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THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

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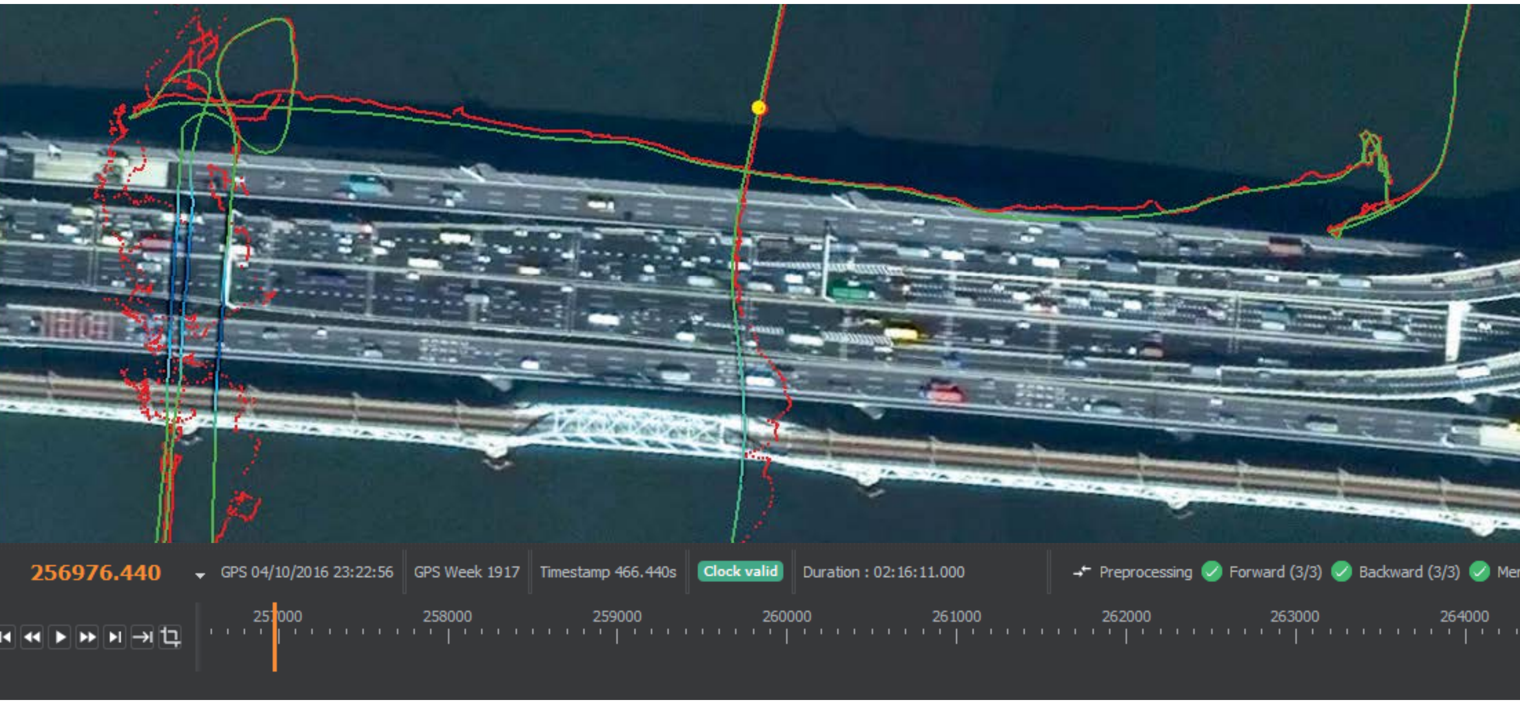


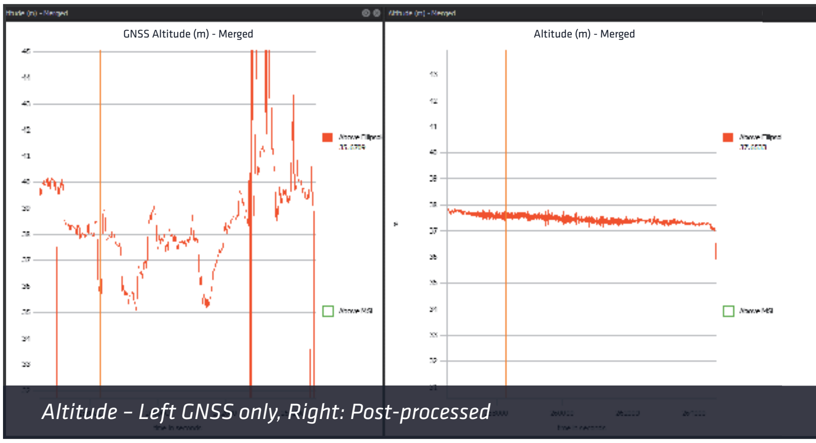
Quality: *Green -> centimetric position; Blue -> decimetric < 30cms; Red -> Raw GNSS data*

SURVEYING UNDER BRIDGES MADE EASY

This survey has been done with an APOGEE INS under very challenging conditions for the GNSS receiver (red dots).

The boat is crossing multiple times three large bridges including one made of steel.

With Qinertia and its unique 100% in-house GNSS/INS tightly coupled forward / backward processing, data collected under the bridges are fully exploitable (blue / green trajectory).



Altitude – Left GNSS only, Right: Post-processed

The Fastest PPK Software	Long GNSS Outages Handling	Easy & Powerful Exporter
Log duration: 2h15 Processing Time: < 2 mins	Example: up to 80 seconds outages and multi-path effects 95% positions < 2 cms Max error < 30 cms	Easy export to third party software (SBET/ ASCII)

Many thanks to Hydro Systems Development (HSD Japan) for their kind collaboration.

Full data available upon request at marketing@sbg-systems.com
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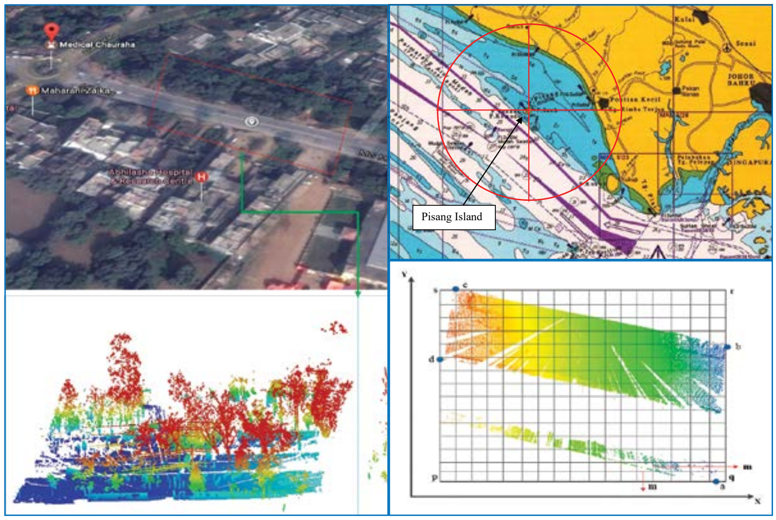

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Columns

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Editor Bal Krishna
Owner Coordinates Media Pvt Ltd (CMPL)

This issue of Coordinates is of 52 pages, including cover.

When humanity triumphs

In Thailand, when thirteen members of Wild Boars football team

Were trapped in the cave,

They refused to cave in.

Demonstrated exemplary level of guts and grit

Their battle for survival

United the world.

The mission that looked impossible

Was made possible

By the human resolve, endurance, perseverance, courage, togetherness, …

And when they all were finally rescued successfully,

The world erupted with joy

To celebrate the triumph of humanity

No one forgets valiant Saman Gunan, a former Thai Navy Seal

Who lost his life in the endeavor.

Bal Krishna, Editor
bal@mycoordinates.org

"The threats of interference, jamming and spoofing are real and serious"

says Professor David Last, Consultant Engineer and Expert Witness in an interview with Coordinates while sharing his views on a range of issues pertaining to GNSS technology

Professor David Last is a Consultant Engineer and Expert Witness specialising in Radio Navigation and Communications Systems. He is a Professor Emeritus at the University of Bangor, Wales and Past-President of the Royal Institute of Navigation. He acts as a consultant on radio-navigation and communications to companies and to governmental and international organisations and is active as an Expert Witness, especially in forensic matters concerning GPS.

This is a world of multi-GNSS systems. What advantages do you see about this scenario?

The advantages to countries or regions of providing their own GNSS are political, not technical. Indeed, so many satellites are now transmitting in the same narrow radio bands that the additional ones are raising the noise level with which they all have to cope!

But many countries are unwilling to have their critical national infrastructure or military capabilities dependent on a satellite system controlled by a foreign state, that will always put its own interests first.

Many countries plan GNSS systems primarily because of defence and security needs. Do you think that this may trigger a race with more countries joining in? What would be the implications?

That is correct. It already has triggered such a race: GPS was followed by the global systems: GLONASS, BEIDOU and Galileo and the regional systems: QZSS and IRNSS. Also, by a host of augmentation systems: WAAS, EGNOS, SDCM, MSAS, GAGAN. Now the UK is exploring the possibility of launching its own GNSS and Australia has recently announced a national augmentation system. The limitation is likely to be financial: satellite navigation systems are immensely expensive and beyond the wallets of many countries.

Recently, the Government of UK has released a report on "Satellite-derived Time and Position: A study of critical dependencies". What are the key recommendations and what is your take?

This revue was initiated by the UK government and directed by its Chief Scientific Adviser. It explored the breadth, scale and implications of the reliance of the UK's critical national infrastructure (CNI) on the "invisible utility" that is satellite

The advantages to countries or regions of providing their own GNSS are political, not technical. Indeed, so many satellites are now transmitting in the same narrow radio bands that the additional ones are raising the noise level with which they all have to cope!

position, navigation and timing (PNT). Government departments and agencies, academia and industry were all consulted. I was a member of the Expert Panel.

The resulting report recommended that Cabinet Office (the top level of government) should require all CNI operators to assess and record their dependence on GNSS. This vulnerability should feature in the National Risk Register and be taken into account in allocating radio spectrum. The government should consider legal sanctions for selling, owning and using jammers and whether to monitor interference at key sites, including ports. Those specifying equipment for CNI should stipulate performance standards. National expertise in PNT should be mapped and coordinated.

The report called for GNSS-independent back-up systems, recommending a range of mitigations, different for each user sector: for example, better hold-over clocks for precise time distribution. But for every sector "a terrestrial radio system" has a part to play.

The report showed widespread acceptance by those consulted of the vulnerabilities of GNSS and their agreement on the need to tackle them. But in my view, the key outcome of the report was that the UK government at its highest level, the Cabinet Office, recognised the seriousness of PNT vulnerability and took ownership of the problem. Already, they have started to implement its recommendations. I believe that this is the only way that governments will succeed in overcoming the vulnerabilities of GNSS; we have seen in many countries that leaving it to individual departments simply does not work.

How serious are the threats like interference, jamming and spoofing? How prepared is the GNSS community to deal with it?

Many recent incidents, and many surveys, have shown that the threats of interference, jamming and spoofing are real and serious. The professional GNSS community has come to accept that; indeed, many technical meetings are now dominated by papers on these problems and proposed solutions. But in contrast, recognition of this vulnerability among policy-makers and governments remains rare. Indeed, in many countries and regions, notably in Europe, the need to defend one's own high-cost GNSS program has resulted in denial of the issue of vulnerability. Until there is acceptance of the problem by governments, the critical national infrastructure of their nations will remain at risk.

The recent government-commissioned report by London Economics estimated the cost to the UK economy of a one-off loss of GNSS lasting 5 days at £5.2B (USD7.1B). In my book, that's a serious threat!

Any back-up must employ a different technology from the GNSS it is to complement. For precise timing that might be a very stable clock. In the air it will be one of the many non-GNSS systems – DME, ILS, VOR, NDB, inertial – that have been retained for both commercial and general aviation. The best back-up will depend on the application

Given this, what's your opinion on GNSS back-ups?

It would be hard now to find a satellite navigation professional who has studied the question of vulnerability and still believes that a single GNSS alone can provide resilient PNT. Equally, most now agree that one GNSS cannot back-up another GNSS, given that they use the same radio frequency bands and are, in effect, slightly different versions of the same technology. The need for our various GNSS to be mutually compatible and interoperable means that when one is lost to interference and jamming, they all may be. And there are now low-cost multi-GNSS spoofers!

So, any back-up must employ a different technology from the GNSS it is to complement. For precise timing that might be a very stable clock. In the air it will be one of the many non-GNSS systems – DME, ILS, VOR, NDB, inertial – that have been retained for both commercial and general aviation. The best back-up will depend on the application.

What's is your take on eLoran?

I am strongly in favour of eLoran, having watched closely the UK and Ireland prototype system that demonstrated its technical viability and excellent performance over more than 2 years. This system employed the transmissions of the legacy Loran-C stations across North-West Europe, until they reached their closedown dates, adding a data channel broadcast from a new UK station. It operated in both stand-alone and differential modes.

ELoran, originally proposed by the US Federal Aviation Administration, has the great benefit of sharing almost no vulnerabilities with GNSS: it operates at low-frequencies (not the microwaves of GNSS), with high power transmissions (not the very low powers of GNSS) and terrestrial transmitters (not space-based). Yet, in many applications, eLoran can take over automatically and seamlessly when GNSS is interrupted, so allowing operation to continue, meeting the same standards. That has been demonstrated at sea, on land and in the distribution of precise time, including to receivers indoors and under-ground. But eLoran comes up against a profound prejudice: given that GNSS replaced an earlier generation of terrestrial radio navigation systems, recommending a terrestrial system to overcome the vulnerability of GNSS is to swim against a powerful tide!

The London Economics report identified eLoran as one of two technologies that offered “the most applicable mitigation strategies for the largest number of applications”. The UK government then signalled its support for the system.

US had to deal with LightSquared a few years before and now again grappling with Ligado. Would you like to suggest some approach in handling such issues?

This has been, and remains, a very hot topic in the US! In my view it is essential to recognise: that nations must take PNT resilience into account in allocating radio spectrum; that GNSS is of profound economic value to contemporary societies; that our use of GNSS will depend heavily on legacy equipment continuing to operate uninterrupted; and that any decisions should be based on firm evidence.

You have been working on legal issues pertaining to GNSS. Your presentation at INC 2017 was titled “Beyond reasonable doubt – Satellite navigation comes to court”. Would you like to share some of key issues that you often come across?

Yes, since I retired from my university position, crime has become an important part of my life! As GNSS has become deeply embedded in all aspects of our society, so it has increasingly featured in evidence in criminal and civil legal cases. For example, a car may now run many million lines of code, across 70 processors. It will record on board vast amounts of data including PNT information: its location, speed, direction of travel, rates of acceleration, braking and cornering, may all have been captured at frequent intervals. When presented with such data as evidence of criminal activity by the occupants of the vehicle, a court will rightly question the accuracy and integrity of the data; and that is familiar territory to us PNT specialists.

Then, some criminals themselves make use of our technologies to monitor their competitors: in addition to bugging them, they will deploy GPS trackers that gather large volumes of data. They will use jammers both to defend themselves and to disable the tracking systems intended to protect high-value targets they seek to hi-jack. In addition, the rapid growth in telematics systems (including those deployed by vehicle insurance companies) provides detailed evidence of events leading up to and during collisions that may support a charge of dangerous driving. It may also form evidence in civil cases concerning liability for death and injury.

How GPS Forensics works?

An expert witness in GPS Forensics advises the court on the accuracy of the evidence and the degree to which it can be relied upon. Interestingly, all the recent and current activity in our PNT community plays into the forensics world. For example, a switched-on defence lawyer will know that: GNSS is vulnerable to jamming and spoofing and that GNSS satellites have failed or data uploads have gone wrong, causing erroneous positions. This knowledge will lead to attacks on telematics data presented in evidence. So an expert must be able to analyse the data to establish whether the GNSS system involved, from satellites to receiver, was working correctly and demonstrate this to the court.

Then, there is the question of accuracy. It is remarkable how many folk who know a little bit about GPS are still living in the era of Selective Availability! Many companies in the telematics industry quote open-site performance figures, whereas in reality the accuracy of GPS positions recorded in urban areas is dominated by multipath propagation. I find myself examining crime scenes with a knowledge of microwave radio propagation and estimating the expected spread of the scatter of fixes there. Unfortunately, many of the commercial systems that document the tracks of vehicles fail to record the measures of quality provided by their GNSS receiver chips. As a result, implausible position fixes due – for example - to the vehicle’s being in an underground car park cannot be identified and explained, so undermining the whole set of evidence.

Much of the data that finds its way into court, even in cases of serious crime, is generated by companies whose professional standards fall well short of those of readers of Coordinates!

What influences do you envisage in satellite navigation in the near future given the advancements in the field of AI, Autonomous Vehicles, UAV, etc.?

AI will play an increasing role in the downstream applications of satellite navigation. There is a lively debate concerning the mix of sensors needed to

But eLoran comes up against a profound prejudice: given that GNSS replaced an earlier generation of terrestrial radio navigation systems, recommending a terrestrial system to overcome the vulnerability of GNSS is to swim against a powerful tide!

navigate autonomous vehicles, including UAVs. The integrity required in these guidance systems, and the complexity of the environments in which they operate, can be extreme; a navigation system that can guide a ship on the open sea or even in a harbour falls well short of what is required to navigate a car through a crowded and chaotic city. Indeed, it is not clear to many of those struggling to find solutions that satellite navigation has much, or even any, part to play there!

> Interestingly, all the recent and current activity in our PNT community plays into the forensics world. For example, a switched-on defence lawyer will know that: GNSS is vulnerable to jamming and spoofing and that GNSS satellites have failed or data uploads have gone wrong, causing erroneous positions

How do you perceive the direction of satellite navigation?

Satellite navigation was one of the outstanding innovative technologies of the late twentieth century, arguably the most successful, being widely adopted with remarkably few downsides, either social or environmental. Through the first decade of the twenty-first century the technology was refined: devices became much smaller, much cheaper, more powerful, and gained superior accuracy, integrity, availability and continuity. But by now we are 45 years on from the meeting at which the principal parameters of GPS were settled.

Satellite navigation has become a very mature technology in which major change is unlikely. Thus its direction will be more about an increase in the numbers of systems, satellites and receivers, all based on essentially the same old technology. But I do expect to see the cost of satellite systems and launchers continuing to fall.

What impacts do you think Brexit may have on Galileo?

Brexit has already led to a conflict between the UK and the rest of the EU concerning future UK access to the Public Regulated Service (PRS), the military-grade part of Galileo. According to the EU, only member states have the right to access the PRS. The UK, requiring either PRS or an equivalent for military purposes has countered by stating that it will consider developing its own independent GNSS. Studies of this option are currently under way.

The row is complicated by the substantial role that UK companies, or the UK parts of multi-national companies, have played and are continuing to play in the development of Galileo. Brexit could end that cooperation, leaving unanswered questions concerning the intellectual property involved. It could also throw into uncertainty the position of the European Space Agency (ESA) which is not part of the EU but acts for it in certain ways.

