions are emerging as a strategic priority for automakers, many of whom are partnering with automotive cybersecurity specialists to ensure the safe and successful deployment of connected and autonomous commercial vehicles.

Frost & Sullivan estimates that 55% of trucks in North America and 43% of trucks in Europe will be connected by 2025. This will highlight the critical need for robust cybersecurity solutions with active multi-layer protection that address the unique safety requirements of connected and autonomous commercial vehicles. *www.frost.com*

## Power Suit for Disaster Relief

Specially developed for deployment in disaster-stricken areas, Augsburg-based robotics specialist German Bionic introduces its new Cray + exoskeleton model. Possible application scenarios for the portable robot system include rescue missions following natural disasters as well as serious traffic accidents or terrorist attacks. External skeletons, or exoskeletons as they are more commonly referred to, are human-machine systems combining human intelligence with machine power to support or amplify the movements of the wearer. The technology incorporated in the Cray + is based on the successful Cray X model, which was developed for implementation in industry and logistics where it has been used for some time. The new disaster relief Cray + model is specially designed for deployment in rescue operations - even if taking place in extreme weather conditions - and also integrates a communication and GPS system. *www.germanbionic.com*

## Staqu launches an AI app for India State of UP police department

One of India's leading Gurgaon-based AI start-up, Staqu announced the launch of TRINETRA, an AI application for the Uttar Pradesh Police (UP) department. The application digitizes and search records using AI and carries records of criminals, assisting police forces at ground zero with real-time information retrieval during investigations, regular checks, verifications, and at police checkpoints.

TRINETRA equips police forces to carry superior technology in their pockets. With this application, police personnel can easily register or search for criminals via simple biometric features, such as images or videos. The app is powered by Staqu's expertise in facial recognition, visual search, machine learning, and deep learning, works well with low-resolution images and videos, and offers better accuracy than any other criminal recognition system. With AI-powered Gang identification Technology, TRIENETRA not only identifies a criminal but also their associates active in different districts and part of the states. *https://tech.economictimes.indiatimes.com*

## Linxup GPS integrates with Fleetio for Fleet Maintenance

Linxup by Agilis Systems, a leading provider of GPS fleet management tools and asset trackers, has partnered with Fleetio to provide automatic mileage tracking for fleet maintenance management.

Fleetio's preventative maintenance scheduling helps fleet managers stay on top of regular service items such as oil changes, mileage service intervals, brakes and more. Fleetio automates service reminders, helping to maximize vehicle uptime and road readiness. Fleetio also automatically forecasts the due date of a service reminder based on a vehicle's daily average usage. *agilissystems.com*

## Droneshield join hands with Thales

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

## Drones help map sea level rise

Drones can be used to create low-cost and accurate 3-D maps of coastal areas, new research shows. The technique – developed by the University of Exeter – was tested at beaches where sea turtles nest, allowing scientists to see how rising sea levels will affect them. It combines drones and photogrammetry (extracting measurements from photographs) with accurate GPS satellite location to create detailed digital models of coastal habitats. Previous methods were either cheap but low in quality, or high-quality but cost thousands of pounds to produce.

Scientists tested the technology at Alagadi in Cyprus – a key nesting site for loggerhead and green turtles – and found that a sea level rise of 1.2 metres would result in the loss of up to 67% of loggerhead nesting sites and 59% of those used by green turtles.

"Being able to accurately map out terrains in such a fine and local scale is crucial if we want to develop effective conservation strategies," said lead author Miguel Varela, of the Centre of Ecology and Conservation on the University of Exeter's Penryn Campus in Cornwall.

"Most of the studies on climate change impacts are done on a global scale, but is also crucial to understand what will happen on local areas. This method allows us to create realistic digital models that are highly accurate (less than 10cm error).

This is a fine scale when compared to global projections. It's ideal for surveying coastal sites, but could also be applied to other habitats and species, and be used to help identify wildlife protection areas."

In this case study, the researchers combined their imagery of Algadi's beaches with data on the location and depth at which turtle eggs are laid. *https://phys.org*

## Airspace launches Galaxy Drone Security Solution

Airspace Systems has introduced Airspace GalaxyTM, the first family of fully-automated, always-on airspace security solutions that accelerate the integration of drones into cities and protects people and property -- on the ground and in the air -- from clueless, careless or criminal drone operators.

The new Airspace Galaxy security platform combines input from multiple sensors to detect drone activity at long-ranges, instantly identifies authorized and unauthorized flights, assesses risk, and if necessary and permitted, deploys an autonomous mitigation system to safely capture and remove an unauthorized or malicious drone. *http://airspace.co/*

## Vodafone organizes 4G trials at the BCN Drone Center

Vodafone is conducting 4G drone test trials at the BCN Drone Center to enable the massive use of drones in the near future.

Soon, all drones equipped with a 5G SIM card will be able to be controlled and geo-localized simultaneously. This will also enable the possibility of landing them in case of accessing restricted areas such as airports or concentration of people.

The flight tests consist in several flights at different altitudes in order to model the aerial coverage. The emissivity patterns of the antennas will be fine-tuned to guarantee capacity of thousands of drone flights simultaneously. *www.barcelonadronecenter.com*

## Drone company inks delivery agreement with Moose Cree First Nation

Drone Delivery Canada (DDC) has executed a commercial agreement with the Moose Cree First Nation to deploy DDC's drone delivery technology platform with the Moose Cree First Nation communities.