It remains to be seen whether this conflict is genuine or part of the manoeuvring between the UK and the EU over the terms of Brexit and the future relationship between the two. Divorces can be messy affairs!

Safety and security needs of marine navigation

The objective of this study is to review the function of Pisang Island lighthouse and to propose the most relevant use of Pisang Island for current navigational needs. The function of the lighthouse was reviewed according to the IALA Navigational Guide and the AIS data image

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Islands have been used as a base to establish facilities to support maritime operations. Japan had established a military radar facility on Yonaguni Island in March 2016 as a monitoring station in East China Sea to increase its military presence over there (Lewis, 2016). The island is part of a chain of islands disputed between Japan and China. In 2014, India plan to establish a radar station at Narcondam Island, which is part of Andaman and Nicobar groups of Islands for security and surveillance measures. The island is significantly important due its location near the Malacca Straits, which provides the ability to monitor the movement of all vessels to and from the Indian Ocean through the Malacca Straits (Vasan, 2014). The island would also enable India to monitor the Chinese naval activity in the North Andaman Sea and around Coco Islands. China had built a military base in December 2016 on an artificial island reclaimed on Fiery Cross reef, which is part of the disputed Spratly Island archipelago (Buckley, 2016; Hunt, 2015). The facilities at the base are harbours, runways, and hangars. The purpose of the base is to support the China's operations and claims over the Spratly Islands.

This study is about Pisang Island, which is one of a Malaysian island at the southern part of the Straits of Malacca (SoM). The importance of Pisang Island to marine navigation was identified by the British colonial government in the mid-19th century upon charting the straits and using the island to mark a hazard (Yong, 2008). The SoM became more important upon the completion of the Suez Canal, where it formed part of the shortest shipping route from west to east. A 16-metre-high cylindrical iron tower lighthouse was established on the highest point on the island in 1914. The current lighthouse's solar powered lighting system produces a luminous range of 21 nm (Yong, 2008).

Problem statement and objective

Currently, long range visual marine AtoNs such as lighthouses are less important for marine navigation, as shown in the UK. The UK 2010 marine atons review resulted in the decommissioning of 20 lighthouses and another 14 lighthouses were transferred to local authorities (ATKINS Ltd, 2010). The Review by the General Lighthouse Authority UK between 2010 to 2015 resulted in the following: 41 lighthouses reduced luminous range, 6 lighthouses discontinued operation, 14 lighthouses were transferred to local authorities, 1 lighthouse was replaced with a Port Entry Light, 1 lighthouse reduced fog signal range, 1 lighthouse was fitted with an Automatic Identification System (AIS), and the remaining 76 lighthouses were unchanged (Commissioners of Northern Lighthouses, Trinity House, & Commissioners of Irish Lights, 2010). Most of the 76 unchanged lighthouses have a range of light below 18 nm, which was previously reviewed between 2005 and 2009. The results of these reviews showed the trend of mariners to depend less on lighthouses due to a higher reliance on GNSS. This long-range marine signal form is not required anymore and has thus resulted in the reduction the light range of lighthouses and even the discontinuation of their operation.

With respect to the current trend in marine navigation, Pisang Island lighthouse remains operational by providing a long-range marine signal, which is not required by current navigation practice. Hitherto, no review of the operation of Pisang Island lighthouse has been performed with respect to current navigational needs such as supporting the operation of Vessel Traffic Services (VTS) and the marine electronic highway to ensure the safety and security of navigation in the SoM. Therefore, the current study addresses this issue by examining the function of Pisang Island lighthouse and identifying more relevant atons with current marine navigation practice to support the safety and security of marine navigation in the SoM.

The function of Pisang island lighthouse

This section examines the function of Pisang Island lighthouse. A lighthouse is generally considered to be a large conspicuous structure (visual mark) on land, close to the shoreline or in the water that acts as a daymark; it provides a platform generally for higher range marine AtoN signal lights (IALA, 2014). The purpose of a lighthouse is to perform one or more the following functions; mark a landfall position; mark an obstruction or a danger; indicate the lateral limits of a channel or navigable waterway; indicate a turning point or a junction in a waterway; mark the entrance of a Traffic Separation Scheme (TSS); form part of a leading (range) line; mark an area; and to provide a reference for mariner to take a bearing or line of position (LOP) (Hooff & Sirks, 1979; IALA, 2014; The Nautical Institute, 2002). With respect to Pisang Island Lighthouse, it's only relevant function is to provide a reference for mariners to take a bearing for a line of position (LOP).

Figure 1 shows the radius of the lighthouse light, which indicates that several coastal beacons are within the radius of the lighthouse light. For a vessel going either north or southbound in the straits, the LOP is performed by taking a visual bearing of the lighthouse's tower during the daytime and by using the lighthouse's light as a reference during the night time.

However, as an alternative to taking a LOP using visual means, the LOP can be performed electronically by using the ARPA radar of the ship. This LOP is performed by using a distinct horizontal feature on the island identified on the radar screen, such as, the edge of the island instead of the lighthouse's structure. This is because the ship's radar is unable to distinguish the lighthouse from the rest of the island's features horizontally. Therefore, the LOP can be performed either visually or by electronic means, where the former is using the lighthouse, while the latter is using the island's physical features.

The application of GNSS, which is most commonly used Global Positioning System (GPS) in the current trend of marine navigation, makes the lighthouse redundant and less important for a positional fix. With the incorporation of GPS, Electronic Navigation Charts (ENC), radar, Echo Sounder, and Gyro Compass into a single display of information in an Electronic Chart Display and Information System (ECDIS), mariners are less likely to be looking out from the bridge to perform the laborious manual positional fix by visual

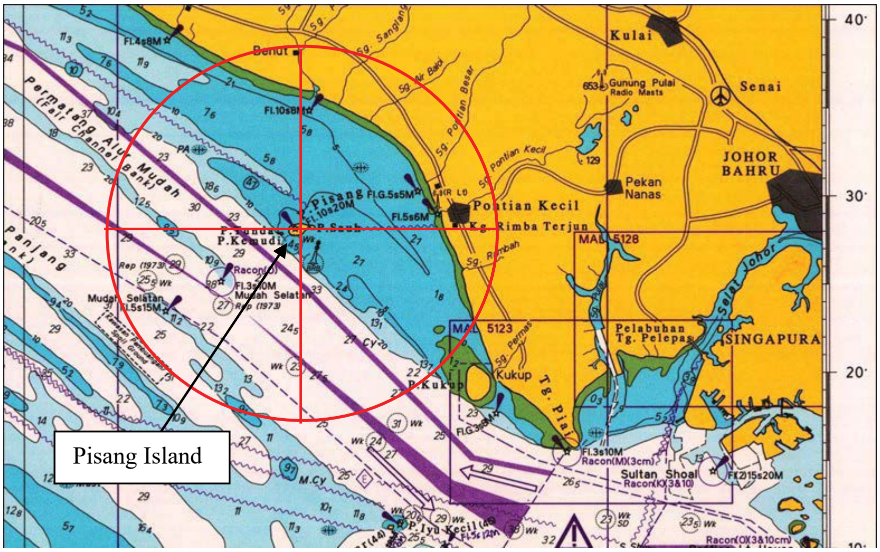

Figure 1: Pisang Island in the bull's eye and Lighthouse Pisang Island 20 nm light's radius

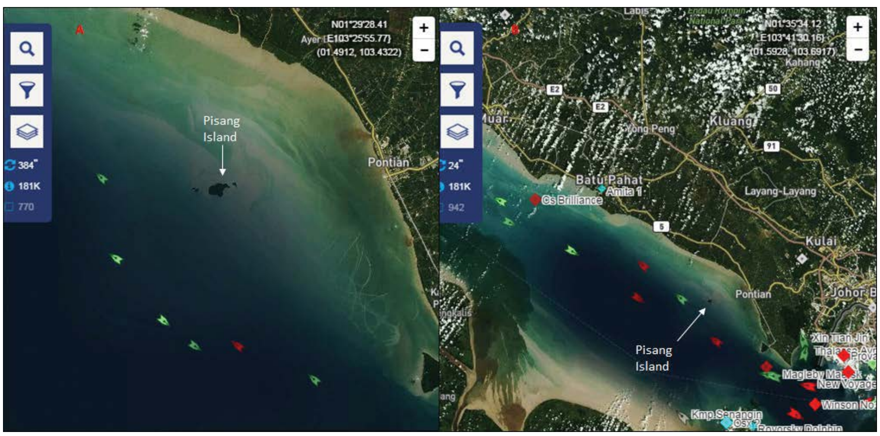

Figure 2: Picture A of Figure 2 (left) shown a close-up view near Pisang Island, while picture B of Figure 2 (right) give an overall view of southern part of the straits. The red coloured are tankers, while green coloured are cargo vessels. Source: www.marinetraffic.com (2016)

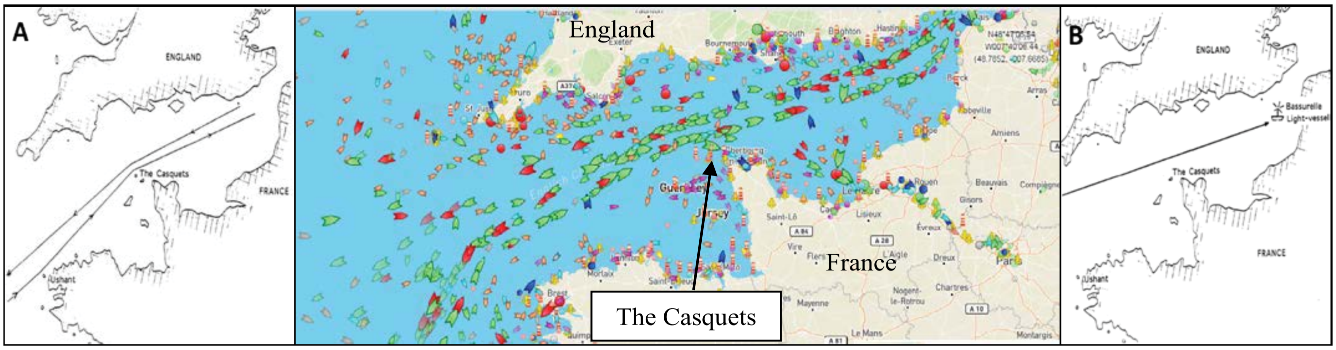

Figure 3: Middle picture shows shipping in Dover Straits. Picture A (left) shows the traditional in and outward bound of shipping pattern in Dover Straits. Picture B (right) shows in and outward bound of shipping pattern using radio navigation.
Source: Hooff, (1982); www.marinevesseltraffic.com (2016)

means due to an easily available accurate automatic positional fix. This is the current situation in the Pisang Island Lighthouse area, where the LOP is assumed to not be practised by mariners on board passing ships, as shown in Picture A of Figure 2.

This situation is due understandably to the high reliance on GPS for navigation and for complying with the Traffic Separation Scheme (TSS). Picture B of Figure 2 shows the overall view of ship's traffic in the southern part of the Malacca straits, which shows the Indonesian coast (the west of the straits) and Singapore (the south of the straits.

Nevertheless, Figure 2 is unable to clearly show that the passing ships were not practising LOP while navigating because that part of the straits is quite narrow. To determine the current trend of marine navigation, the movement of ships in the Dover Straits in Figure 3 was used as a reference for the study. The top picture shows the movement of ships in the straits based on AIS data on November 2016; picture A (bottom left) shows the traditional inbound and outbound shipping pattern in the Dover Straits using the lighthouses as the landfall light at Ushant and Casquets points; and picture B (bottom right) shows the shipping pattern in the straits using radio navigation (Hooff, 1982). To determine whether pattern of middle picture is similar to A or B, Figure 3 was shown separately to three lecturers of the Nautical Science and Maritime Transportation Program, Universiti Malaysia Terengganu who hold the Master Foreign Going qualification, during January 2017. Each of them agreed that the ship's route pattern in the middle figure is like the pattern in picture B as proposed by Hoof in 1982. The reason was that most of the ships entering the Dover straits were in the middle of the straits mouth; instead of near to the lighthouse at Ushant point to practice LOP. This shows that the mariners are currently not relying heavily on the lighthouse for navigation. This example supports the similar practice of mariner in the waters surrounding Pisang Island.

Another example to support the view that mariners currently do not practice LOP on lighthouses is shown in Figure 4. The previous and forecast track of a Japanese registered tanker Hakkaisan on its way from Malaysia to Japan on 1st April 2017 was used. The track shows that the vessel was navigating too far from any coast to take

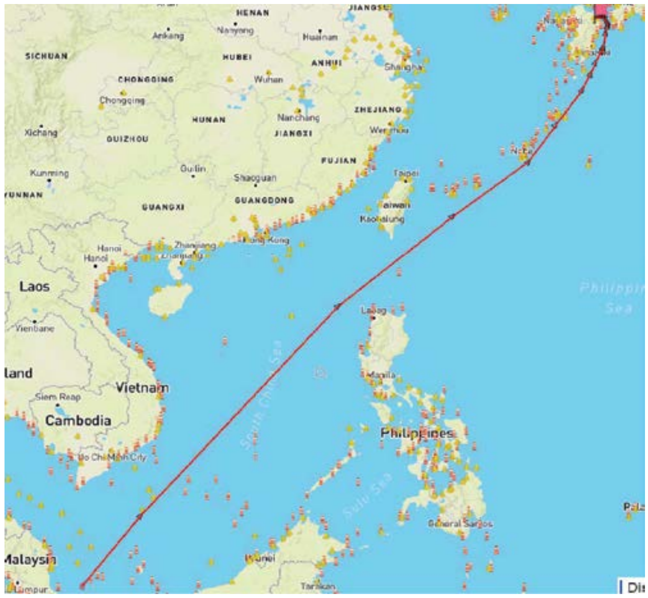

Figure 4: Track of Tanker Hakkaisan from Malaysia to Japan on 01 April 2017
Source: www.marinetraffic.com (2017)

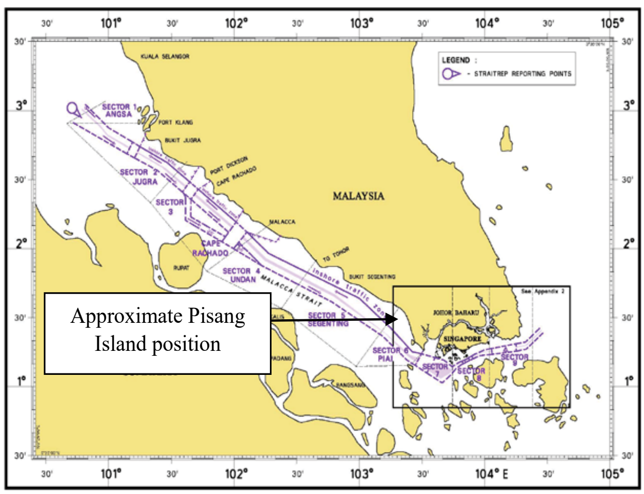

Figure 5: STRAITREP Sector 1 to 9
Source: MPA Singapore (2009, 2012a, 2012b)

a bearing from a lighthouse for a LOP fix. This route clearly shows that the vessel was relying mostly on GNSS for navigation.

The example of the shipping pattern in the Dover Straits, UK, the route of tanker Hakkaisan, the significant reduction of range of light of lighthouses and the discontinuation the operation of lighthouses in the UK has proved that lighthouses are less relevant for current marine navigational practice. The current role of lighthouses is to complement the current marine navigational aids during the very rare event of the failure of all means of radio/electronic navigation such as GNSS, radar, VTS and land-based radio navigation.

The relevance use of Pisang island for current navigation practice

Since Pisang Island lighthouse is less relevant for current marine navigational practice, the question arises, what is the most relevant use for Pisang Island to support current marine navigational needs? To answer that question, the current requirements for marine navigation in the Straits of Malacca are investigated. The Mandatory Ship Reporting System in the Straits of Malacca, known as the STRAITREP, has been enforced since 1st December 1998 to support the Traffic Separation Scheme (TSS) (IMO, 1998). STRAITREP consists of 9 sectors (Figure 5), sectors 1 to 6 fall under the responsibility of the government of Malaysia, while sectors 7 to 9 fall under the government of Singapore's responsibility (IMO, 1998). The Malaysian sectors of STRAITREP are maintained by the Malaysian Vessel Traffic Services (VTS). Pisang Island is in Sector 6 (Piai) and near to the border of Sector 5 (Segenting). The sectors of the Malaysian VTS are supported by a series of surface radar, VHF radio and AIS transponders.

There are two shore-based facilities, namely Klang and Johor VTS. Each of these facilities is equipped with telephone, facsimile, telex, VHF radio and real-time display consoles for "X" and "S" band radar signal from remote radar stations (MPA Singapore, 2012a). There are seven remote stations that support the VTS, namely Pulau Angsa, Bukit Jugra, Cape Rachado, Pulau Undan, Bukit Segenting, Tanjung Piai and Bukit Pengerang. Each of these stations is equipped with 1 unit "X" band radar facility, 1 unit "S" band radar facility, and VHF radio transmitters and receivers.

Figure 6 shows the 48 nm (89 km) radius of the VTS radar coverage from two shore-based remote stations, namely Bukit Segenting (north) and Tanjung Piai (south). There is a small gap area between the coverage of those two radars. The VTS operator can increase the range of the radar to complete the coverage by reducing the radar pulse frequency rate, which increases the radar pulse length. However, this would degrade the detail of detection or the ability to discriminate two or more targets on the same bearing but at different ranges. The long radar pulse length would merge two targets on the same bearing that are half the pulse length as a single target on the radar screen (Bartlett, 2002; Bole, Dineley, & Nicholls, 1992). The ability to discriminate targets on the same bearing is critical for a VTS operator to detect the movement of a suspicious boat such as a small fast pirate boat approaching a larger commercial vessel. Therefore, the maximum current range is the best setting based on the trade-off between range and the detail of detection. However, the movement of small boats in the area near the maximum radius of both radars around Pisang Island are difficult to detect especially when these boats are made of fibreglass or wood. This is due to the radar pulse being less reflected or absorbed by these materials compared to metal. Another issue related with the VTS radar in the Pisang Island area is the existence of a shadow zone behind the island that faces the radar. The shadow zone exists due to the side of the island that faces the radar blocks the radar beam from reaching any target on the other side of the island. These radar issues may provide opportunity for unlawful activities to happen in this area such as sea robbery and human trafficking, which compromises the safety and security of marine navigation in the SoM. The best way to address this issue is by establishing a radar station on Pisang Island that would serve as a remote station for the SoM VTS.

Therefore, a radar station is more important than the existing lighthouse to support the operation of the SoM VTS and to ensure the safety and security of marine navigation in this busy strait. Corresponding to the current needs, there is no other site that is suitable to place the radar station other than the existing site of the Pisang Island lighthouse. This is the most suitable site in the area because it is located at the highest point on the island, which will give the fullest performance on range and detail of radar detection. Figure 7 shows the radius coverage of the proposed radar on Pisang Island by using a similar specification of the existing VTS radar. The radar on the proposed site would eliminate the existence of the shadow zone around the islands, which currently exists by using the shore-based radar. The Pisang Island radar can serve as a backup in the event of radar failure at either Bukit Segenting or Tanjung Piai. To accommodate the establishment of an "X" and "S" band radar facility on Pisang Island, the existing lighthouse should be discontinued from operation and replaced with a beacon to mark the island. The metal lantern house of the lighthouse should be removed to prevent any obstruction to the radar wave. Relevant equipment to support the operation of the marine electronic highway such as the AIS and Automatic Weather Station should be established on the site. The proposed beacon to replace the lighthouse should be established without a day mark and should produce a luminous range that is as minimal as possible and corresponding to the speed limit of commercial vessels in the SoM TSS.

Conclusion and recommendation

Current marine navigational practice is relying less on long-range visual marine signal such as lighthouses for reference. This is due to the availability of GNSS, which are integrated with other navigational aids on ships. The current trend shows that Pisang

Island lighthouse, is less relevant for current navigational practice and is not incorporated directly into the coastal state VTS operation and the establishment of the marine electronic highway. Furthermore, the existing shore-based VTS radar has a limitation on range and detail of detection in the area near Pisang Island. Therefore, a new radar station should be established on Pisang Island and the most suitable place is at the existing site of the lighthouse.

The establishment of a new radar station as an addition to the existing radar for VTS would eliminate the weaknesses of the existing VTS radar and improve the safety and security of marine navigation in the SoM. This study has justified technically the reason to replace the Pisang Island lighthouse with a radar station to support the current needs of safety and security of marine navigation. Therefore, this study recommends that further research be carried out to establish a radar station on Pisang Island as an additional remote station to the existing VTS system that would improve the safety of navigation in the Straits of Malacca and security of Malaysia.

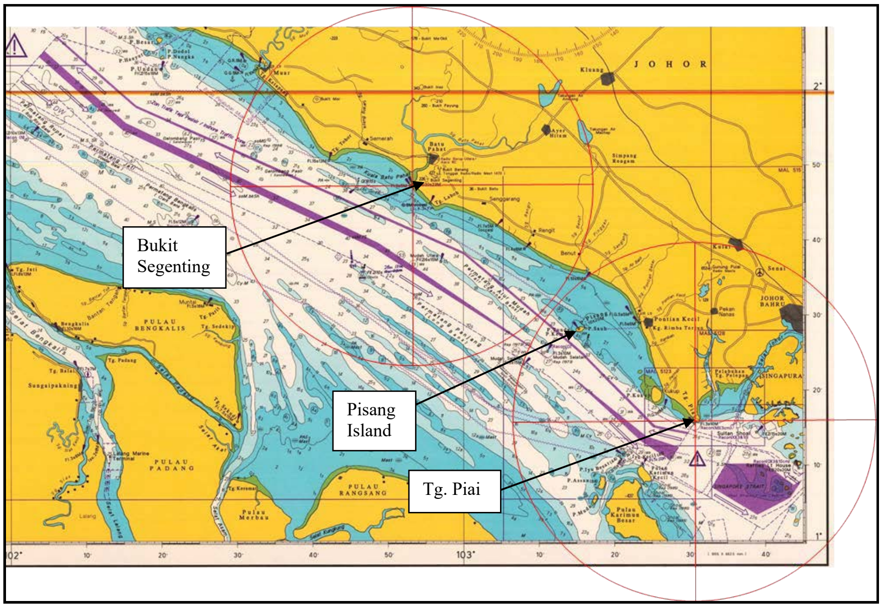

Figure 6: The existing VTS radar Coverage

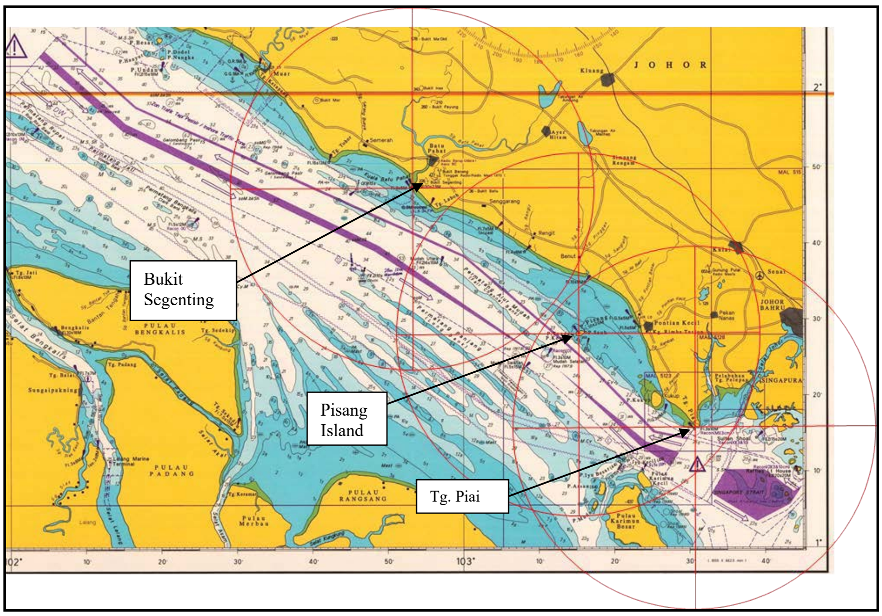

Figure 7: The proposed Pisang Island radar coverage with existing VTS radar coverage

The practical feasibility to conduct further research in the aspect of safety of navigation is to bridge the gap of coverage between the two coastal VTS radar stations that ensure a continuous detection of vessels in the straits, especially the hard to detect small glass-fibre or wooden construction vessels for better maritime traffic control and accident prevention.

In terms of the maritime security aspect to conduct further research, the continuous radar detection and elimination of shadow zone would be used to prevent the smuggle of illicit materials from Indonesia to Malaysia such as drugs and small arms; the smuggle of tax evasion materials to Malaysia such as liquor and cigarettes; and the smuggle of consumer products from Malaysia to Indonesia such as subsidised fuel and rice.

The cost to establish a new radar station on Pisang Island would be compensate easily by the saving from losses of the smuggle of materials mentioned above.

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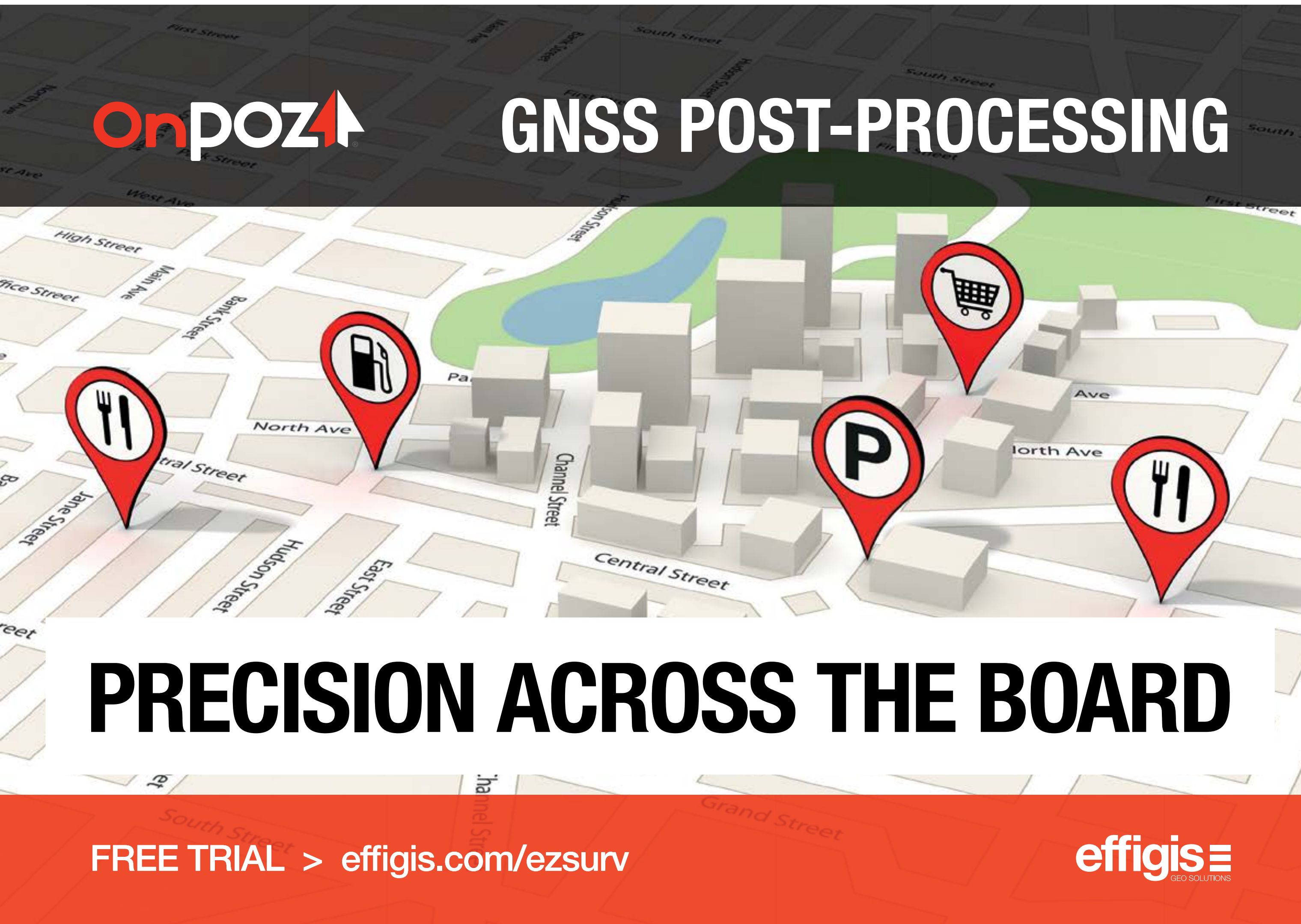

An automated method for street floor detection

In present study an automated method for detection of street floor using the Terrestrial Laser Scanner (TLS) point cloud dataset has been proposed

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Roads are the crucial geospatial feature and play vital role in national development and growth. They are the major component of nation infrastructure and economy of nation is also dependent at them. Therefore, modeling, management planning and condition assessment of road network are the major field of concern. Geographical Information System (GIS) with various surveying techniques is generally used in order to carry out these tasks.

Several traditional methods like ground surveying, Global Positioning System (GPS), photogrammetry and Distance Measurement Instruments (DMI) can be used but they are time consuming, labour intensive and costly. To overcome these complexities, Light Detection and Ranging (LiDAR) can be used. There are different platforms associated with it namely terrestrial, airborne and space borne (satellites). LiDAR is a remote sensing device which measures range and scan angle of the target by analyzing the amplitude and orientation of reflected light.

A very viable and efficient survey method to evaluate road surface along with its parameters is a Terrestrial Laser Scanner (TLS). There is a rapid growth in the utilization of TLS systems in many road corridor applications. This increase is due to the continuous development in terms of data capture speed, accuracy and density of point data obtained from these systems. These systems capture huge point clouds that describe very highly detailed road scenes. It also supports survey on demand by extracting desired features and attributes from the point cloud, removing the need to return to the field for measurements.

Various benefits of using TLS are lower safety risks associated, day or night data collection, very high point density, fast collection rates, reduced time usage, provision for linking additional sensors, high resolution capabilities, reduced number of field visits (collect once, use many times), multiple end users and opportunities to share data. An inherent feature of LiDAR data is that it is acquired, processed and delivered in a digital format, making it very easy to work with and to create data products that meet a wide range of needs. Some of the drawbacks associated with TLS are that the initial setup cost is high, points require processing to be classified which is generally a semi-automatic process, skilled workers are required, and data acquired can be cumbersome.

The difficulties in automating the detection of road features comes from the complexity of the scene, unorganized nature of the point data, no prior information of the position and orientation of the road features and combination of multiple data sources. These data sources are the position and orientation data from the navigation sensors and the point cloud data from the laser scanning sensor.

Extraction of the road surface using the TLS data was the area of interest of many researchers, various techniques, algorithms and methods were proposed by them. Tsai, et al. 2013 [1] was proposed a method to measure cross slope using terrestrial LiDAR. After LiDAR calibration and data acquisition, Region of Interest Interval (ROI) extraction was performed on the collected LiDAR point cloud to extract the rectangular region within a single lane between the pavement markings. Individual

cross slope measurement was conducted within each ROI. All of the cross slope measurements were computed in the tested road section, each measurement from the corresponding ROI was represented by a single geo-referenced point. Since the cross slope was computed based on the regression result of the LiDAR point's elevation, there was a trade-off in selecting the ROI interval. Photobus for the fast acquisition of road geometry with a real-time data quality control for Advanced Driver Assistance Systems (ADAS) was used by Gontran, et al. 2005 [2]. It provides early warning and lateral control of the vehicle which coupled with Radio Direction and Ranging (RADAR) and a Variable Message Signal (VMS) to prompt a driver with reducing speed was also used. Thuy and Puente 2010 [3] was devised a method for lane detection and tracking based on LiDAR data. The registration of the measured LiDAR points with regard to time and space was done by calibrating the onboard sensors with respect to the ego-car. The obtained ego-position was transformed into Universal Transverse Mercator (UTM) coordinates. A binarisation was performed to distinguish and improve the contrast between road surface and lane markings for pre-detection of lane. For better lane detection, Canny filter was applied. For individual lane detection two vertical detection windows within the map was defined, having m rows and n columns. If the number of white pixels exceeds a velocity-dependent threshold, lane detection was assumed. A clothoid road model was applied to track the lane, least square method or extended Kalman filtering can be used. Wang, et al. 2014 [4] was presented an automatic approach for the delineation of both the direct environment of a road and the road itself into local catchments starting from a Laser Mobile Mapping System (LMMS) point cloud to estimate the road runoff. A uniform voxel size was selected for downsampling procedure as the point cloud density was very high. Surface normal was estimated during the iterative filtering of the road points. Then the largest one dimensional (1D) slope in one of the eight adjacent directions was selected to obtain the first approximation of the two dimensional (2D) slope in the regular grid defined. An algorithm was used for segmenting the roadsides points. Using the D8 algorithm, the primary flow direction was determined by selecting the direction to the neighbor having maximal 2D gradient for each of the query point present in the grid. In the succeeding steps, the flow was followed. All flow terminates at the pixels in the bottom row. An effective path detection and tracking method was designed by Lee and Cho 2009 [5]. The designed procedure consists of four main processes: initialization, lane segmentation, post-processing and adaptive parameter updating process. The initial Probability Density Functions (PDFs) were estimated based on conventional color or edge-based lane segmentation method. After initialization, lane pixels were segmented by the statistical Bayes decision rule in the lane segmentation process and the misclassified lane pixels were excluded using the Least Mean Square (LMS) algorithm for the post-processing. The LMS algorithm estimates each optimal lane at right and left side of the region assuming that lane consists of a set of straight lines. Finally, each PDF of color and edge-orientation were updated using the current detected lane pixels. The use of the Gradient Vector Flow (GVF) snake model for the automated extraction of road from terrestrial based terrestrial laser scanning system was proposed by Kumar, et al. 2010 [6]. The GVF snake model was implemented by deriving its energy terms from the LiDAR point data and then initializing the snake contour based on the navigation information. To calculate the GVF energy from the surface slope, the Digital Terrain Model (DTM) of the LiDAR point data is needed. It was an iterative process. Point thinning over LiDAR points was achieved using the z-mean window filter method. The slope was calculated as the rate of change of the surface in the horizontal (*dz/dx*) and vertical (*dz/dy*) directions from its center point to its neighbors by the natural neighborhood interpolation method. LiDAR point cloud data and planimetric road centerline data were used by Hubo and Rasdorf 2008 [7], for modeling road centerlines and predicting their lengths in 3D. For the 3D modeling Linear Referencing Systems (LRS) were used. In LRS a 3D point can be located in a three-dimensional space via the planimetric distance and the associated elevation. The comparison of interpolation and snapping method was carried out to get better results. But the prime importance was the selection of buffer size. Barbarella, et al. 2014 [8] was applied LiDAR to the study of taxiway surface evenness and slope. In this study a TLS was used for evaluation of the geometry of taxiway. The TLS measures points belonging to the pavement with a predefined sampling rate in zenith and azimuthal angles. The extremes of line segment of predefined width were calculated, which was orthogonal to the axis at intervals along the axis line. The DEM was then interpolated along those sections obtaining the profile. The least square method was used for the estimation of the slope. A line was calculated that better interpolate all points of every segment. The angular coefficient of the line was the slope of the section. Cheng, et al. 2007 [9] was developed automatic road vector extraction engine for mobile mapping systems. The road information extracted by ARVEE (Automated Road Geometry Vectors Extraction Engine) includes 3D continuous lane lines, road edges and lane lines attributes.

Study area and test data

For the data collection purpose, FARO Focus3D X 330 TLS has been used. It is a dynamic 3D TLS mapping system that uses the very latest laser scanning technology combined with a precise navigation system, advanced data processing software and an innovative system design to scan highways, infrastructure, buildings and vegetation. In FARO Focus3D X 330 the onboard navigation system includes a Global Positioning Satellite (GPS) receiver. It offers a 360-degree field of view, a range from 0.6m up to 330m with distance accuracy up to ±2mm, delivering high precision performance and coverage. It is easy to use as it has a dedicated touch screen Liquid Crystal Display (LCD) display that shows status information and allows the data capture parameters to be adjusted. It can be used with ease for the road related data extraction purpose.

The test data is captured from the Mahatma Gandhi Marg, Civil Lines, Allahabad city, Uttar Pradesh, India (25° 26’ 47.4108’’ N, 81° 51’ 9.6984’’ E), including 7837278 points. The maximum elevation difference within the dataset is 23.48 meter. There are very low slopes along the horizontal streets, and in some areas streets are heavily blocked by trees. Overall, the data set have an urban as well as nonurban behavior. The length of the street is 62.172 meter. Some street floor points of captured dataset are missing due to the traffic at the time of data capturing. Figure 1, shows the Google Earth image of the corresponding location along with side and top view of captured dataset.

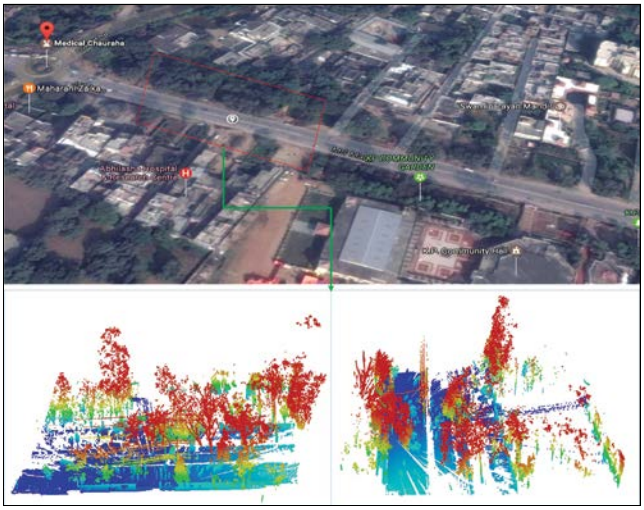

Figure 1. Google Earth image of test site along with side and top view of captured dataset.