The Company is currently permitted to commercially operate its drone delivery platform within the Moosonee and Moose Factory communities with its Compliant Special Flight Operations Certificate (SFOC), which permits DDC to conduct drone operations in all Canadian provinces and territories. DDC, with its Compliant SFOC in hand, will deploy its drone delivery platform to service the communities of Moose Factory and Moosonee, two northern towns located in Ontario approximately 19 kilometres south of James Bay. *www.sudbury.com*

## Spanish Army acquires two Alpha 800 UAS

The Spanish armed forces has acquired two Alpha 800 UAS from Alpha Unmanned Systems.

The 14kg gasoline-powered Alpha 800 provides three hours of continuous flight with a 3kg payload and 30km operating range. It has a light and robust airframe and is equipped with a military-grade autopilot with high precision GPS and sensors. It can be used for ISR, including unexploded ordnance detection, as well as for the delivery of supplies. *www.shephardmedia.com*

## DJI reveals Mavic 2 Enterprise Dual

DJI has revealed the Mavic 2 Enterprise Dual, a portable industrial drone equipped with powerful, side-by-side visual and thermal cameras that provide commercial pilots a reliable tool to operate better, safer and quicker in challenging environments.

Developed in partnership with FLIR Systems, the Mavic 2 Enterprise Dual features the compact design of DJI's Mavic 2 Series drones with the same array of advanced controls and accessories found in the Mavic 2 Enterprise.

## ISRO to launch two satellites under IDRSS

As a part of its proposed manned space mission, India will launch the Indian Data Relay Satellite System (IDRSS) to improve data relay and communication links with its remote sensing/earth observation satellites. The first one is expected to be launched in 2019.

The two-satellite IDRSS will maintain a continuous communication link with India's remote sensing/earth observation satellites and also with the Geosynchronous Satellite Launch Vehicle Mark III (GSLV Mk III) that would carry three Indian astronauts to space in 2022.

The proposed system will also reduce the dependence on the ground stations in tracking satellites. The other benefit is that the communication and data transfer could be in real time as the remote sensing satellites can relay the data gathered to IDRSS satellites which in turn can transmit them to the ground. *www.indiatoday.in*

## Russia to open RS data gathering center in Antarctica

The holding company Russian Space Systems will open a ground center in the Antarctic for gathering and processing data from remote sensing satellites in February 2019. The information will be transmitted from the analytical center to any point on the globe.

The research ship The Akademik Fyodorov delivered the equipment for the data processing center on November 7. The facility will be controlled either on site from a remote working place at the wintering party's base and also from Russia via satellite.

The Antarctic center of the government-run corporation Roscosmos has been deployed in accordance with Russia's federal space program for 2016-2025, which envisages creation of an integral information system of remote sensing of the Earth. The system's full-scale operation began in 2016. It consists of centers scattered over the whole territory of Russia. The system ensures the centers' cooperation with the cluster of remote sensing satellites, plans remote sensing, gathers and processes data and provides information to the end users. *http://tass.com*

## PJTSAU inaugurates Remote Sensing and GIS lab

The Remote Sensing and GIS lab established by the Professor Jayashankar Telangana State Agricultural University (PJTSAU) will now help students, researchers and faculty members to easily access satellite images of various agriculture projects.

The lab which has come up in collaboration with the National Remote Sensing Centre (NRSC) was recently inaugurated by Vice Chancellor Dr V Praveen Rao in the premises of Water Technology center on the campus. *https://telanganatoday.com*

## Vietnam to complete legal corridor for remote sensing activities

The Ministry of Natural Resources and Environment (MONRE) recently proposed a draft decree on remote sensing activities. The decree aims to complete policies on the use of high technology in managing natural resources and the environment.

MONRE is drafting a decree on remote sensing, specifying principles in these activities such as providing remote sensing images for basic and professional survey and mapping, regularly updates of data and information, monitoring natural resources and the environment, search and rescue, disaster prevention, response to climate change and ensuring national defence and security.

The national remote sensing database will be maintained, operated and updated regularly and used to update the national geographical spatial system.

According to the ministry, the policy framework, legal documents, standard system and technical regulations of remote sensing will be formulated by 2025 and legal framework will be completed by 2030. *http://vietnamnews.vn*

## China launches two RS satellites for Saudi Arabia, ten microsats for private companies

Reently, China carried out its 35th orbital flight of 2018 with the launch of two remote sensing satellites for Saudi Arabia and a host of microsatellites for Chinese commercial space companies.

The two high-resolution Earth observation satellites were developed by King Abdulaziz City for Science & Technology (KACST) and carry hyperspectral observation systems, with Saudi Arabia and China signing an agreement for their launch in January 2016.

The China Great Wall Industry Corporation (CGWIC), an arm of the main Chinese space contractor, CASC, created to provide commercial launch services, announced afterwards that ten small satellites from Chinese commercial companies piggybacked on the launch. https://gbtimes.com

## Indian Government approves Rs 10,000 cr Gaganyaan project

The Central Government of India recently approved India's first indigenous human spaceflight programme- Gaganyaan. It has approved funds of Rs 10,000 crore for the ambitious project which would carry three-member crew for minimum seven days in space.