Table 1. Statistical specification about dataset

File Size	*No. of Points*	*Street Length (meter)*	*Area (meter^2)*	*Point Density (per meter^2)*
358 MB	7837278	62.172	92375.5985	84.841

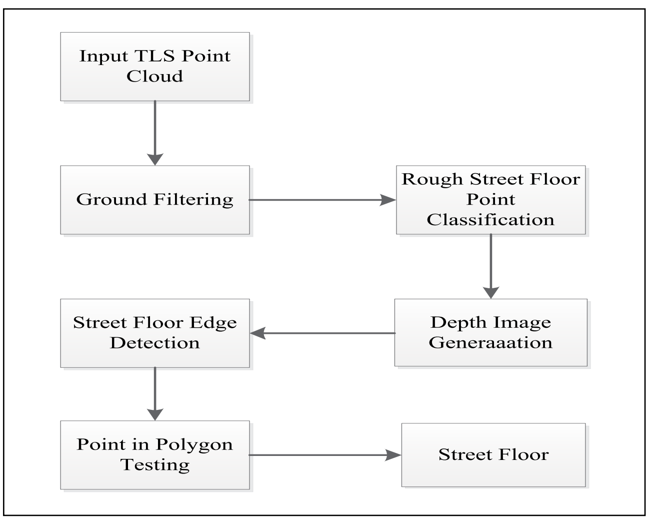

Figure 2. Flow chart of proposed method

Proposed method

In present study, a novel method for street floor detection using TLS point cloud data is proposed. Method includes five steps namely ground filtering, rough street floor points classification, depth image generation, street floor edge detection and point in polygon testing (Figure 2). All these steps are described in subsection of this section.

Ground filtering

Initially, the point cloud data is projected at X-Y plane. Further, first point of the projected dataset is selected as a seed (query) point. Then, K-Nearest Neighbor (K-NN) search algorithm is applied to find the *K* neighbor points of the selected seed point. All the *K* nearest neighbor points are taken collectively and their standard deviation of Z coordinate is calculated. If the calculated deviation value is less or equal to a predefined threshold, then the seed point is labeled as ground points (1). Similar procedure is applied for all the points of point cloud dataset.

$$\forall k_j\left(j\text{=seed point}\right):\begin{Bmatrix}\text{if} \quad Z_{std} \le Z_{std}^{\text{th}} & \textit{Ground Object} \\ \text{else} & \textit{Non Ground Object}\end{Bmatrix} \qquad (1)$$

Where, Z_{std} and Z_{std}^{th} represent the calculated standard deviation and predefined threshold for the standard deviation. Kj shows the number neighbors for the jth seed point. Figure 3, shows the ground filtered points.

Rough street floor point classification

Filtered ground points are further used for rough classification of street floor. Captured TLS point cloud contains both positional (XYZ) and radiometric (Red, Green, Blue (RGB)) information. Radiometric information of filtered ground point cloud is used for rough street point classification.

The process of classification of street floor is similar as ground point filtering. Likewise of ground filtering first point of filtered ground point cloud dataset is selected as a seed point. Then, K-Nearest Neighbor (K-NN) search algorithm is applied to find the K nearest neighbor points of the selected seed point. All the K neighbor points are taken collectively and average of their RGB value is calculated. If the calculated average value is less or equal to a predefined threshold, then these points are labeled as street floor points (2). Similarly, one by one the points from the filtered point cloud dataset are taken as seed point.

$$\forall k_j\left(j\textit{=seed point}\right):\begin{Bmatrix}\textit{if} \ \left(RGB_{avg} \le RGB_{avg}^{th}\right) & \textit{Street Floor Point} \\ \textit{else} & \textit{Other Point}\end{Bmatrix} \qquad (2)$$

Where, RGB_{avg} and RGB_{avg}^{th} represent the calculated average

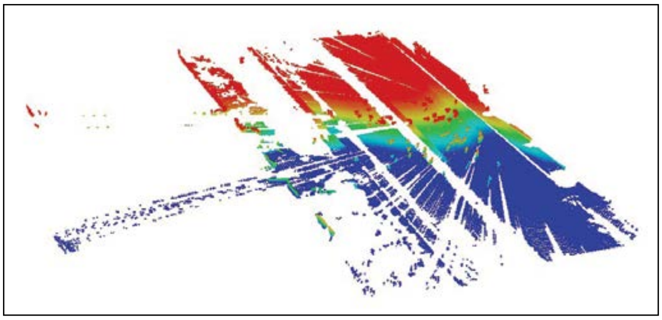

Figure 3. Filtered ground points.

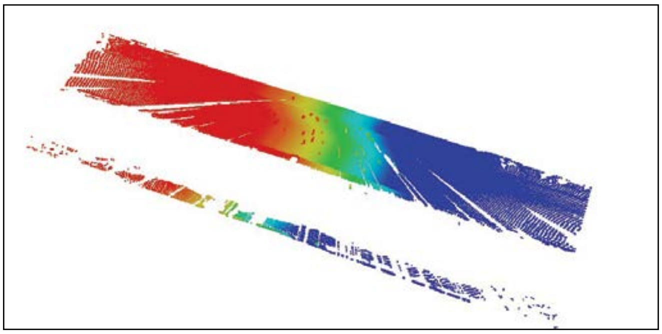

Figure 4. Roughly street floor classified point.

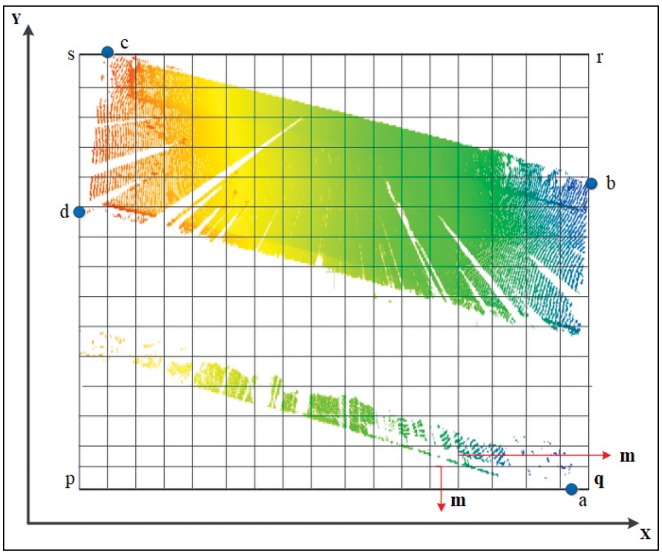

Figure 5. Roughly street floor classified point.

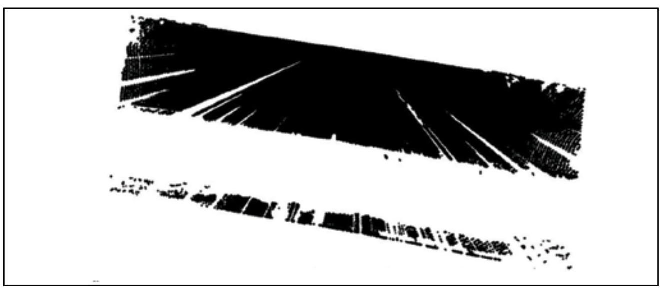

Figure 6. Generated depth image.

and predefined threshold for average. K_j shows the number of neighbors for the j[th] seed point. The roughly classified street floor points are shown in Figure 4.

Depth image generation

In this step, roughly street floor classified points of previous step are mapped into regular standard grids (Figure 5). The size of grid is taken *m* meter in both X and Y directions. For each grid, points belonging to the same grid are taken collectively and their average of Z coordinate value is calculated (7). These values are treated as Digital Number (DN) value of depth image for corresponding grid. Each pixel of depth image is represented by a particular grid. The number of pixels in depth image will depend on the grid size (*m*) (3,4,5,6,8).

$$Length\ of\ bounding\ box(bl) = \begin{bmatrix} (maximum\ X - minimum\ X) \\ or\ (P_x - Q_x)\ or\ (R_x - S_x) \end{bmatrix} \quad (3)$$

$$Width\ of\ bounding\ box(wl) = \begin{bmatrix} (maximum\ Y - minimum\ Y \\ or\ (P_y - S_y)\ or\ (Q_y - R_y) \end{bmatrix} \quad (4)$$

$$Number\ of\ rows\ (f) = \left\lceil \frac{wl}{m} \right\rceil \quad (5)$$

$$Number\ of\ columns\ (g) = \left\lceil \frac{bl}{m} \right\rceil \quad (6)$$

Where, P_x, Q_x, R_x, S_x are the X coordinate value of bounding box corner points and P_y, Q_y, R_y, S_y are the Y coordinate value of bounding box corner points.

$$DN_p = \left\lfloor \frac{\sum_{i=1}^{n} Z_i}{n} \right\rfloor \quad (7)$$

$$Number\ of\ pixel\ in\ depth\ image = f \times g \quad (8)$$

Where, DN_p is Digital Number value for the p[th] grid, *n* represents the total number of points are present in p[th] grid, *f* shows the number of rows and *g* shows the number of columns of generated depth image. Figure 6, shows the generated depth image.

Street floor edge detection

Canny edge detection method has been chosen to detect the edges in depth image (Canny, 1986 [10]). The Canny edge detection includes noise reduction using Gaussian filtering, computing the depth gradient and finding the maximum localized edges, and finally tracing the detected edges to

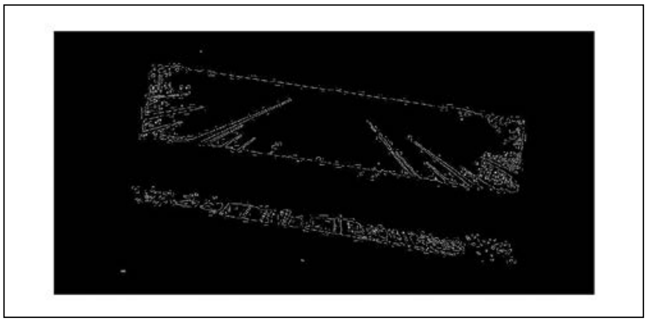

Figure 7. Edges of generated depth image

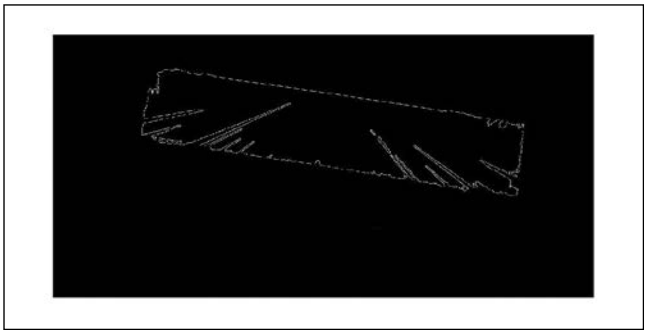

Figure 8. Remained edges of depth image after point density analysis

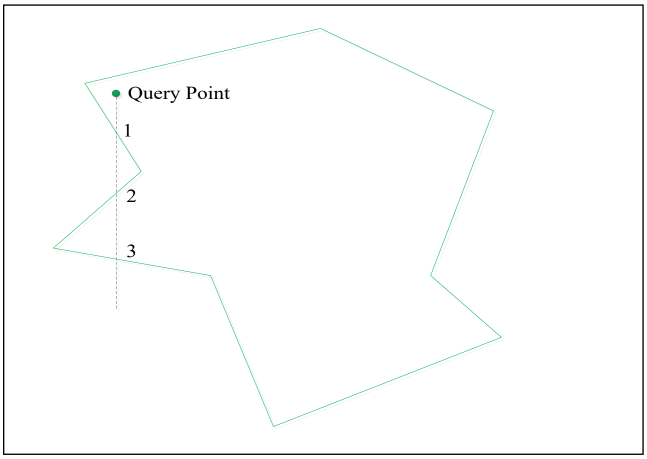

Figure 9. Point in polygon test (point inside the polygon).

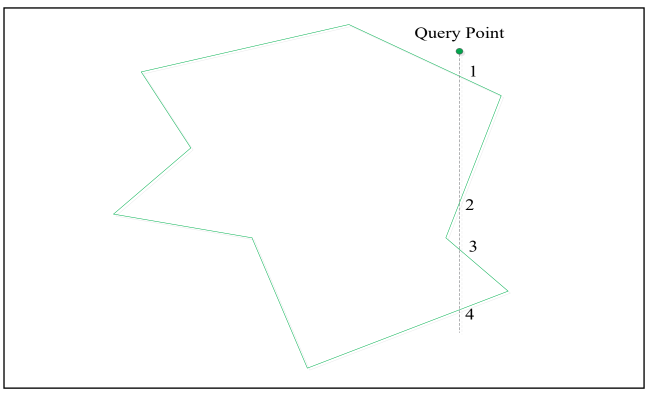

Figure 10. Point in polygon test (point outside the polygon).

include the weaker gradients if they exhibit natural extension to the strong edges. It finds a lot of edges in depth image besides the boundary edges of street floor (Figure 7). These boundary edges exist on the sides of the street floor which exhibits the highest point density across the whole scene. This high density is used to filter out the remaining edges (Figure 8).

Point in polygon testing

After detecting the boundary edges of street floor, point in polygon test is applied in order to detect the street floor points. Representing the edges as a closed shape around the street floor helps the point in polygon test to identify the street floor points in the roughly classified street floor.

After applying the point in polygon test, roughly classified street floor points are segment into two classes; the street floor (inlier points to the curb polygon) and non-street floor (outlier points to the curb polygon). The point in polygon test simply classifies every point in either street floor or non-street floor. The test determines whether a given point lies inside, outside or on the boundary of a polygon. In this study, point in polygon test counts how many times the query point cuts the boundary of polygon (cutting number), if a line is drawn from the query point in downward Y direction (Figures 9, Figure 10). If the cutting number is even, point is outside the polygon (Figure 10). Furthermore, if cutting number is odd, it means that the point lies inside the polygon or on the polygon boundary (Figure 9).

Result and discussions

Proposed method is tested on captured TLS point cloud dataset (Figure 1). Statistical specification of the same is shown in Table I. The method uses two parameters average of RGB value (RGB^{th}_{avg}) and standard deviation of Z coordinate (Z_{std}) in two different steps. The threshold (used) values of these parameters are shown in Table II. Apart from positional information (X, Y, and Z coordinate) of each terrestrial laser scanner point, radiometric information (RGB) is also used by the proposed method. So, the proposed method depends on this additional information. Proposed method is independent of point density. Method has been coded at Matlab2013a installed on Sony Vaio E Series notebook (OS: Windows7 64bit, CPU: Intel Core i3@2.4GHz, RAM: 3GB). The execution time of the proposed method at standard parameters values (Table II) is 451.36 seconds.

The street is precisely removed manually from the captured TLS point cloud for the generation of reference dataset. Cloud Compare open source software is used to carry out this task.

$$Completeness = \frac{Street\ points\ detected}{Reference\ Street\ points} \quad (9)$$

$$Correcteness = \frac{Street\ points\ detected}{Street\ points\ detected + Non\ Street\ points\ detected} \quad (10)$$

Figure 11. Detected street points by the proposed method.

Table 2. Parameters and their used values

Average of RGB value (RGB^{th}_{avg})	11
Standard deviation of Z coordinate (Z^{th}_{std})	0.3

Table 3. Completeness and correctness statistics

Number of street points in reference dataset	3011262
Number of points detected by proposed method	2940704
Number of street points in detected dataset	2864915
Non street in detected dataset	75789
Completeness	95.14 %
Correctness	97.42 %

Conclusions and future recommendations

Present study describes an effective method for the classification of street points from TLS point cloud data using both the geometric and radiometric information. K-NN search algorithm is used in ground filtering and rough street floor point classification. Roughly classified street floor points are converted in depth image in order to identify the street floor edges by Canny edge detection technique. Point in polygon test is performed for exact classification of street floor points.

The results achieved appear encouraging; although, a direct comparison could not be made to other published methods that use other data sources such as aerial photography. The classification is performed on urban area. The algorithm presented appears to work well in all areas. The shape of polygon generated by the edge detection step is not in rectangular form due the occlusion in street floor of captured data. Future work is to be focused on the automated obtaining of optimal parameters values for good classification results of the LiDAR data.

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Introducing J-Mate

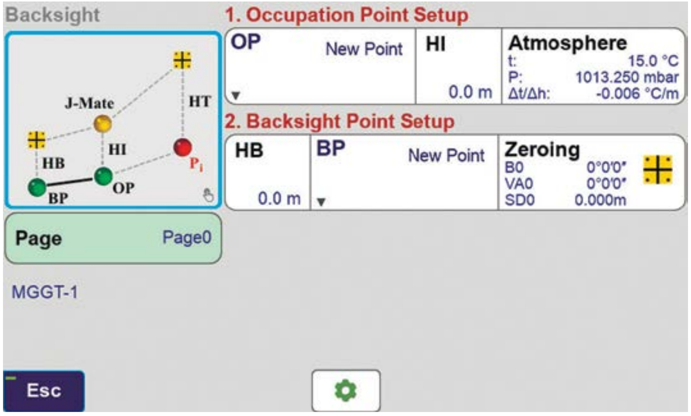
This is J-Mate

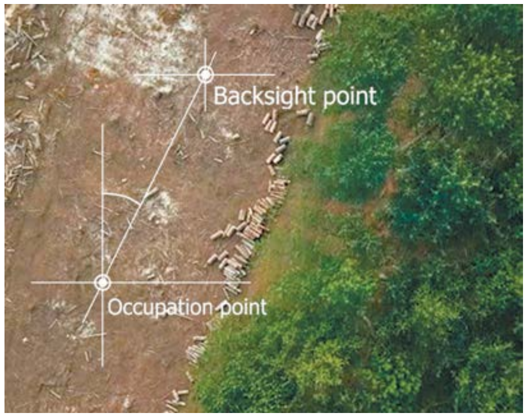
Why follow a workflow designed for yesterday's equipment?

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. Three **precision vials** allow a visual check on levelness of the instrument.

Backsight icon

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

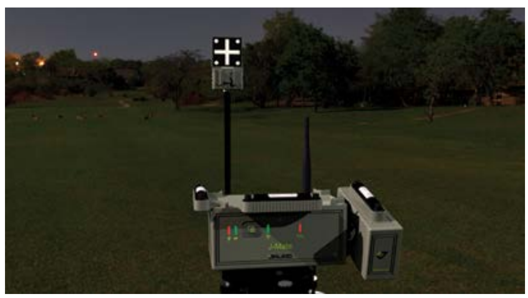




This screen appears which guides you to determine the accurate positions of the Occupation Point and the Backsight Point, to establish an azimuth and calibrate the J-Mate angular encoders.

- The tripod is setup at the "Occupation Point" (OP).
- The J-Mate is secured on the tripod.
- Next, TRIUMPH-LS is placed on top of the J-Mate with its legs registered to the matching features on the J-Mate.
- Next, Use the RTK Survey feature of the TRIUMPH-LS to quickly determine the accurate location of the Occupation Point. You can use your own base station or any public RTN.