In his Independence Day speech on August 15, Prime Minister Narendra Modi had announced that India will launch a manned mission to space by 2022 and become the fourth nation to do so after Russia, the United States and China.

The three-stage heavy-lift launch vehicle, GSLV Mk III, will be used to launch Gaganyaan, and national agencies will collaborate with the Indian Space Research Organisation to bring the mission to fruition.

The programme aims to establish a broader framework for collaboration between the national space agency, academia, industry, national agencies,

and other scientific organizations. It is also expected to generate employment and train human resources in advanced technologies and inspire young students to take up careers in science and technology, according to the government.

## Earth observation satellite (CSO) launched successfully

The first of the CSO (Composante spatiale optique) Earth observation satellites for the French Armed Forces, has been successfully launched on a Soyuz launcher from the Kourou European Spaceport in French Guyana.

CSO will provide very high-resolution geo information intelligence to the French Armed Forces to its partners Germany, Belgium and Sweden. The CSO satellites are equipped with a very agile pointing system and are controlled via a secure ground control operations centre.

As prime contractor for the CSO satellites programme, Airbus has provided the agile platform and avionics, and was also responsible for the integration work, testing and delivery of the satellites to CNES. Thales Alenia Space provided Airbus with the very-high resolution optical instrument. Airbus teams will also continue leading the User Ground Segment operations, as they do currently with operating legacy programmes(Helios, Pleiades, SarLupe, Cosmo-Skymed). *airbus.com*

## FCC fines Swarm $900,000 for unauthorized smallsat launch

Swarm Technologies will pay $900,000 to settle an investigation by the U.S. Federal Communications Commission into the startup's launch of four picosatellites on an Indian rocket this January without regulatory approval, the FCC announced Dec. 20.

Swarm defied the FCC by launching the satellites after the agency dismissed its application for an experimental authorization to communicate with the spacecraft. The FCC said Swarm's satellites, measuring one fourth the size of a standard single-unit cubesat, were too small to be reliably tracked once in orbit.

The $900,000 penalty, though small compared to fines as high as $120 million the FCC imposed this year on spoofed robocall operations, is nonetheless meant to send a signal to those that might intentionally or inadvertently follow Swarm's footsteps.

Swarm's renegade actions garnered condemnation across the satellite industry, which feared a regulatory clampdown in the aftermath of Swarm's decision. The FCC withdrew an authorization it previously granted for another four satellites Swarm intended to launch on a Rocket Lab Electron mission that occurred in April.

Spaceflight, the company that arranged Swarm's January launch on a Polar Satellite Launch Vehicle from India, said it will now check to make sure its customers have necessary licenses ahead of time instead of relying on them to do their own self-regulation. h*ttps://spacenews.com*

## Enugu govt partners World Bank on GIS-based road mapping

ENUGU State Government has said it is partnering with World Bank on GIS-based road inventories and mapping for easy identification of rural road and economic development. Ifeanyi Ugwuanyi Project co-ordinator of Rural Access and Mobility Project, RAMP, ll, Chief Chinedu Ugwu, who revealed this at a stakeholders' sensitisation workshop and training on GIS-based road inventories and mapping in Enugu, said it would improve security, infrastructure and agriculture. Ugwu said the GIS system and its mapping would allow the state to have real-time data for proper satellite identification of places and locations within the state. He noted that the project would also help the government to know the situation of all roads, houses, schools, markets, hospitals, bridges, river crossing, farms and other important landmarks of the state. *www.vanguardngr.com*

## BASF Automotive Solutions to develop paints that reflects LiDAR

BASF Automotive Solutions is working on improving lidar detection with near-infrared reflective dark automotive paint colors so that it's easy for lidar to detect vehicles and pedestrians.

Dozens of companies, possibly even more, are racing to improve upon existing lidar to solve this problem. Current versions of lidar can have difficulty distinguishing dark-colored cars as Dark colors tend to absorb more of the lidar's pulses than they reflect, which makes them difficult to see. It's kind of like wearing a black shirt on a sunny day versus wearing a white shirt. The black shirt absorbs, the white shirt reflects.

BASF is changing the chemistry of its automotive paints so that they are more reflective to lidar. Specifically, the company stated that the color coat doesn't use any carbon black, which is one of the main culprits in the absorption of lidar waves, and the undercoat is formulated so that it's highly reflective to lidar. *https://automotive.basf.com*

## The World Bank to support Geospatial Information Management in 30 countries

The World Bank and UN-GGIM collaborated in the development of the Integrated Geospatial Information Framework (IGIF), which was endorsed at the eighth session of the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) from 1 – 3 August 2018 at the United Nations Headquarters in New York. This framework and subsequent implementation guide is designed to help member states to better manage their geospatial information at national or sub-national levels.

As next steps, the World Bank will provide assistance to countries to apply the IGIF at the country and local levels. The first country-level Action Plan has already been prepared for Palestine and, at the sub-national level, for Tirana, Albania. The work is underway in other countries such as Vietnam and Guyana. Simultaneously, the World Bank is working with partners to advance plans for more countries.

In this context, the World Bank announced a call for action and an ambitious goal to help at least 30 countries in three years, to cover activities like;

- Development of the geodetic reference framework
- Financing of Continuously Operating Reference Stations (CORs)
- Collection of fundamental data
- Establishment of a geoportal
- Financing equipment/ computers/systems
- Training and capacity building programs
- Support in drafting laws and regulations in this area

The process of requesting World Bank support for investment in geospatial information involves the responsible agency for a geospatial information infrastructure to send a request to the World Bank through their Ministry of Finance. Once the request has been formally received and accepted, the Bank mobilizes a team of experts to work with governments to prepare the Action and Investment plan and detailed project.

## ICTA launches NSDI in Sri Lanka

The National Spatial Data Infrastructure (NSDI), a highly awaited platform for geo spatial information in Sri Lanka, was ceremonially launched by the Information & Communication Technology Agency of Sri Lanka (ICTA) recently at Trace Expert City.

Former Telecommunication, Digital Infrastructure and Foreign Employment Ministry Secretary Wasantha Deshapriya, the pioneer in initiating NSDI in Sri Lanka, graced the occasion as the Chief Guest. Other distinguished invitees, including senior Government officials, industry leaders, academia, NGOs, INGOs, and media also dignified this launching ceremony.

The NSDI is a platform consisting of a website, a metadata catalogue and a geo-portal which facilitate accessing geospatial information for decision makers. While the website provides the introduction to the NSDI and its services and governance structure, the metadata catalogue provides the background details about the geospatial data. The available geospatial data, which were scattered across many organisations, can be accessed through this geo-portal in a single window.

Addressing the audience, Chief Guest Wasantha Deshapriya congratulated everyone involved in bringing NSDI to the current state and launch. "Being a public-funded platform, NSDI could be used to provide marvellous benefits to citizens of the country through sharing data and information among organisations."

The development of the Sri Lanka NSDI is a collaborative effort of many Government organisations, including the Survey Department of Sri Lanka, Disaster Management Centre, Department of Agriculture, Department of Wildlife, Department of Forest, Coast Conservation Department, Department of Census and Statistics, etc., facilitated by ICTA. NSDI can be accessed via *https://nsdi.gov.lk.*

## Dr Gladys West inducted into Air Force Pioneers Hall of Fame

An 87-year-old doctor whose programming of accurate earth models led to the current GPS system has been inducted into the Air Force Space and Missile Pioneers Hall of Fame. Dr. Gladys West was presented with the Air Force Space and Missile Pioneers award for her decades of contributions to the Air Force's space program.

West was one of only a few women who participated in computing for the U.S. Military in an era before electronic systems. She is also credited for programming calculations that ultimately became GPS.

The mathematician worked on accounting for variations in gravitational, tidal, and other forces that distort Earth's shape in the 1970s and 1980s. She was also involved in astronomical studies that won awards and changed the way we explore space. West was among the so-called "Hidden Figures" part of the team who did computing for the U.S. military. *www.wsfa.com/*

## GPS Alliance asks FCC to reconsider denial of Galileo E6 signal

The Federal Communications Commission in the USA — after a multi-agency process that started in October 2013 — approved on November 15 of this year a request from the European Union that Galileo signals be allowed to be received in the United States. Though the Galileo signals were already being broadcast in the U.S., and there was no enforcement effectively denying their informal use, the official approval enabled nonfederal agencies to use Galileo signals to meet official needs. For example, it will now be possible to use the two approved Galileo signals to more accurately locate cell phone callers who are dialing 911 for help in an emergency.

But it was just two signals that were given the thumbs up by regulators. The original request was for approval of the Galileo E1, E5 and E6 signals. The FCC approved receipt of E1 and E5, which overlap with U.S. GPS signals. That approval also means that those signals will be protected from future interference when requests to use spectrum in other ways come before the commission.

The FCC declined to approve the E6 signal, which falls in the 1260-1300 MHz band. The commission determined that allowing receipt in the U.S. might create interference issues and limit options for expanding use of the neighboring 1300-1350 MHz band.

On December 17 the GPS Innovation Alliance (GPSIA) asked the FCC to reconsider its E6 decision. The Alliance also noted that U.S. policy statements and international agreements indicated broad support for approval of GNSS signals including those from Galileo. In particular the agreement between the U.S. and EU that ensured GPS and Galileo compatibility, stated that the U.S. would not restrict "use of or access to" Galileo signals in the U.S.

## SpaceX launches U.S. military navigation satellite

Fifth time's the charm.
SpaceX successfully launched a U.S. military navigation satellite after being scrubbed for the fourth time. Heather Wilson, secretary of the Air Force, says this next-generation GPS satellite is three times more accurate than previous versions and eight times better at anti-jamming. It's the first in a series and nicknamed Vespucci after the 15th-century Italian explorer who calculated Earth's circumference to within 50 miles (80 kilometers). It was SpaceX's 21st and final launch of the year, a company record. *www.wftv.com*

## China ramps up global coverage for Beidou satellite navigation system

Beidou, China's home-developed satellite navigation system has launched its global service ahead of schedule.

Ran Chengqi, director general of the China Satellite Navigation Officeannouncing completion of the global coverage of the third-generation positioning system, ahead of the previous rollout target of 2020.