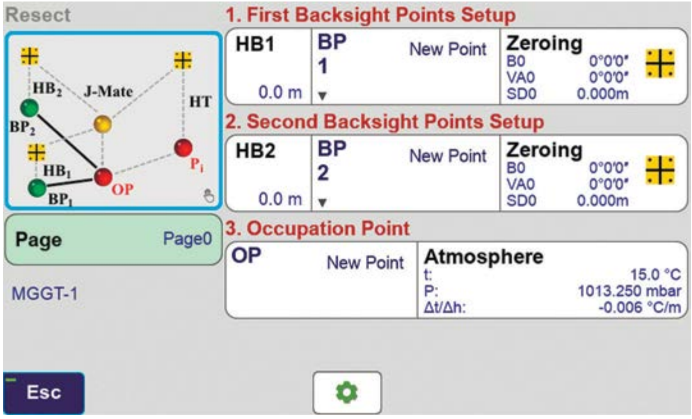
- Next, slide the Plus sign target on top of the TRIUMPH-LS, lift it from the J-Mate and move to the "Backsight Point" (BP). The camera of the J-Mate will robotically follow the plus sign target. The camera's view is visible from the TRIUMPH-LS screen, which mostly focuses on the plus sign. When at the Backsight Point, its accurate position is determined by the TRIUMPH-LS, and the Azimuth from the Occupation Point to the Backsight Point is established, and the J-Mate is calibrated and ready to shoot other points.

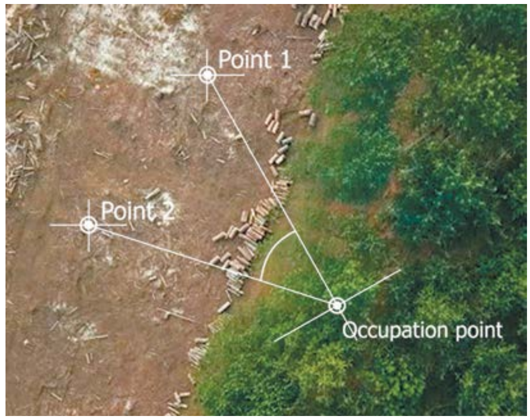


- After this calibration is complete, if the tripod is disturbed, the red LED on the front of the J-Mate will blink to show that re-calibration is required.
- We can now replace the TRIUMPH-LS on top of the J-Mate at the Occupation Point and proceed to shoot as many "Target Points" as the job requires. From now on the TRIUMPH-LS is used as a controller and you can hold in your hand too, but it is more convenient to put it on its place on top of the TRIUMPH-LS to have free hands.

Resect icon

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





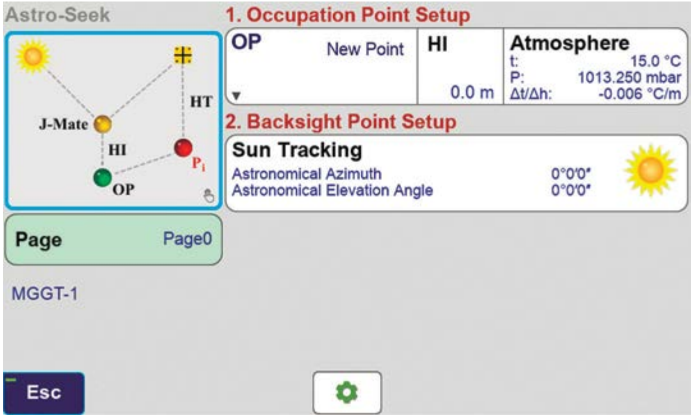
Shoot two or more known points to establish an accurate position and calibrate the encoders. Then continue to shoot the unknown points.

The “J-Mate Resect” automatically finds the plus sign “+” that you carry to two, or more, known points, and shoots them to determine the accurate position of the J-Mate and the azimuth to calibrate the encoders of the J-Mate and then you can proceed to shoot other points.

LIVE video at www.javad.com

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.

If doing a sun-shot, attach the Sun filter to the J-Mate

Click the “J-Mate-Astro-Seek” icon

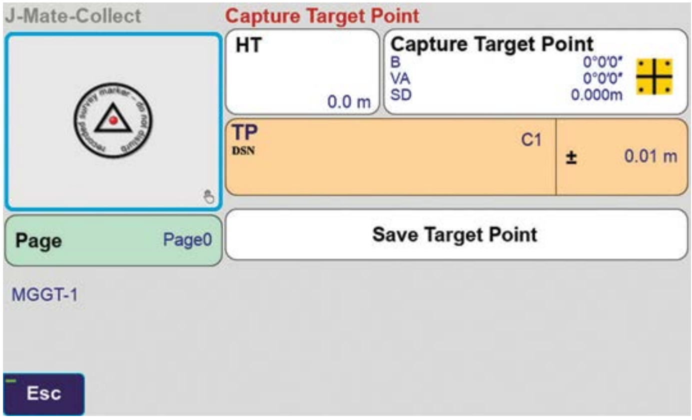
Then click the “Sun” icon in the screen which appears

J-Mate will automatically find the Sun, and use its position to calibrate the angular encoders automatically.

LIVE video at www.javad.com

J-Mate-Collect

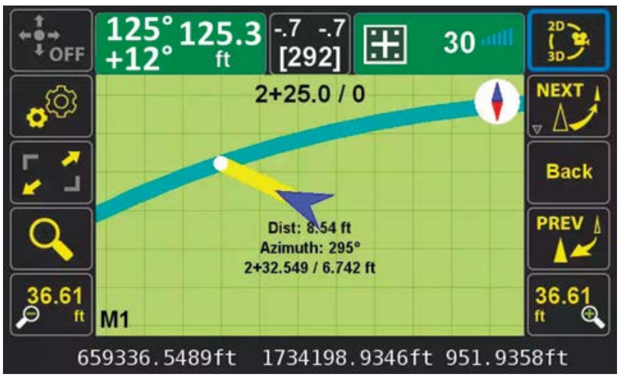
After calibration is performed, click the J-Mate Collect icon to shoot the unknown points.

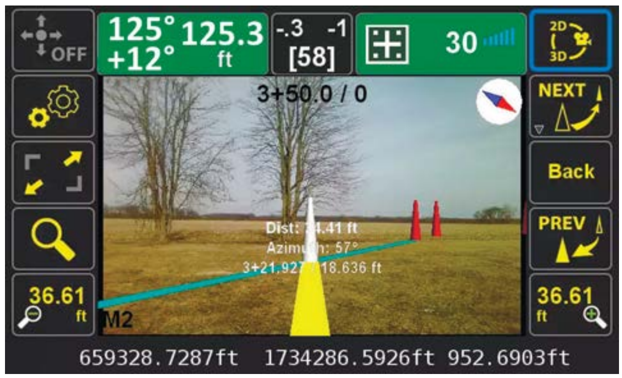


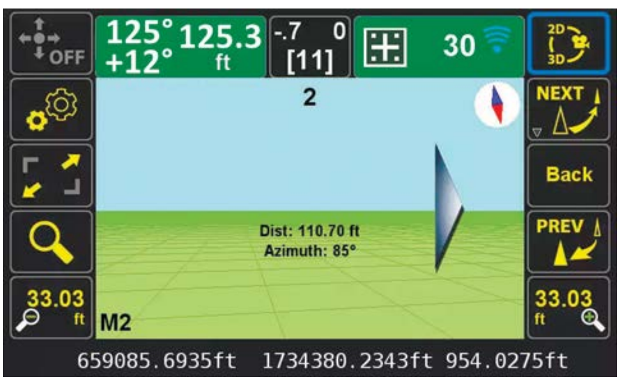
J-Mate-Stake

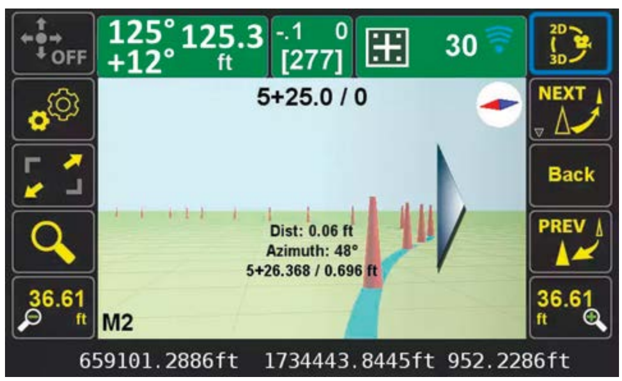
Click the J-Mate Stake icon to use the J-Mate for stakeout.

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 "+" sign that you carry 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.

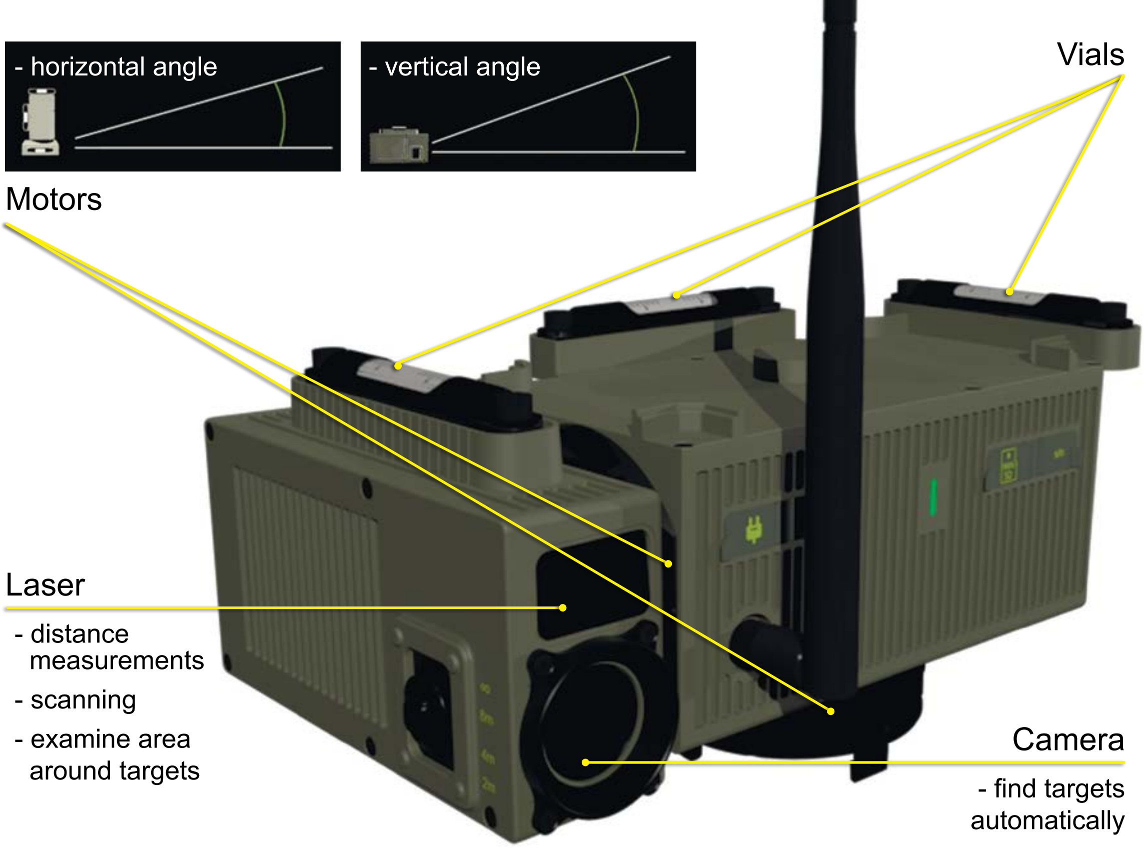








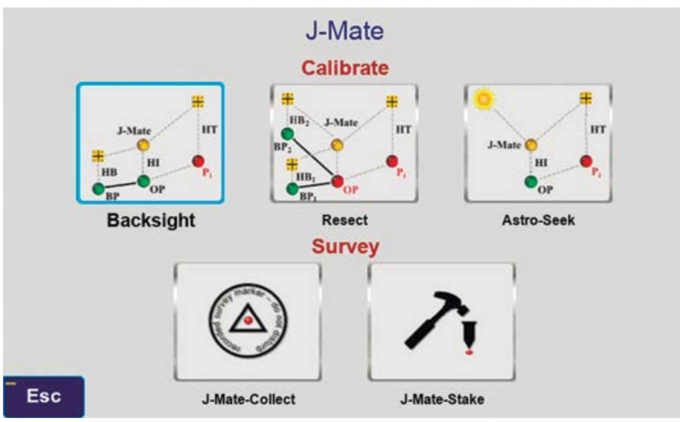
Take control with J-Mate + TRIUMPH-LS



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).

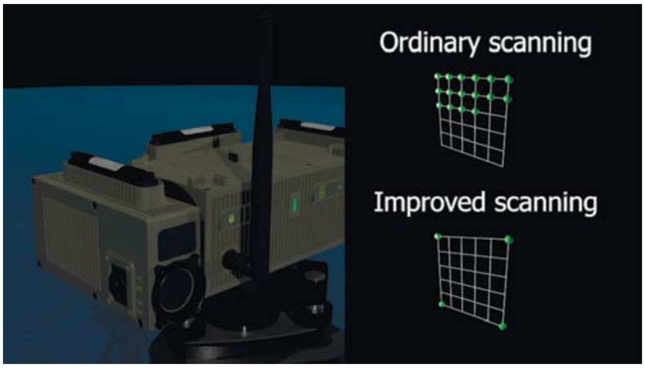
After the J-Mate is calibrated, you can proceed with your work as normal via the Collect or Stake icon.

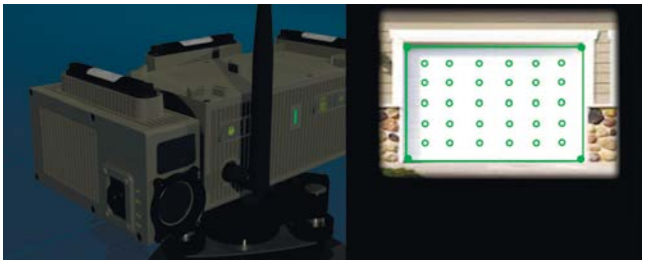


*We plan to ship by **September 2018**.*

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

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.

Future national geospatial agencies: contributing to the society and the SDGs

The paper illustrates how geospatial information supports the delivery of SDGs, and demonstrates some of the key national changes that will enable this to occur

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'*Geospatial is like a general-purpose technology; it's the oil for the next generation of the digital economy*.'
Nigel Clifford, CEO Ordnance Survey, opening the quadrennial Cambridge Conference, Oxford University, July 2017

Globally the geospatial community continues to transform as the world increasingly uses location to unlock value. Disruption sees new ideas, new providers, often bypassing the traditional surveying and mapping authority. The mantra '*evolve or die*' has never held so true to national mapping and geospatial authorities (NMGA) everywhere. But it is also a time of great opportunity for national mapping agencies to become national geospatial agencies, actively helping to drive the social-economic benefits that good data can help bring.

Why is data important to development and SDGs?

The 2017 World Bank Land and Poverty conference, (Kedar, J, 2017), provided insight into the many and varied socio-economic benefits GI can bring a nation. It reflected that economic and societal benefits of geospatial enablement are well documented in high-income nations but not in low and middle-income nations.

Quality statistics are accepted as the tool to measurement of progress in implementing the Sustainable Development Goals (SDG). Geospatial data contributes too, and it is the integration of such datasets that can add real value. Take the measurement of SDG Tier II Indicator 11.2.1 'Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities'.

In some cases, such as Tier 1 Indicator 15.1.1, Forest area as a proportion of total land area, GIS analysis on a range of spatial datasets can provide measurement without recourse to further statistical collections. Clearly, to be of use internationally, there must be common global standards defining forest, data must have the right attributes, be accessible and be of sufficient quality, currency and in the case of SDGs, national coverage. Some Indicators will take more complex geospatial analysis, for example Indicator 6.1.1, Proportion of population using safely managed drinking water services. Here, factors such as natural and artificial barriers to access such as fences, land ownership and control, consistency in supply all are relevant factors. It becomes evident that not only is better data required by analysts, but greater skill and understanding of the decisions being taken from the analysis.

Measurement is one benefit of integrating good GI. In the same three indicators described above, decision makers can use the same data to understand the current situation, plan efficient mitigation, and make investment decisions and commission projects. Contractors then deliver the mitigation, working with the same data, and measurement of progress maintained. In other words, the utility of GI supports the delivery of SDGs, not just measurement.

In some nations, the most complete national coverage data about a national infrastructure is still the 1970/80's UK Directorate of Overseas Survey's 1:50,000 scale paper map, which may have subsequently been digitized. Projects have collected data additionally, particularly around addresses, administrative boundaries, water sources and roads, and thus the concept of a national spatial data infrastructure holds good. But the trusted fundamental geospatial data is lacking and GI benefits are not being realized.

Illustrating the benefits of GI to SDG delivery

This paper draws upon examples to demonstrate how geospatial capabilities have a real part to play in SDGs. They are not comprehensive examples but do demonstrate the reach across SDGs.

Goals 1 and 10:

United Republic of Tanzania

Urban Development: More than 70% of urban settlements are unplanned. About 1.5 million land parcels are surveyed, 900,000 are allocated and 650,000 are registered. Rural Land Use: Only about 10% of villages have land use plans.

Action is happening: ILMIS, Land Investment Unit, large farm inventory, review of national land policy, increased surveying of land parcels in rural areas.

Security of land tenure is a key enabler. Land is 75% of the value of world's gross domestic product. Land administration requires effective geospatial data management and provides access to credit and tenure security, enables effective infrastructure planning and delivery, fair compensation and land taxation.

Goals 3 and 10

Responding to fire, serious illness and accident. Time saves lives and money. In Ireland, for example, a navigation device and geospatial data enhances the response time by 17% and reduce cardiac arrest deaths by 10%.

Goals 2, 12, 14 and 14

Rural development. Support through agricultural cadastre, calculation of farming subsidies or compensation payments, irrigation and drainage planning and maintenance, land use planning, getting produce to market, environmental protection and large-scale agricultural investments.

Goals 10 and 12

Taxation and government revenue generation. This includes property tax, agricultural land tax, business and income tax

Arusha Local Government Revenues (McCluskey, W, 2017)

As part of World Bank and DANIDA supported Tanzania Strategic Cities Project (TSCP) Arusha has introduced a Local Government Revenue Collection Information System. Over four years from 2013 revenues have more than doubled. These revenues are from sources such as: service levy, property tax, billboards, parking fees, income from sale or rent, market fees and charges, secondary school fee, licenses and permits on business activities and hotel levies.

A key element of this success has been the ability to geographically locate all taxpayers and properties. This has required a comprehensive spatial database: satellite imagery, roads and individual buildings digitised, unique property reference number, attributes (e.g. use, condition, age).

This database could provide a wide range of benefits to other departments, agencies and businesses when shared.

Goals 2, 4, 4, 6 and 9.

National infrastructure development benefits from integrated planning, and integrating data. Benefits include the ability to better manage and optimise existing infrastructure assets, increase efficiency and maintain integrated planning.

Burkina Faso (Ouiba, Y, 2011)

In Ouagadougou, a pilot project has been implemented to reduce water losses within the distribution system of the municipal utility.

The programme has generated positive benefits for the local economy. Local jobs have been created, public health improved, and water efficiency had been increased.