China has already shipped more than 70 million Beidou systems, which include microchips and modules, domestically and to over 90 countries, and the system is being well-received in Russia, Pakistan, Thailand, Indonesia and Kuwait, according to Ran.

Completion of the navigation system comes after China launched 19 positioning satellites this year, seen as enough to provide basic coverage. Twelve more will be launched over the coming two years to improve the precision of the system. *www.scmp.com*

## NTSC realizes high-precision test evaluation of GNSS satellite navigation signals

Recently, the signal quality assessment team from the National Time Service Center (NTSC) of the Chinese Academy of Sciences established Global Navigation Satellite System (GNSS) spatial signal quality assessment system based on 40m antenna in Luonan County, Shaanxi Province.

It realizes high-precision test evaluation of GNSS satellite navigation signals by using the international initiative special evaluation system, which covers the spatial signals of the new navigation signal system of major satellite navigation systems such as BDS and GPS.

The system uses the satellite common-view and two-way time transfer technology of NSTC to achieve synchronization between system time and UTC (Coordinated Universal Time).

And for the first time in the world, it adopts the optical fiber transmission network standard absolute delay method and uses high-frequency standard instruments and the dedicated navigation signal test equipment to realize the closed-loop calibration of the RF signal.

It has broken through the technical problems of broadband RF signal group delay and power precision calibration and realized innovative application of multi-disciplinary technology in the navigation field. *http://english.cas.cn*

## Russian GLONASS station opens in Armenia

The Russian GLONASS station will improve the accuracy of navigation systems and have an impact on many areas, from air navigation to agriculture, Armenian Deputy Minister of Transport, Communication and Information Technologies Armen Arzumanyan said.

The ground station will operate on the territory of the Byurakan Astrophysical Observatory and now includes three towers for communication with satellites, as well as a server center for processing the received data.

A total of 24 satellites are working with GLONASS, while the accuracy of determining the location is from 3 to 7 meters. *https://news.am*

## India to host GLONASS ground station for Russia

The Indian Space Research Organisation is getting ready to host a ground station for Russia's GLONASS. The ground station will help the Russian navigation system become more efficient.

The ground station will be built in Bengaluru, a city that is already home to the ISRO Telemetry, Tracking and Command Network (Istrac). Istrac will host the Russian ground station as well.

A memorandum of understanding was signed between the two nations in October 2016. In return, Roscosmos will host ground-measurement gathering stations in Russia for India's NavIC, which will boost the operations of the IRNSS satellites. *http://timesofindia.indiatimes.com*

## Russia plans to place positioning satellites around the Moon

In a draft document describing Russia's program for lunar exploration, plans include deployment of navigational and communications satellite groupings in lunar orbit.

According to the document, the tasks described for 2025-2030 include "the delivery to the Moon of a series of spacecraft for orbital research and the establishment of a global communications and positioning system."

The concept envisions the deployment of a lunar satellite navigation constellation between 2036 and 2040. A Roscomos press release Nov. 28 says a moon base is the agency's top priority. "The interest of mankind to the moon is associated primarily with the fact that unique regions with favorable conditions for the construction of lunar bases were discovered on the satellite. The implementation of the lunar program will be held in several stages until 2040."

Russia will reportedly implement its new strategy in three phases: the launch of an orbital station, a manned mission to the surface, and the eventual construction of a permanent base.

## Venezuela to use Russia's GLONASS satellite navigation system

Venezuela will use Russia's satellite navigation system GLONASS, Venezuelan President Nicolas Maduro said on Thursday.

"The GLONASS satellite system developed in Russia goes to Venezuela," he said in an recently. "It will help improve our country's telecommunications possibilities," he said, adding that this is an "utterly new" cooperation area. *http://tass.com*

## Roscosmos in talks on deploying GLONASS stations in US

Russia's space corporation Roscosmos is conducting talks on placing ground stations of the system of differential correction and monitoring of the satellite navigation system GLONASS in the United States.

The stations are needed to ensure proper operation of the entire GLONASS system - satellites in orbit and the ground component - to ensure the GLONASS satellites send the correct signal. http://tass.com/science/1034847

## UK ends Galileo talks, says it will explore a homegrown alternative

The United Kingdom has walked away from negotiations over its post-Brexit involvement in the Galileo. Instead of using Galileo's military-grade signal, Prime Minister Theresa May announced Nov. 30 that the U.K. will explore building its own GNSS.

That means that after Brexit, British companies would not be able to bid for contracts involved in developing and maintaining PRS, and the U.K. would have to work out a deal with the EU even to become a passive user of the military-grade signal, unless another arrangement was reached.

May blamed the end of the negotiations on the European Commission's "decision to bar the UK from being fully involved in developing all aspects of Galileo."

Earlier this year U.K. space officials had floated the idea that they could partner with another country, such as Australia, to build a new GNSS. In August, the British government announced it would spend92 million pounds ($117 million) from a "Brexit readiness fund" to study the prospects for building an independent alternative. *https://spacenews.com*

## First detection of rain over the ocean by navigation satellites

A new approach by a team around Milad Asgarimehr, who works in the GFZ

section for Space Geodetic Techniques and at the Technical University of Berlin, together with researchers from the Earth System Research Laboratory of the National Oceanic and Atmospheric Administration of the USA (NOAA) and the University of Potsdam, uses information contained in radar signals from GNSS satellites (Global Navigation Satellite System) to detect rain over the sea. The technology is called GNSS Reflectometry. It is an innovative satellite remote sensing method with a broad spectrum of geophysical applications.