For the case of Ouagadougou, the direct savings of the water loss programme has been estimated to be around 0.8 EUR/m³. With the surplus costs on top, the total economic profit might well exceed 2.0 EUR/m³.

Goal 11

Urban planning and resilient cities. In Tanzania more than 70% of urban settlements are unplanned. Planning for tomorrow requires a comprehensive understanding of today. Dar es Salaam is expected to grow by 85% by 2025. As cities become larger, urban planning and managing the urban environment becomes more complex. The use of geospatial data not only leads to integrated city development but enables planning across power, water, and waste, and improves resilience planning & disaster response, environmental management, transport planning and operations.

India (Scott, G and Chopra, R, 2016)

GI provides spatial insights on basic infrastructure, other services and facilities, and the environmental condition of slums. This empowers local Government authorities in planning and executing slum improvement plans. Mapping and analysing changes in urban neighbourhoods to help planners and decision makers. Sustainable planning and management of population growth and urban expansion are achieved through continuous monitoring of an area.

Goal 5

It is often stated that countries with gender equality have better economies.

Gender equality is derived from a range of measures, such as better health and education, but also land tenure, access to transport to employment, improved policing and fair taxing and benefits distribution (where these exist). The geospatial analysis of wider statistics data enables understanding and more focussed interventions.

Rwanda (DfID)

Esperance, 39, a mother of four used to be in constant dispute with her neighbours over ownership of the land she lived on. Through a DFID-funded land registration programme, the dispute is now settled and she is a proud landowner. Esperance says: “I will now work and invest confidently in my land to provide a better future to my four children as I now know that nobody can take my land from me.”

Goals 13, 14, 15

Natural resources and the environment. Sustainable management, particularly water sources and lakes, forestry, coastal zones, national parks and crop yield prediction. The planning and management of extractives industries is often aided by taking a geospatial approach. Sustainable management of the environment often also uses remote sensing data to give a current view on the state of natural environment, and climate change monitoring is enabled.

Zanzibar Sustainable Tourism

Balancing coastal development, growth through tourism, citizen and environmental demands is challenging. Land use, fisheries, property rights and the environment all need to be considered and decisions taken based on ‘where’ development best balances conflicting demands. Unregulated or illegal development can be identified and equally tourists, using innovative locally produced smartphone apps, can be encouraged to visit heritage sites. Geospatial data enables this.

Goals 8, 9

Internationally it has been demonstrated that the availability and use of maintained geospatial data can grow an economy by 0.25 to 0.6%, (Kedar J, 2017) in part due to better government and in part due to better businesses outcomes. Studies also demonstrate that benefits are evident across a wider-range of sectors, directly or indirectly. These studies are not directly transferable to developing nations. Examples include: marketing, telecoms, logistics, transport, extractives, financial services, tourism and utilities.

Most goals:

Disaster risk reduction and management. From famine to flood, disaster risk reduction and management demonstrates the importance not just of fundamental geospatial data, but of the need to integrate data from many sources rapidly to enable decision making. Weather forecasting to predict new rainfall, terrain data to model where and when flooding will occur, population data to estimate the impact, road data to understand how to conduct relief effort. Integrated location data such as this saves lives and reduces damage.

Integrating government services saves money and improves lives. Online services rely on geospatial data such as national address and administrative boundary data. The ability to build services combining data from different government departments, or to update many different databases from a single entry, is increasingly commonplace.

Most sustainable development goals (SDGs), to which all UN member states have committed, aim to alleviate poverty and provide benefit to citizens. Geospatial data supports the achievement of many of the associated targets, through understanding, planning, decision-making, delivery, operations and measurement. Further examples are noted in the UN GGIM Paper “The Role of Geospatial Information in the Sustainable Development Goals”, which demonstrates the value of geospatial information to 5 particular SDG Goals.

Measuring the benefits of GI

The benefits between nations, or even

	Atlantic	Quebec	Ontario	Prairies	British Columbia	The North	Canada
	%	%	%	%	%	%	%
Agriculture, forestry, fishing and hunting	2.50	1.04	1.33	0.96	1.38	4.47	1.22
Mining, quarrying, and oil and gas extraction	3.32	4.44	4.67	4.55	5.12	4.32	4.54
Utilities	1.60	1.73	1.68	1.19	1.51	2.09	1.58
Construction	1.34	0.94	0.82	1.90	1.17	1.50	1.23
Manufacturing	0.16	0.57	0.30	-0.18	0.86	1.75	0.33
Wholesale trade	0.88	0.85	0.81	1.14	0.93	4.03	0.90
Retail trade	0.51	0.46	0.43	1.11	0.55	1.68	0.60
Transportation and warehousing	1.57	1.65	1.59	1.45	2.16	0.26	1.64
Information and cultural industries	0.47	0.32	0.43	1.01	0.45	1.14	0.51
Finance and insurance	0.74	0.66	0.80	0.97	0.59	2.52	0.78
Real estate and rental and leasing	0.55	0.45	0.49	1.47	0.63	1.65	0.72
Professional, scientific, and technical services	0.72	0.34	0.28	0.94	0.57	1.54	0.57
Management of companies and enterprises	1.06	0.82	0.84	1.75	0.93	2.52	1.08
Administrative and support, waste management, and remediation services	0.87	0.71	1.00	1.13	0.89	3.11	0.95
Educational services	0.28	0.35	0.35	0.66	0.35	0.98	0.40
Health care and social assistance	0.60	0.57	0.55	1.17	0.57	1.48	0.70
Arts, entertainment and recreation	0.40	0.39	0.37	0.72	0.42	0.77	0.45
Accommodation and food services	0.56	0.59	0.64	1.46	0.74	1.59	0.83
Other services (except public administration)	0.38	0.28	0.36	0.92	0.44	1.86	0.48
Public administration	1.59	1.36	1.43	2.03	1.15	1.89	1.51

Figure 1: Estimated percentage change in Canadian industry output as a result of geospatial information, 2013 (%). Contains information licensed under the Open Government Licence – Canada.
Source: Hickling Arthurs Low, Canadian Geomatics Environmental Scan and Value Study, published 2015.

across a nation, vary considerably. Hickling Arthurs Low, Canadian Geomatics Environmental Scan and Value Study, published 2015, includes an examination of the estimated increase in industry output because of GI. The detailed figures themselves are not important in the context of this paper, but the table is extracted at Figure 1.

The first conclusion is that GI underpins across a wide range of sectors, a finding replicated in many studies of high income nations. The second conclusion is that, even in Canada, there are significant differences across provinces and territories due to differing needs and uptake. The use of GI, indeed different types of GI, therefore will vary across sectors and geographies.

This has worldwide applicability and the detailed benefits to every nation will differ. National economic benefit and Return on Investment Studies are justified and will also help determine GI priorities.

UN GGIM Europe's Working Group on Data Integration is examining the integration of data, particularly INSPIRE data, to support SDG delivery and measurement. UN GGIM Europe has concluded that some INSPIRE data themes contribute to all Goals but is now looking more specifically at detail.

GI brings significant benefits to a nation across all sectors and to the economy. The level of economic benefit in low and middle-income nations is little understood and resource should be expended gaining this understanding in order to help investment decision makers consider whether and how to invest in national GI and associated institutional capacity and capability. The UNGGIM and World Bank MOU, 'Roadmap for collaboration between World Bank's Global Practice on Social, Urban and Rural Development, and Resilience and United Nations Statistics Division to assist countries to bridge geospatial digital divide', signed at the 7th session of the UN Committee of Experts on Global Geospatial Information Management (UN-GGIM), provides a welcome step forward in trying to realise this gap in understanding.

Developing national geospatial agencies and capabilities

Traditional mapping agency role

NMGAs exist globally. Low-income nations may in part still use mapping from the last century, perhaps 1:50,000 scale, but neither maintained nor digital. Updates have been project-specific rather than through a maintenance regime, and many development projects do not consider the wider national benefits of data collected for a project. On the contrary, high-income nations maintain large scale, attributed and accurate data from addressing to topography, imagery to networks, and cadastre to geology.

In some cases, NMGAs have not recognised the changing world, and most have found it difficult to deploy the winning arguments for investment. These NMGAs are now left facing the stark reality that the World is moving on, that there are many geospatial players in government, it is no longer a simple customer/supplier relationship, and that they could become irrelevant.

For geo-political reasons, NMGAs are often 'the authority'. This has benefits, for example in the philosophy 'create once, use many', but it also places a responsibility on them to lead the move into national spatial infrastructures and deliver the fundamental geospatial data that underpins the Nation's data infrastructure.

Transforming NMGAs from surveying and mapping to delivering underpinning geospatial data to a nation is a challenge, a challenge that in UK took 30 years. The recent Ethiopian Government announcement that the Ethiopian Mapping Agency is being re-established as the Ethiopian Geospatial Information Agency shows that nations are rising to the challenge.

But nations need data now if SDG achievement is to benefit from this data, and so 30 year, or even 10 year, sustainable transformation programmes can only be part of the answer.

What is the future?

National mapping and geospatial agency director generals from across the Globe debated the future of their organisations at the 2017 Cambridge Conference. They concluded that NMGAs do have a future if they adapt.

- The increasing reliance on location, from delivery of SDGs to the internet of things, is an opportunity. Managing the fundamental geospatial data layer, fit for purpose, maintained and trusted, underpins the integration of all spatial data and allows better decisions and efficient delivery and operations.
- Future NMGAs may become data brokers as well as collectors/managers, SDI authorities, service providers and service consumers. Whatever, NMGAs have to be the 'go to' authority for trusted fundamental geospatial data.
- NMGAs need to focus more on the user and their requirements over the next 10 years to deliver real value and their data must remain authoritative, trustworthy and accessible.
- In wider government, NMGAs can assist in integrating cross-government digital public services, helping realise their value in delivering SDGs. It is not enough to produce data; NMGAs need to be close to their customers and work to understand and solve their problems.

This is far more easily said than done. According to the UN Statistics Division, only 3% of Africa is covered at 1:25k scale, against 87% of Europe. For national coverage a number of nations use mapping from the last century, perhaps 1:50,000 scale at best, but neither maintained nor digital. Compare that with nations such as the United Kingdom and Singapore, maintaining large scale, attributed and accurate data from addressing to topography, imagery to networks. There is a widening geospatial divide, in itself contributing to the widening digital divide.

Nations are often investing heavily into land administration supported by the global community. A sustainable land administration system can bring economic and social benefits in line with SDG objectives. The need to collect and maintain geospatial data brings benefits more widely than SDGs though. It is part of a nation's digital infrastructure. Improved availability of this geospatial foundation data leads to opportunities for better government, more transparency, effective urban planning, improved resilience, increased resource/asset and environmental management, and new business opportunities. But little investment is being made into national geospatial capabilities, the arguments still need to be won.

What are the challenges? (1) Cost, but innovative approached can reduce this, far more important in the first instance is demonstrating 'value'. (2) People, who at all levels need to understand why geospatial makes a difference and how to use it. (3) Policy, primarily a willingness to share data in a manner that allows others to consume it. (4) A market ready and willing to use it and lastly, (5) winning the political and financial investment arguments. With these, investment can pay dividends.

Data as national infrastructure

The Organisation for Economic Cooperation and Development (OECD) considered in 2015:

'Data are an infrastructural resource – a form of capital that cannot be depleted and that can be used for a theoretically unlimited range of purposes.'

OECD likened it to roads and bridges that support a wide range of national and local uses from healthcare to profitable business, some unanticipated. The cost of such infrastructure is significant and the benefits are so widespread that no one use case can justify the investment on its own. Funding an underpinning, cross-cutting, data infrastructure therefore needs to be considered centrally. This is demonstrated for geospatial data in Figure 2.

The OECD continued:

'Physical infrastructure such as roads and bridges enables benefits to 'spill over', for instance, by fostering trade and social exchanges. In the same way, greater access to data also has beneficial spill-overs, whereby data can be used and re-used to open up significant growth opportunities, or to generate benefits across society in ways that could not be foreseen when the data were created. But some of the spill-overs of data cannot be easily observed or quantified.... As a result, countries – and governments in particular – risk under-investing in data and data analytics and may end up giving access to data for a narrower range of uses than socially optimal. This risks undermining countries' capacity to innovate…'

So, whilst the direct benefits of an infrastructure might be observable and measurable, and contribute to a business case, the spill-over benefits are not. The relative invisibility of these can lead Government to under-prioritise funding for the infrastructure. A paradigm shift is required: from government-funded data collection for its own purposes, to funding the facilitation of an ecosystem around an infrastructure.

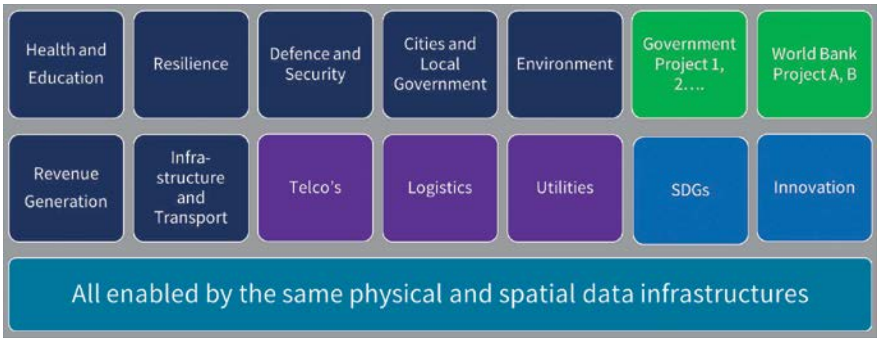

Figure 2: Infrastructure, whether physical or data, enables most government department and local authorities, businesses, projects and ultimately growth through innovation.

The future NMGA will contribute to the step changes necessary and, as a key enabler, adapt or transform internally and externally. The remaining sections consider this change and how national mapping and geospatial agencies can remain core to the delivery of sustainable development going forward.

Leadership, policy and governance

It is a truism that, without the drive of leadership, achieving the benefits of geospatial information at national scale is not possible. Experience shows that identifying and incubating those political and business leaders is important. With leadership then governance can follow in a 'coalition of the willing'. This then leads to policies that have 'buy in'. Others will follow.

Nations do have geospatial information and many different government departments, agencies and businesses are collecting or procuring similar data for similar purposes. Bringing focus to 'make once, use many' as a policy driver is efficient and effective. It covers a sharing (including open data) but also clarity on who produces what data and services. Engendering the sharing of existing data is essential, not only will it improve efficiency but suppliers will seek to improve the data.

A singular NMGA collecting, managing and serving all fundamental geospatial data will be swamped in requirements. NMGAs have a developing role as a broker of trusted data for use by both government and the citizen. Policy should reflect this.

Policy needs to consider data priorities. Whilst the UN is developing the concept of 'fundamental national geospatial data', nations need to adapt this to their stakeholder needs – for example a nation may decide it's data should support national priorities in sustainability of natural resources, green energy, health, agriculture, pollution abatement and resilience and prioritise creation and maintenance accordingly. Focusing on how geospatial solves problems, rather than the data itself, will serve NMGAs well. The paper demonstrates this need to focus more on the user and their requirements to deliver real value.

Volunteered Geographical Information and Citizen Science are creating ecosystems such as Open Street Map. Crowdsourcing requires different thinking about quality but has a valuable place in a nation. Likewise EO and other new collection techniques bring more data into the mix. Policy can address these; trust levels are dependent upon use; land tenure and GPS navigation require two different levels in data trust.

Cost

Communication is essential to winning funding. Ask a layman 'should we invest in a 'national spatial data infrastructure' or three new hospitals and it is obvious what they will answer. We instil an element of separation through the term 'Spatial' where we should be shielding the complexity from the user.

To acknowledge the value geospatial data presents, it needs to be regarded as infrastructure; an infrastructure that is reliable, economic, accurate and trusted, which comes with an investment. Justifying that investment ultimately requires an understanding of the direct and indirect benefits, government revenue generation and economic value.

The UK Government's Chief scientific advisor expressed the problem bluntly: Maps matter – It's not enough to know they are important but WHY they are important. The local appropriation of simple, practical and tangible use cases is therefore essential - a universal approach is neither desired nor appropriate, with cultural and infrastructural variations as crucial considerations. Understanding the political drivers of a government offers the opportunity to approach geospatial matters in an accessible way, presenting the relevance of NMGAs in advancing towards sustainable development. In Jamaica, factors contributing to susceptibility to hazards include a lack of adherence to building codes and development in high risk areas. Reliable and timely geospatial information linked to data from other government agencies is helping reduce disaster risk and save lives.

But the other side of 'cost' is the need, on an international scale, to deliver Geospatial Information and Services quicker, cheaper and to a wider range of technological platforms and people. Solutions should be sustainable, and that requires partnership and collaboration over many years; we are developing a NMGA and national approach to geospatial. New solutions, such as cloud based managed services and greater use of cheap, accurate remote sensing coupled with automated feature extraction, will enable nations to remove risk and increase resilience whilst remaining in control and building internal capacity. And such solutions require a different financial model, perhaps more attractive to nations.

People

People drive change, and not just at the leadership level. The stairs of benefits realisation demand changes in culture, competence and attitudes, and they should be taken one step at a time. This particularly applies to NMGAs, where individuals that do change are often quick to depart, resulting a skills drain that governments find difficult to resolve.

A major challenge facing future governments is the lack of skilled manpower to develop and implement emerging technologies of all types. The involvement with capacity-building projects is crucial for a successful future, the long-term partnership approach. Partnering with academia is frequent, but how often do NMGAs have similar partnerships with business, the engine of growth?

Fundamental geospatial data

Spatial data infrastructure is a means to an end; many nations do not have formal spatial data infrastructures yet do have the components. The bedrock of a spatial data infrastructure is sharing data. A physical infrastructure on which to do this is a real advantage, but overcoming behavioural reluctance to share is often the real challenge, and any form of sharing can bring benefit. Geospatial data exists in all nations, NMGAs can help national agendas by leading the way on sharing existing data widely.

Development programmes funded by development banks and national aid can also set an example by insisting that all collected geospatial data, from imagery to cadastre, is shared. Provision of a small uplift in capability at a NMGA, as well as the data itself, can assist.

National institutions should manage fundamental geospatial data layers, many of which are the responsibility of NMGAs. Step changes are necessary.

- NMGAs should focus more on the user and their requirements over the next 10 years and develop priorities, data and services that meet customer needs. Data must be fit for purpose, and that purpose is evolving. The trend is towards increasing accuracy, frequent update, metadata and attribution, greater access and open standards.
- Stakeholder engagement is vital, and clear means of maximising benefits from limited resources, i.e. making choices, is required. In the 2017 Autumn Budget, the UK announced a Geospatial Commission that aims to derive greater benefit of geospatial data to the nation.
- To deliver real value data and services must remain trustworthy and in many use cases that data will have to be both trusted and authoritative data – cadastral or addressing data for example.
- At national level, and thus particularly in pursuit of SDGs, national coverage is important although data specifications might vary between urban and rural as do the use cases. SDGs also point to maintained data; not least because measurement

of change is not possible if the very data has not changed.

The role of NMGAs can and will adapt.