According to the researchers, the new approach could help to monitor atmospheric precipitation better than before. Asgarimehr: "Our research can serve as a starting point for the development of an additional rain indicator. We can provide precipitation information using GNSS Reflectometry with unprecedented temporal resolution and spatial coverage."

"GNSS are 'all-weather navigation systems,'" explains Asgarimehr. "A long-held basic assumption was therefore that their signals are composed in such a way that they are not noticeably attenuated by clouds or typical precipitation in the atmosphere and therefore cannot detect precipitation." The new study therefore uses a different effect to detect rain over the sea: The roughness of the sea surface. *https://phys.org*

### Space technology allows precise navigation without GNSS

The German Aerospace research center DLR developed an optical navigation and inspection system for use in environments where position determination is not possible via a satellite navigation system such as GPS or Galileo. The Integrated Positioning System (IPS) can accurately determine one's own position without additional "prior knowledge" of the environment and without external reference points. Originally developed for missions in outer space, the scientists also see possible applications in tunnels, mines or industrial facilities, for example. *www.intelligent-aerospace.com*

# Galileo update

## Galileo: 2 years after Initial Services, Accuracy Matters more than ever!

December 16 marked two years since the launch of Galileo Initial Services. Timed to coincide with this milestone, an 'Accuracy Matters' campaign aims to increase public awareness of Galileo's successes over the past two years and highlight the added value that Galileo brings to the mass market.

The new 'Use Galileo. Accuracy Matters' campaign focuses on the fact that today "Accuracy Matters" more than ever before for the latest location-based applications and services. The initiative features a series of short video clips that give an entertaining glimpse of everyday situations where 'Accuracy Matters' to anyone using location data on their smartphones.

## Milestone after milestone

A number of milestones with major significance for the Galileo programme have been reached since the launch of Initial Services in December 2016. In September 2017, semiconductor developer Broadcom announced the launch of the world's first mass-market, dual frequency GNSS receiver for smartphones - the BCM47755. This was followed, in June 2018, by the launch of the first dual frequency smartphone – the Xiaomi Mi 8.

According to the latest figures, over 500 million devices - most of them the latest smartphone models - are already Galileo-enabled.

This new campaign aims to make users of these devices aware of the benefits that they can enjoy thanks Europe's investment in the Galileo programme. *www.gsa.europa.eu*

## Gaming with Galileo: New android smartphone apps

Two new Android smartphone apps based on Galileo are now available for general download, the results of a competition by ESA trainees.

With newer Android smartphones you can access the raw signal measurements used to compute position, opening the door to the development of applications where the user can indeed select which satellites to use. So ESA ran an internal competition for its trainees to develop an app capable of making positioning fixes using only Galileo satellites.

The Callisto – Galileo's Spaceship app uses Galileo satnav signals to run a virtual maze game based on walking through a real world location.

Looking down on Earth as if from a spaceship, players use a standard Google map display to traverse a rectangular area filled with randomly generated obstacles and collectibles. You play against the clock to grab prizes, with points deducted for running into virtual barriers.

Another app developed through the competition is also available for download from Google Play. *https://phys.org*

## Carlson Software releases Carlson iCAD 2019

Carlson's specialized drafting package, Carlson iCAD 2019, has just been released. The software allows technicians to supplement the finished product in their project deliverables.

New additions and functions to the iCAD 2019 release are new tool palettes, new 3D solid commands, additional DGN support, and new express tools. iCAD features Google Earth import and export KML/KMZ, standard CAD entities, the drawing inspector tool and more. *www.carlsonsw.com*

## CHC Navigation releases all-in-one GNSS RTK solution

CHC Navigation has unveiled its i50 GNSS receiver, an all-in-one GNSS RTK solution.

The GNSS receiver comes bundled with the CHC HCE320 Android controller and CHC LandStar 7 field data collection software. According to the company, it is a cost-effective solution for topographic and construction positioning tasks in land surveying, small- and medium-sized construction projects, and precision GIS data collection.

## Allystar releases multi-band GNSS raw data chip and module

Allystar Technology Co. Ltd., has released a multi-band multi-GNSS chipset, the HD9310. The new product is based on the Cynosure III architecture integrating multi-band multi-system GNSS RF and baseband. It supports BeiDou-3 and is capable of tracking all global civil navigation systems (GPS, BeiDou, Galileo, GLONASS, IRNSS, QZSS and SBAS) in all bands (L1, L2, L5, L6).

Designed for high-precision applications, the HD9310 measures 5.0mm x 5.0mm. The architecture integrates floating-point arithmetic units based on ARM CortexM4, 160 KB RAM, 32KB backup RAM with VBAT, 386 KB embedded FLASH and peripheral interfaces UART, I2C, SPI, GPIO, CAN.

## Qualcomm launches Snapdragon 855 with Dual-Frequency GNSS and 5G

Qualcomm Technologies has unveiled the newest generation in the 8 Mobile Platform Series, the dual frequency Qualcomm Snapdragon 855 Mobile Platform. It can make your voice, camera, gaming, and XR smarter, faster, and more intuitive. That means smartphones can deliver a personalized, optimized experience, without the user needing to adjust the settings.