- Nations will want to capitalise on all geospatial data and services, but which do they trust, which are fit for purpose? NMGAs may therefore become data brokers as well as collectors/managers. In so doing they can provide a level of assurance to users and add value through feature extraction, generalisation and integration services
- In becoming data brokers NMGAs will also become service consumers. Is it necessary to own assets to collect, manage and serve data? The answers may well be 'yes', but consuming a service for some components might be cost effective, meet capability gaps and reduce capital risk. The role of open data in a national infrastructure should also be considered.
- The NMGA may also become the spatial data infrastructure authority. There are strengths in this but also weaknesses. SDI is a pan-Government activity and a NMGA is really a data and service provider. If a NMGA has not been seen to share its data and services willingly, it may not have the credibility to lead SDI.
- Service provision is likely to feature increasingly, from smart phone apps to asset management.

Creating data is one side of a coin. The other side is use, often through integration to make effective decisions. This integration is the key to improved decisions and socio-economic benefits. In wider government, NMGAs can assist in integrating cross-government digital public services, helping realise their value in delivering SDGs. It is no longer enough to produce data and services; NMGAs need to be close to their customers and work to understand and solve their problems. There are several components to this:

- Education and Training.
  - Educating decision makers, at all levels, in the benefits they can gain from geospatial capabilities, is a challenge. NMGAs need to be close to these stakeholders, seek to help solve their problems and then use these leaders as champions.
  - Increasingly populations are using geospatial data without realising it – Uber and Google being obvious examples. Some education systems are recognising that there is an education component, using geospatial tools to help with school and University projects for example, and in some countries, national curricula mandate this.
  - Training NMGA staff, data scientists, database managers, cyber security professionals, GIS operators etc. takes time and is expensive. Such individuals can be in short supply, and governments often lose such experienced professionals to the private sector. This is a real problem in low and middle income nations and can hold back NMGA development. It is another reason where alternatives, such as partnership with private sector for aspects of delivery may be beneficial. NMGAs can work with professional associations and Ministries of Education to promote the need for a suitable education pipeline.
  - Integration through address, or place, is a key means of analysis and understanding – turning data into a picture. But a geospatial data is only one element of the data environment and geospatial representation is only one outcome - graphics, tables, answers to questions are equally relevant. Our education and training of geospatial 'users' must take this into account.
  - NMGAs can help users gain more value through running cross-cutting workshops and masterclasses, both for government and business users, aimed at helping customers gain more value from geospatial data. Some of these could focus on particular SDGs and bring relevant ministries and businesses together.
- Organisation. NMGAs that stay close to their stakeholders are likely to best understand their needs. As 'underpinning' and 'cross-cutting' data, stakeholder and customer groups provide the two-way communication that NMGAs need, and also the exchange of wider geospatial data between ministries. This is particularly relevant for ministries charged with delivering SDGs and statistics bureaus. NMGAs can help promote wider use of geospatial data in solving problems in this context, in turn increasing demand.
- Innovation. Businesses grow economies and create jobs. Helping grow new geospatial businesses is therefore in the interests of governments and their NMGAs. Two UK examples have wider relevance, 'geovation challenges' and a geospatial innovation incubator, the Geovation Hub. The latter is led by Ordnance Survey, supported by HM Land Registry and a number of other 'big' businesses and the Open Geospatial Consortium. It provides a real opportunity for entrepreneurs to develop ideas and then, if they have real value, and provides assistance in finding funding, including venture capital.

Winning the arguments

To be relevant, NMGAs and their partners have to be the 'go to' authorities for trusted fundamental geospatial data. But many NMGAs are significantly under-invested for today's data challenge, and so arguments need to be built that open doors to investment, whether capital, operational or human.

There is, however, a shortfall in data available to convince decision makers. The benefits demonstrated in this paper, and many others, only serve to 'whet the appetite'. Hard financial arguments are necessary, the 'business case' needs to include a 'return on investment' that shows demonstrable economic benefit, revenue benefit to government and the wider social benefits that are often difficult to place a dollar value upon.

Benefit studies of geospatial enablement are largely of high-income nations, and tend to indicate 0.2% to 0.6% GDP uplift. There are very few studies of low and middle income nations. One exception is Albania, where work to understand the financial benefits of an SDI was reported at the World Bank Conference on Land and Poverty in 2017 (Anand, A et al).

Recognising this, the UN and World Bank initiative to generate a global 'best practice' framework and a series of country 'action plans' is to be welcomed. These action plans set out the road map for change and seek to convince Finance Ministers that proposals are based on good practice and contain the necessary social and economic benefits necessary for decision making.

Transforming a mapping agency into an effective geospatial agency is a long-term programme, yet results will be expected immediately if SDG implementation is to be enabled by NMGAs. There are different approaches that can be combined in different forms to achieve this, different approaches that can strengthen or weaken a business case:

- a long-term 'in-house' capacity building approach, which may take a decade or longer to achieve, particularly developing the human capacity to meet technical capability.
- a technology solution through a project approach, with inherent project delivery and sustainability risks.
- a data collection and services project to provide useable data and services 'once off'.
- A managed service that provides different components of capability, long term in partnership. This can bring 'data today', provide proven technology as a service and capacity building for tomorrow.

Transformation takes time and partnership with 'transformed' NMGAs can help with achieving sustainable solutions. The NMGAs may choose a managed services partner to help build initial GI data, so the nation benefits quickly whilst sustainable transformation is implemented.

Conclusion

The paper argues that NMGAs do have a future if they adapt. The increasing reliance on location, from delivery of SDGs to the internet of things, is an opportunity. Managing the fundamental geospatial data layer, fit for purpose, maintained and trusted, underpins the integration of all spatial data and allows better decisions and efficient delivery and operations. Future NMGAs may become data brokers as well as collectors/managers, SDI authorities, service providers and service consumers. Whatever, NMGAs have to be the 'go to' authority for trusted fundamental geospatial data.

NMGAs need to focus more on the user and their requirements over the next 10 years to deliver real value and their data must remain authoritative, trustworthy and accessible. In wider government, NMGAs can assist in integrating cross-government digital public services, helping realise their value in delivering SDGs. It is not enough to produce data; NMGAs need to be close to their customers and work to understand and solve their problems.

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United Nations Argentina workshop on the applications of GNSS

As part of the United Nations Programme on Space Applications, a United Nations/Argentina workshop on the applications of global navigation satellite systems was organized by the Office for Outer Space Affairs in cooperation with the National Commission for Space Activities (Comision Nacional de Actividades Espaciales, CONAE) of Argentina. The Workshop was held at the Centro Espacial Teofilo Tabanera, a facility of CONAE, in Falda del Carmen, Argentina, from 19 to 23 March 2018. It was co-sponsored by the European Union and the United States of America through ICG. The European Space Agency (ESA) is also co-sponsored the workshop.

At the opening of the workshop, introductory and welcoming statements were made by the Secretary General of CONAE and by the representatives of ICG and ESA as co-sponsors, and by the representative of the Office for Outer Space Affairs.

The Deputy Technical and Administrative Director of CONAE delivered the keynote presentation focusing on CONAE's actions and projects that were developed in accordance with the national space programme, materialized through Earth observation, exploration and peaceful uses of outer space, and technological developments for space use, which was periodically updated and extended to ensure that it suits the socioeconomic and productive requirements of the country.

The workshop technical sessions promoted productive discussions among participants, and covered a wide range of topics related to GNSS technology: (1) overview of GNSS in operation and development; (2) GNSS reference frames and reference station networks; (3) implementation of GNSS technology; (4) GNSS applications; (5) space weather; (6) capacity-building, education and training in the field of GNSS; (7) international and regional experiences of the use and implementation of GNSS technologies; and (8) national GNSS programmes.

During the workshop, a one day and half seminar on "GNSS spectrum protection and interference detection and mitigation" was organized. The purpose of the seminar was to highlight the importance of GNSS spectrum protection at the national level and explain how to reap the benefits of GNSS. Specific presentations that demonstrated GNSS jamming and spoofing were carried out.

Additionally two discussions sessions were held, where participants were split in three working groups to exchange views on: (1) capacity-building and institutional strengthening; (2) geodetic reference network; (3) specific GNSS applications. The discussion sessions were preceded by a presentation on the publication entitled "European Global Navigation Satellite System and Copernicus: Supporting the Sustainable Development Goals" (ST/SPACE/71) that was jointly prepared by the Office for Outer Space Affairs and the European GNSS Agency (GSA).

The programme was developed by the Office for Outer Space Affairs and CONAE in cooperation with ICG and ESA.

The presentations made at the workshop, abstracts of the papers given and the workshop programme and background materials are available on the website of the Office for Outer Space Affairs at: http://www.unoosa.org/oosa/en/ourwork/psa/schedule/ 2018/2018-workshop-on-global-navigation-satellite-systems_-presentations.html. The following 22 Member States were represented at the workshop: Argentina, Brazil, China, Colombia, Croatia, Ecuador, Egypt, France, Italy, Japan, Latvia, Mexico, Morocco, Panama, Paraguay, Peru, Russian Federation, Spain, Thailand, Turkey, the United States of America and Venezuela. The European Union and the European Space Agency were also represented. Representatives of the Office for Outer Space Affairs also participated.

Observations

The workshop addressed the use of GNSS for various applications that provide sustainable social and economic benefits, in particular for developing countries. Current and planned projects that use GNSS technology for both practical applications and scientific explorations were presented.

Two discussion sessions were held as part of the workshop. During the first, three working groups met in parallel to discuss the following themes: (1) capacity building and institutional strengthening; (2) geodetic reference network; and (3) GNSS applications. During the second, the groups presented the results of their deliberations and formulated a common plan of action for the region. The participants put forward a number of observations and recommendations, which are summarized below:

Capacity-building and institutional strengthening

The working group on capacity building and institutional strengthening held discussions in GNSS education and training, as well as on the appropriate format for a regional network that would enable the creation of partnerships in the use of GNSS and related applications, including space weather and its effects on GNSS operations.

The working group recognized the need to continue building national and regional expertise through the long and short-term training courses and education offered by the regional centre for space science and technology education for Latin America and the Caribbean, affiliated to the United Nations, and also through other academic and thematic centres of excellence worldwide.

Geodetic reference network

The working group on geodetic reference network held discussions on geodetic reference frames, noting the United Nations resolution on a global geodetic reference frame (GGRF) for sustainable development adopted by the General Assembly on 26 February 2015 (A/RES/69/266). The working group recognized:

(a) The importance of GGRF for developing and improving the global spatial infrastructure (GSDI) in support of sustainable development goals of the 2030 Agenda for sustainable development;

(b) The effort committed by the Latin America and the Caribbean countries for deploying, maintaining and continuously improving their GNSS networks for the GGRF realization at national level;

(c) The success achieved by SIRGAS in coordinating the operation of the GNSS networks at regional level, and in processing the GNSS data to provide the community with a GNSS-based regional realization of the GGRF;

(d) The existence in Latin America and the Caribbean of other observing infrastructures that could enhance the current GNSS-based GGRF regional realization, namely:

i. Satellite Laser Ranging (SLR) stations in Arequipa, Peru (in partnership between Peru and the United States of America), in San Juan, Argentina (in partnership between Argentina and China) and Brasilia, Brazil (in partnership between Brazil and the Russian Federation); and a very-long-baseline interferometry (VLBI) station in Fortaleza, Brazil (in partnership between Brazil and the United States of America);

ii. the Argentina - German Geodetic Observatory that co-located SLR, VLBI and GNSS;

(e) The need of deepen the geodetic knowledge installed in the region to reach the highest international standards related to GGRF realization.

The working group recommended to develop a capacity building activity (with the assistance of international experts in the subject matter) to process and analyse SLR and VLBI data in combination with GNSS data and that this activity would be carried out at regional level in order to maximize the participation of representatives from the Latin America and the Caribbean countries.

Based on the above mentioned considerations and recognizing that in spite of the progress achieved in the region, either in the availability of GNSS observing stations as well as in the data analysis capabilities, the need for geodetic training at a more basic level than stated in the previous recommendation still persists in several countries of the region.

Considering the above stated, the working groups recommended:

(a) To implement capacity-building through training courses designated to space agencies especially geared towards the best use of georeferencing in the production of spatial information (for example, images, statistics, etc.), highlighting the infrastructure available in the region;

(b) To provide assistance for the acquisition, deployment and operation of GNSS networks in countries that still lack them or need to improve them;

(c) To provide assistance for the installation of the vertical component of the GGRF;

(d) To implement an outreach programme to promote the use of the SIRGAS observational infrastructure for applications complementary to the GGRF realization, for example, space weather, water vapour monitoring, augmented navigation assessment (space-based augmentation systems (SBAS) or ground-based augmentation systems), image processing;

(e) To encourage all geodesic data producing agencies to implement open access policies for their data.

The working group also recommended to prepare a proposal for a pilot project aiming to augment the existing GNSS networks in order to transmit real time differential corrections for multi-purpose applications

GNSS applications

The working group on GNSS applications structured the discussion at three different levels: scientific and technical, organizational, and specific applications. Synergies between the different levels were also considered.

At scientific and technical level, it was recommended:

(a) To consider the incorporation of multiple constellations into SBAS, which might have an impact across different services, in particular, civil aviation, and benefits to other sectors;

(b) To consider increasing the number of an international satellite-based search and rescue (COSPAS-SARSAT) stations for search and rescue applications;

(c) To organize a workshop on disaster management using the enhanced capabilities of GNSS, COSPAS-SARSAT, and earth observation.

At organizational level, it was recommended to create an inventory of equipment, applications and services, and capacity-building opportunities that were available in the region. This inventory could be used to enhance the communication between institutions in the region.

The complete report can be seen at www.unoosa.org/oosa/en/ourwork/psa/schedule/2018/GNSS-un-argentina-workshop.html

Airborne LiDAR to be used to survey electricity network in Queensland

Powerlink will use aerial surveying technology to undertake an engineering assessment of their Northern and Central transmission network. Working with NM Group, the project will use helicopter laser (LiDAR) scanning to identify maintenance issues and update records on over 3000 km of powerline.

Provided by NM Group, the updated drawings will enable Powerlink to plan improvement work, manage vegetation risk and help plan future powerlines. In addition, it will also assist with engineering designs.*www.powerlink.com.au*

Technical cooperation MoU between India and Netherlands extended

The Union Cabinet of India chaired by Prime Minister Shri Narendra Modi was apprised of the Memorandum of Understanding (MoU) signed between India and Netherlands on technical cooperation. The objectives of this MoU are to promote and strengthen the collaboration between the signatories in the areas of Spatial Planning, Water Management and Mobility Management on the basis of equivalence, affordable housing, smart city development, GIS for water supply & sewerage system, waste water reuse and recycle, conservation of fresh water by artificial recharge of aquifer, integrated solid waste management and heritage conservation and mutual benefit, taking into account the practical needs of both the countries.

Under this MoU, a Joint Working Group (JWG) will be set up to strategize and implement programmes on cooperation under the framework of the MoU. The Joint Working Group will meet once in a year, alternately in the Netherlands and in India. *http://pib.nic.in*

Isro's Antrix signs MoU with SatSure for promoting geospatial technology

SatSure Analytics, a satellite data analytics company, has signed a strategic Memorandum of Understanding (MoU) with Antrix Corporation, the commercial arm of the Indian Space Research Organisation (Isro), for furthering geospatial big data analytics.

The MoU would increase the penetration of geospatial technology-based services and develop large area analytics products in different sectors like agriculture, banking and financial services, social infrastructure, energy and telecommunications. *www.business-standard.com*

Pix4D launches Pix4D fields

Pix4D's first fully dedicated product for agriculture – Pix4Dfields: created with the input of farmers, agronomists and breeders is now live.

This product is developed with input from farmers, agronomists and breeders, meaning it focuses on what matters when it comes to agriculture fields of application.

The built-in analysis tools allow you to produce accurate and repeatable measurements of crop health.

Russia launches Glonass-M navigation satellite

Russia has launched a Soyuz-2.1b carrier rocket from the Plesetsk space center to orbit a Glonass-M satellite, the Russian Defense Ministry said.

"The middle-class Soyuz-2.1b carrier rocket launched on June 17 from the Plesetsk space center (Arkhangelsk Region) successfully put the Russian navigation Glonass-M spacecraft to the designated orbit." Earlier, a satellite producer Reshetnev Information Satellite Systems reported that the signal interface control document for GLONASS would be updated in 2018, making radio signals to the satellite navigation system less susceptible to corruption.

Next european satellite navigation competition is sure to deliver innovation

Who knows what's in store for this year's 15th edition of the European Satellite Navigation Competition (ESNC), which is currently scouting for new business ideas through July 31, 2018. The innovation competition annually awards the best services, products, and business ideas using satellite navigation in everyday life.

Since 2004 the competition has been proving that satellite navigation technologies open the door to countless applications. The international innovation competition is designed to serve as an accelerating instrument for space related entrepreneurs and startups, providing Europe with path breaking novelties. The spectrum of submitted business ideas reflects the manifold opportunities made possible by this future oriented technology: from healthcare and leisure to traffic management and other rail, sea, and air transport logistics, individuals and entire industries alike can benefit from satellite navigation.

No matter what stage a pioneering idea is at, the ESNC provides support for innovative ideas at each development stage, with the ultimate aim to turn them into real business cases. Thus, the diversity offered by the ESNC and its entire network are best described as "service all along the value chain".

China's plans to upgrade its Beidou navigation satellite system

By 2020, the Beidou satellites will form a complete global satellite navigation system, with 35 satellites.

Recently, it was announced that China would launch another eleven satellites in 2018 to add to its third-generation Beidou Navigation Satellite System (BDS).

Launched in 1994, the Beidou project began to serve China in 2000. Since 2000, 33 satellites have been launched for the network. Beidou began serving users in the Asia-Pacific region in December 2012. It is the world's fourth navigation satellite system, following GPS in the United States, GLONASS in Russia and Galileo in the European Union.

Compared to earlier generation satellites, the Beidou-3 is able to send signals that are more compatible with other satellite navigation systems and provide satellite-based augmentation, as well as search and rescue services in accordance with international standards. Its positioning accuracy has reached 2.5 to 5 meters.

In 2019 and 2020, China will send six third-generation Beidou satellites into medium Earth orbits, as well as three to inclined geosynchronous satellite orbits and two to geostationary orbits.*www.opengovasia.com*

Chinese first OTTC for ERA-GLONASS equipped vehicle is certified

Bureau Veritas has announced that Bureau Veritas VEO, a Bureau Veritas Group company, has successfully facilitated the first OTTC Certificate issuance in China for an ERA-GLONASS enabled vehicle with its localized solution in China.

OTTC is the certificate to vehicles exported to Eurasian Economic Commission (EEC) member states. ERA-GLONASS, an automatic emergency call system, provides rapid assistance via emergency cellular service and reduces casualties in the event of an accident. ERA-GLONASS has been compulsory since 1 January, 2017 and is now an integral part of OTTC which requires In Vehicle Systems (IVS) within the EEC member states to be equipped with ERA-GLONASS.

As an intelligent telematics-based system, deployment of ERA-GLONASS is also an impetus to the Connected Vehicle. The EEC has brought ERA-GLONASS certification into the legislation of OTTC to pave way for the continued realization of this project. *http://en.portnews.ru/news/259526/*

DARPA pursuing global positioning system alternatives

The Defense Advanced Research Projects Agency is looking to develop alternative positioning, navigation and timing capabilities.