The latest offering from Qualcomm Technologies is the first commercial mobile platform supporting multi-gigabit 5G, industry-leading AI and immersive extended reality (XR) collectively, ushering in a new decade of revolutionary mobile devices.

## Brexit-dodging SCISYS Brits find Galileo joy in Dublin

Chippenham-based space systems specialist SCISYS has announced that it will trouser €11.2m as part of a contract to keep the Galileo project running. The award, with Thales Alenia Space France, is for the continuation and enhancement of four Galileo Ground Mission Segments (GMS). The GMS comprises control centres and a network of transmitting and receiving stations, as well as telemetry and control for the satellite constellation. SCISYS has opted to move its parent company to Dublin, something it said "has proved decisive in securing this contract". *www.theregister.co.uk*

## Brazil upgrading Bahia LPD's navigation, electronic warfare systems

The Brazilian Navy is to upgrade its NDM Bahia (G40) multi-purpose landing dock platform (LPD) with new surface navigation and electronic warfare systems .Bahia was purchased from the French Navy in 2015 and is now being upgraded for Brazilian service.

A Northrop Grumman Sperry Marine VisionMaster FT250 navigation radar will replace the existing DRBN34A navigation radar (French designation for the Decca 1229). The ship was received from France with its two original DRBN34As, one for navigation and another for helicopter approach. It is also equipped with a single DRBV21A search radar system that incorporates identification friend or foe (IFF) capability. *www.janes.com*

## Raytheon's GPS OCX supports modernized GPS satellite into orbit

The U.S. Air Force used Raytheon Company's GPS Next-Generation Operational Control System, known as GPS OCX, to support the launch of the first modernized GPS satellite into space. GPS OCX will now maneuver the GPS III satellite into its final orbit, a process that will take the ground control system 10 days to accomplish. The fully modernized GPS OCX Block 0 launch and checkout system will support the launch of future GPS III satellites, enabling the introduction of a new civil signal, enhanced military signals, and anti-jam capabilities.

The ground system has achieved the highest level of cybersecurity protections of any Department of Defense space system, and its open architecture allows it to integrate new capabilities and signals as they become available, ensuring continued protection against future cyber threats. *www.raytheon.com*

## Septentrio launches tiny Mosaic high-precision GNSS module

Septentrio has launched the Mosaic high-precision GNSS receiver module. Despite its compact size (31 x 31 x 4 millimeters, 1.29 x 1.29 x 0.15 inches), the Mosaic module supports more than 30 signals from all six GNSS constellations, L-band and various satellite-based augmentation systems. As a multi-band module tracking all GNSS satellites in view, it is also designed to support future GNSS signals

## Laser Technology, Inc. Signs Digi-Key Electronics as Global Distributor

Laser Technology, Inc., the industry leader in the design and manufacture of innovative non-contact laser sensors, announced the signing of a worldwide

distribution agreement with Digi-Key Electronics whom will sell and distribute Laser Technology's Industrial Sensor product line, TruSense®. The TruSense line of non-contact laser sensors serves a variety of industries including oil & gas, chemicals, mining, power, food and beverage and water and waste water.

## Vexcel Imaging opens office in China

Digital aerial camera and mobile mapping solution provider Vexcel Imaging GmbH, Austria announced the opening of its newest office in Shenzhen, P.R. China. Vexcel Imaging began providing cutting-edge photogrammetry-grade aerial film scanners into the China market as early as 1998 followed by introducing digital aerial cameras 2005 in China.

## Delair and Trimble cooperate to support high-precision PPK drone data

The recent release of Trimble Business Center v5.0 now supports high-precision PPK drone data with a new JXL output exclusively available with the Delair UX11 PPK drone. The latest collaboration between Delair and Trimble's Trimble Business Center v5.0 (TBC) team was to develop the next generation JXL format that supports streamlined high-precision drone data processing. This is an important feature to fully realize the benefit of PPK-processed datasets from the Delair UX11. This new feature enables high-precision horizontal and vertical accuracy estimates for GNSS positions, as well as the precise lever-arm offset (measurements of the distance between the GNSS antenna and camera on the drone), to be carried through to TBC and utilized by Trimble's photogrammetry algorithm.

The result of this joint software enhancement between Delair and Trimble is that you can now maintain the centimetric accuracy of your camera positions from the UX11 PPK system when you do your photogrammetry processing with TBC. The benefit is that you maintain the full value of PPK-enabled GNSS from the UX11 when processing your data with TBC and you will not need to rely solely on ground control points because the accuracy of the PPK-corrected camera positions is respected.

## Hexagon's Geospatial Division Releases Luciad V2018.1

Hexagon's Geospatial division announced the release of V2018.1 the Luciad Portfolio. It focuses on further expanding 3D capabilities and includes additional data formats and standards for users in military and maritime domains. To accommodate organizations' expanding geospatial data, LuciadFusion introduces a RESTful API to automate the entire process of data crawling.

## Tersus Releases GeoCaster Software for NTRIP Corrections

Tersus GNSS Inc. recently released the Tersus GeoCaster, which is a Networked Transport of RTCM via Internet Protocol (NTRIP) Caster Software to expand its product line and provide users with better and more comprehensive services.

The Tersus GeoCaster supports configurable bases online simultaneously and configurable rovers for one base. It supports Ntrip protocol and it has 7X24 hours operation.

The end users involved in various applications including surveying, construction engineering, deformation monitoring, automated vehicle, precision agriculture, Unmanned Aerial Vehicle, machine control, robotics, and etc.

## Motion Auto selects HERE Technologies' location platform

HERE Technologies, a global leader in mapping and location services, and Motion Auto, a mobile first telematics auto insurance company, have announced the integration of HERE location services across Motion's platform. Motion Auto will embed HERE maps within their consumer mobile app, while utilizing a rich set of HERE location data and analytics to better understand driving conditions down to a road segment. *www.here.com*

## System to provide operators with up-to-date information

Trimble introduced the Trimble D2M rolling stock allocation and management system that provides operators the ability to better control rolling stock resources to maximize utilization and minimize rail service disruption.

The D2M system manages rolling stock allocation and schedules to meet timetable and service requirements. With a single view, fleet controllers can allocate, deallocate, reallocate, swap and perform special traffic moves while receiving information from the operator's maintenance management system. Operational staff and maintenance teams can then obtain up-to-date information on train allocations to services and track key usage data such as mileage accumulation for fueling and maintenance. TAGSGIS & MAPPINGTRIMBLE

## Seismic vault-quality data in a lightweight and compact sensor

Trimble has introduced the portable REF TEK Colt broadband seismometer that provides high-quality data for scientists and academics using seismic networks to conduct earth movement studies.

Working in combination with a Trimble or third-party seismic data recorder, the REF TEK Colt sensor enables scientific and academic researchers to study local, regional and global seismicity to learn more about the physics of earthquakes and to gain a deeper understanding of plate tectonics. The Colt can be used in Earthquake Early Warning (EEW) applications as well as in monitoring and cataloging earthquake activity.

## Trimble and MODERN collaborates

Trimble and MODERN have announced that they are partnering to enhance the customer experience by integrating automated text communications with the Trimble PULSE suite of solutions for field service optimization and workforce management. This integration enables equipment dealers and field service organizations to improve the customer experience during service through faster communication and improved visibility into technician and work order status.

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### January 2019

**Cognizant Autonomous Systems for Safety Critical Applications (CASSCA) 2019**
28-29 January
Reston, VA USA
**www.ion.org**

**International LiDAR Mapping Forum (ILMF)**
28 - 30 January
Denver, United States
**www.lidarmap.org**

**International Technical Meeting (ITM)/ Precise Time and Time Interval Systems and Applications (PTTI) 2019**
28-31 January
Reston, VA USA
**www.ion.org**

### March 2019

**2019 URSI Asia Pacific Radio Science Conference**
9 - 15 March
New Delhi, India
**www.aprasc2019.com**

**Munich Satellite Navigation Summit**
25 - 27 March
Munich, Germany
**www.munich-satellite-navigation-summit.org**

**Land and Poverty Conference 2019**
25 - 29 March
Washington, DC, USA
**www.worldbank.org**

### April 2019

**Pacific PNT**
8-11, April
Honolulu, HI USA
**www.ion.org**

**European Navigation Conference 2019**
9 - 12 April
Warsaw, Poland
**http://enc2019.eu**

**FIG Working Week 2019**
22 - 26 April
Hanoi, Vietnam
**www.fig.net/fig2019**

**AUVSI Xponential 2019**
29 April - 2 May
Chicago, United States
**www.auvsi.org/events/xponential/auvsi-xponential-2019**

### May 2019

**13th Annual BasÌŒka GNSS Conference,**
5 - 8 May
BasÌŒka,Krk Island, Croatia

**4th Joint International Symposium on Deformation Monitoring and Analysis**
15 - 17 May
Athens, Greece
**http://jisdm2019.survey.ntua.gr**

**Geo Business 2019**
21 - 22 May
London, UK
**www.GeoBusinessShow.com**

**GISTAM 2019**
**5th International Conference on Geographical Information Systems Theory, Applications and Management**
3-5 May 2019
Heraklion, Crete, Greece
**www.gistam.org**

### June 2019

**HxGN LIVE 2019**
11 - 14 June
Las Vegas, USA
**https://hxgnlive.com/2019**

**TransNav 2019**
12 - 14 June
Gdynia, Poland
**http://transnav.am.gdynia.pl**

### July 2019

**Esri User Conference**
8 - 12 July
San Diego, California
**www.esri.com**

### August 2019

**The South-East Asia Survey Congress(SEASC) 2019**
15 - 19 August
Darwin, Australia
**https://sssi.org.au**

### September 2019

**GI4DM**
3 - 6 September
Prague, Czech Republic
**www.gi4dm2019.org**

**Intergeo 2019**
17 - 19 September
Stuttgart, Germany
**www.intergeo.de**

**ION GNSS+2019**
16 - 20 September
Miami, Florida, USA
**www.ion.org**

**ISDE 11**
24 - 27 September
Florence, Italy
**digitalearth2019.eu**

**Interdrone**
3-6 September 2019
Las Vegas, USA
**www.interdrone.com**

### October 2019

**Commercial UAV Expo Americas**
28 - 30 October
Las Vegas, USA
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