Dave Tremper, a program manager at the agency's strategic technology office, said relying solely on GPS provides users with a single point of failure.

"GPS is so good that it's kind of knocked all of the other players off the field," he said. "What happens when it's not there and what happens when your system still needs that degree of timing and you still need that degree of position? … We're going back and scrubbing systems and saying, 'We need to really think about having that redundancy to GPS.'"

One of the agency's projects is the Spatial, Temporal and Orientation Information in Contested Environments program, he said. The effort, known as STOIC, is focused on developing a GPS backup, Tremper noted.

Part of the STOIC project leverages information gathered from a former program called Adaptable Navigation Systems, he said, which examined different types of signals for positioning, navigation and timing. One of these signal types included very low frequency transmissions, he said. These signals allowed for gathering location information that was about one to two kilometers off because it did not account for changes in the ionosphere, which is a layer of the atmosphere that can reflect and modify radio waves, he noted.

DARPA is examining low-frequency commercial receivers that can be used for military platforms. The antennas for the project are small enough to be used on ships and vehicles, he added. *www.nationaldefensemagazine.org*

FAA now has better, more precise GPS coverage across US

The Federal Aviation Administration's Geosynchronous Earth Orbiting 5 Wide Area Augmentation System navigation payload, developed by Raytheon's Intelligence, Information and Services business, is now operational and fully integrated into the WAAS network. The GEO 5 payload joins two others already on orbit in correcting GPS satellite signal ionospheric disturbances, timing issues, and minor orbit adjustments, giving users increased coverage, improved accuracy, and better reliability.

In operation since 2003, WAAS increases GPS satellite signal accuracy from 10 meters to 1 meter, ensuring GPS signals meet rigorous air navigation performance and safety requirements for all classes of aircraft in all phases of flight.

WAAS provides precision navigation service to users across the United States from Maine to Alaska, as well as portions of Canada and Mexico. For aviation users, WAAS offers pilots more direct flight paths, precision airport approaches and access to remote landing sites without depending on local ground-based landing systems. *www.raytheon.com*

EGNOS geostationary navigation payload services

The European GNSS Agency (GSA) has issued a Request for Information (RFI) in preparation for the procurement of EGNOS geostationary navigation payload services: GEO-4 and GEO-5.

The EGNOS space segment is provided by commercial satellite operators on the basis of service contracts. The GEO-1, GEO-2 and GEO-3 service contracts currently cover the EGNOS space segment needs and the GEO-1 and GEO-2 services will be the first of these to end. These will be replaced by GEO-4 and GEO-5 – the subject of this RFI.

The GSA is already planning how it will replace the services currently delivered by the GEO-1 and GEO-2 satellites. Ahead of this procurement, the Agency is conducting a preliminary market analysis and issuing an RFI to collect information about opportunities to embark navigation payloads on-board GEO satellites launched in a suitable timeframe.

Galileo to receive Orolia atomic clocks

Orolia has been awarded contracts totalling USD30.6 million to provide atomic clocks for the Galileo Global Navigation Satellite System (GNSS).

Under these contracts, Orolia will supply its Spectratime Rubidium Atomic Frequency Standard and its passive hydrogen maser physics package for an additional 12 Galileo satellites. Each satellite will carry two rubidium atomic clocks and two passive hydrogen masers.

SES gets Galileo services contract

Luxembourg satellite operator SES has landed a contract to help run Galileo.

The contract is with Spaceopal, the German firm that operates the Galileo satellite fleet under contract with the EU, SES said in a press release on 30 May:

"SES will provide Spaceopal with services to support the maintenance and seamless operations of the Galileo Global Navigation Satellite System (GNSS). SES will be responsible for in-orbit measurements for the Galileo satellite constellation".

In addition, the Luxembourg firm will provide services for connecting Galileo ground stations. *http://delano.lu*

Japan looks to launch driverless car system in Tokyo by 2020

A self-driving car service could be on Tokyo's public roads in time for the 2020 Olympics as Japan looks to drive investment in new technology to drive economic growth, according to a government strategic review announced. The government plans to begin testing a driverless car system on public roads sometime this fiscal year with the goal of launching a self-driving car service for the 2020 Tokyo Olympics. The government will then try to commercialize this system as early as 2022.

Economists see enormous potential in the development of autonomous vehicle and artificial intelligence technologies, which could help businesses cope with an aging and declining workforce. However, Japanese companies have struggled to keep up with their Chinese, European and U.S. counterparts in implementing such innovations into their work practices. The government also plans to change regulations for universities to make it easier for students to earn multi-disciplinary degrees needed to work in artificial intelligence. *www.reuters.com*

World's first dual-frequency GNSS smartphone hits the market

Xiaomi - one of the fastest growing mobile brands - has launched the world's first dual-frequency GNSS smartphone. Fitted with a Broadcom BCM47755 chip, the Xiaomi Mi 8, launched on May 31, is the world's first smartphone providing up to decimetre-level accuracy for location-based services and vehicle navigation.

This smartphone is the first commercial deployment of Broadcom's revolutionary BCM47755 chip. Until now, mobile location-based applications have been powered by single frequency GNSS receivers whose location accuracy is limited to a few meters. However, in recent years GNSS systems have been launching satellites broadcasting signals on new frequencies to open up new possibilities. Specifically, Galileo has the majority of satellites with E1/L1 and E5/L5 frequency capabilities.

EU-wide rules for safety of drones approved

MEPs approved an agreement reached between Council and Parliament negotiators in November 2017 on EU-wide principles for drones and drone operators to ensure a common level of safety and give operators and manufacturers the predictability to develop products and services. Currently most drones fall under differing national rules, which can hamper market development.

Under new rules, drones would need to be designed so that they can be operated without putting people at risk. Based on risk related to, for example, the weight of the drone or area of operation, the drone would need additional features, such as automated landing in case the operator loses contact with the drone or collision avoidance systems. Some drone operators would be required to go through training before they can operate a drone.

To help identify the drone operators if there is an incident, operators of drones would need to be on national registers and their drones marked for identification. This would not apply to operators of the smallest drones.

Based on the key principles, the EU Commission is tasked with developing more detailed EU-wide rules, such as maximum altitude and distance limits for drone flight, and which drone operations and drones would need to be certified based on the risk they pose. The rules would also determine which operators need additional training and to be registered and which drones would need to have additional safety features.

Currently, drones lighter than 150kg fall under the jurisdiction of national authorities and therefore manufacturers and operators are subject to different design and safety requirements.

Civil drone technology could account for an estimated 10% of the EU aviation market within the next 10 years (i.e. about €15 billion per year). According to the Commission, the drone industry could create some 150,000 jobs in the EU by 2050. *www.europarl.europa.eu*

Cansel becomes the first Canadian reseller of Delair

Delair, a leading global supplier of commercial drone solutions, has announced an agreement with Cansel, a full-service provider of surveying and mapping solutions to the Canadian market. Cansel becomes the first Canadian reseller of Delair UX 11 long-range drone.

Leica's Aibot UAV is built on the DJI platform

Leica Geosystems has announced its latest UAV, the Leica Aibot. The UAV is a multi-rotor airframe based on DJI's aerial platform, the M600 Pro, and is designed for fast acquisition of 3D mapping data.

The solution is fully integrated with Leica Geosystems' current suite of software solutions, including Cyclone and Cloudworx. Users can now leverage Leica Infinity for point cloud, surface model, and orthophoto generation for current workflows in construction and surveying.

Brazilian farmers use drone mapping

SimActive and Brazil's Portal Produtos Agropecuários (Portal) are working together with local farmers to provide them with as much functional data regarding their farmland as possible, so that these businesses can maximize profits and increase seasonal yields. For Portal, that means creating aerial mapping of farmland. This is then turned over to SimActive who can, through its Correlator3D software, process those maps into detailed, informative data. This process allows a farm's crop management to be strategized more efficiently. *www.thedrive.com*

Detection of unauthorised sand mining using drones

The Gurugram forest department, India has completed the drone mapping of two villages in the first phase to check encroachment or illegal activities in the Aravallis.

During the mapping process a team of forest, wildlife and technical officials, detected illegal sand mining in Sakatpur and Tikli villages.

Trucks, laden with sand, were spotted leaving these villages, a forest official said. Before the mapping teams could get hold of the sand miners, they drove away, the official added.

"The mining surveillance system enables us to get a satellite view of quarrying sites and any illegal activity taking place in the Aravallis." Vinod Kumar, additional principal chief conservator of forest, Gurugram, said. *www.hindustantimes.com*

Insitu Receives Interior contract award for small UAS services

Insitu, a wholly-owned subsidiary of The Boeing Company has received a first-of-its kind contract from the U.S. Department of the Interior (DOI) to provide fire suppression services within the contiguous 48 states and Alaska using its ScanEagle Unmanned Aircraft System (UAS).

UAS will assist in combatting wildfires using geospatial mapping and full motion video.

Per the contract, Insitu will support manned aerial operations including fire suppression, search and rescue, emergency management, and other operations as needed on a "call when needed" basis. *insitu.com*

Firestorm UAV sole supplier of TigerStrike lite

Firestorm UAV Inc. has announced its position as the sole supplier of an innovative handheld search and rescue sensor intended for all types of field-rescue operations. The mobile TigerStrike Lite hardware pairs with Firestorm's unique iRDF™ technology to position the company as the foremost expert and manufacturer of mobile ISR search and rescue signal readers.

The TigerStrike Lite mobile device reads three different types of distress signals: personal locator beacons (PLBs), emergency locator transmitters (ELTs) and the emergency position indicating radio beacons (EPIRBs) used in maritime applications. To find a signal's location, the TigerStrike Lite device simply takes a single vector reading from two fixed locations. Generally this is all that is required to pinpoint a signal to within an accuracy of five degrees. The signal's location can then be sent via an Android-based smartphone to the operational base of choice. *www.fsuav.com*

REIN's DroneInsurance.com launches insurance portal

REIN, an insurtech company focused on creating new insurance solutions around the emerging risks posed by robotics, mobility and online ecosystems, is announcing the launch of its first digital portal, DroneInsurance.com. It provides a smart and paperless drone insurance experience, offering dynamic policy solutions to address the unique risks, pain points and insurance needs of commercial drone operators.

DJI announces drone law enforcement partnership with Axon

DJI has announced a new collaboration with Axon, a provider of connected law enforcement technologies.Under the partnership, DJI drones will be sold directly to public safety and law enforcement agencies worldwide through the new Axon Air program.

vHive releases AI-based automatic workflow

vHive, the developer of cloud-based AI that enables enterprises to deploy autonomous drone hives for the acquisition, management and processing of field data, has announced the availability of a fully automated workflow for high-accuracy data products. vHive currently provides solutions to companies in a variety of industries ranging from telecom towers, to rail, bridges and civil engineering. In many cases vHive customers require high accuracy data products, including high relative-accuracy (intrinsic to a map or model) and absolute-accuracy (geographic location). *www.vHive.ai*

Next-generation mapping drone raises capital for further expansion

Drone startup Atmos UAV has closed it's next investment round with investment firm Disruptive Technology Ventures (DTV). Atmos has developed an industrial drone that is a clever crossover between an airplane and a helicopter. The drone can already be found flying all over the world to help professionals in mapping large areas of land. The series A of undisclosed amount enables the startup to further scale up their distribution, product development and support organisation. DTV, the fund of amongst others Ad Scheepbouwer (former CEO of TNT) and the founders of cybersecurity leader Fox-IT (Ronald Prins & Menno van der Marel) will support Atmos by fuelling growth and international roll-out.

Airbus to provide an end-to-end Geo-Information system to Thailand

The Geo-Informatics and Space Technology Development Agency of Thailand (GISTDA) has selected Airbus as partner for its next-generation national geo-information system. The end-to-end system will make Thailand one of the few nations able to fully exploit geo-information for societal benefits. Fully in line with Thailand's 4.0 policy, the THEOS-2 programme will constitute a major milestone in the development of Space in the Eastern Economic Corridor and its Digital Park.

As part of the contract, a comprehensive capacity building programme will involve Thai engineers in the development of an integrated geo-information system, ground segment and two Earth observation satellites: a very high-resolution and a small satellite system. The small satellite system from Airbus' subsidiary SSTL will be assembled and tested in-country by Thai engineers to deliver technology transfer and involve local suppliers. This will be complemented by an extensive training scheme capitalizing on Airbus' comprehensive geo-intelligence expertise, and will further develop Thailand's geo-spatial industry.

EarthSense air quality sensors activate zero emission running to reduce city air pollution

Air quality monitoring technology from EarthSense has provided real time data for trials into the use of low emission vehicles to improve air quality in polluted city centres. The data, collected by both mobile and static EarthSense Zephyr air quality monitoring sensors, was used to automatically activate zero-emission running of hybrid vehicles as they passed through some of the most heavily polluted city streets.

ACCRA (Autonomous and Connected vehicles for CleanerR Air) was a twelve month project, led by Cenex, the UKs first Centre of Excellence for low carbon technology, in partnership with Leeds City Council and Transport Systems Catapult. Using parts of Leeds Clean Air Zone, ACCRA used real time air pollution measurements, captured by EarthSense, to trigger zero-emission running mode in a 7.5 tonne Range Extended Electric Vehicle (REEV) when entering a designated control zone. During the trials, EarthSense sensors were mounted in key locations in the city centre as well as on vehicles travelling through the area. Data from the sensors was used to update an air quality model, in real time, which was then used to regulate the vehicle's emissions in the most polluted/traffic-dominated areas. *www.earthsense.co.uk*

Ordnance Survey MasterMap freely available

Making key parts of the Ordnance Survey (OS) MasterMap freely available will help businesses use geospatial data more easily and drive innovation across the UK economy. As part of the Prime Minister's London Tech Week roundtable today, the Government has announced that key parts of the OS MasterMap will be made openly available for the public and businesses to use. It is estimated that this will boost the UK economy by at least £130m each year, as innovative companies and startups use the data. This is a step on a journey towards more open geospatial data infrastructure for the UK.

HIPS and SIPS 11.0 simplifies bathymetric processing workflow

Teledyne CARIS™ has announced the release of HIPS and SIPS™ 11.0. This release introduces several improvements making it easier for users to start new projects and process data, as well as an enhanced user experience while interacting with survey data.

Version 11.0 offers one-step processing. The new Georeference Bathymetry function is a single step which initiates Sound Velocity Correction (SVC), Load Tide, Apply Tide, Merge, and Compute Total Propagated Uncertainty (TPU). The same trusted algorithms are still applied but with the added benefit of being combined into a single process. This creates a more streamlined user experience requiring fewer interactions, and eliminates the need to concatenate Sound Velocity Profiles into a single file. Another new capability is the concept of having Dynamic or Static layers for tracklines. This allows the user to create a rule-based layer using any of the trackline attributes. *www.teledynecaris.com*

PolyU to apply smart sensing technology in urban tree management

The Hong Kong Polytechnic University (PolyU) on14th June kicked off the Jockey Club Smart City Tree Management Project, a large-scale pilot project in Hong Kong, with the support from academia, non-government organisations (NGOs) and the Government, to apply smart sensing technology (SST) and GIS for monitoring tree stability to enhance timely appropriate mitigation measures for sustaining longer tree lives.

Tree anchorage is critical to its structural stability. Weak anchorage will be reflected in a tree tilting, which in serious case poses the hazard of falling. In the Project, sensors will be tailor-made and installed on the lower trunk of selected urban trees to monitor their tilting angle in a 3-dimensional manner, as a way of assessing the stability of the root and thus the tree. Data will be collected for a quantifiable analysis of the trees' root plate movement through the use of SST, i.e. the technology of monitoring environmental changes with the use of remote sensors and techniques, via the GIS-based platform.

Taking into consideration of various environmental factors, a threshold will be determined to design the monitoring system as a scientific measurement of the root plate movement and stability. When the tilting angle of a tree exceeds the threshold, the project team will be alerted to conduct a visit to verify the data for the purpose of calibrating the system. When considered necessary, it will inform the relevant tree management team to undertake actions in a timely manner.

Members of the PolyU-led Project team include The University of Hong Kong (HKU), The Hong Kong University of Science and Technology (HKUST), and Friends of the Earth (Hong Kong). The project also receives support from relevant government departments.

HxGN MineDiscover display 9

HxGN MineDiscover Display 9 is an advanced machine display that will maximize the user experience for equipment operators. The new display features an optically bonded, anti-glare 9-inch touchscreen that guarantees visibility in tough environments. Its multi-touch capable, allowing future applications to utilize features such as pinch-to-zoom and gestures. It is designed for harsh environments and can withstand the extreme environmental conditions typically encountered in mines. *hexagon.com*

HxGN MineOperate UG pro for miners

HxGN MineOperate UG Pro is a platform for managing underground fleet equipment and broadcasting time-utilisation information the instant it's needed in remote areas deep below the surface.

It monitors task-level activities, updating miner and machine workflows in real-time as the mine develops and produces ore. Developed specifically for mines lacking data networks underground, UG Pro optimises efficiency using tablets that store and forward critical information between supervisors and workers via network access points.

First 3D laser scanner with automatic in-field pre-registration

Hexagon AB, launched Leica RTC360, a laser scanner equipped with edge computing technology to enable fast and highly accurate creation of 3D models in the field. The RTC360 combines high-performance laser scanning, edge computing, and mobile app technologies to pre-register captured scans quickly and accurately. With the push of a button, two million points per second of High Dynamic Range (HDR) imagery can be captured to create a full-dome scan in under two minutes. Laser scanner movements between setup positions are automatically tracked by a Visual Inertial System (VIS) while scans are combined and pre-registered on a mobile device, where they can be viewed and augmented with information tags saving precious time and speeding up decision-making right from the field.

Oscilloquartz launches enhanced PRTC solution for 5G network timing

Oscilloquartz, an ADVA company, has launched its enhanced primary reference time clock (ePRTC) system to enable unprecedented timing accuracy and stability even when the GNSS signal is lost. The technology provides the ideal timing source for mission-critical transport systems, such as utility networks; government infrastructure and radio access networks, and provides the strict synchronization needed for LTE-A and 5G applications. Featuring the OSA 3230B ePRC atomic cesium clock connected to an Oscilloquartz clock combiner and grandmaster, the new solution offers the extremely stable frequency of a cesium clock with the UTC-traceable signal provided by GNSS. What's more, when combined with the OSA 5430, the OSA ePRTC system is the only solution available that provides full hardware redundancy and multiple fan-out options including PTP over 10Gbit/s. *www.oscilloquartz.com.*

Broadgnss releases high precision GPS receiver

Broadgnss Technologies recently announced a new high precision satellite position receiver with patented RAC (Real-time Array Calibration) technology. It features positioning accuracy better than one meter (up to 10 centimeters). By receiving only single frequency (GPS L1) satellite signals, the RAC technology in high precision satellite positioning frees the dependence on traditional augmentation network and significantly reduces the cost to enable high precision satellite positioning to enter large-scale applications. RAC receivers are designed to balance the performance and cost, overcoming some common barriers of traditional high accuracy GNSS receivers.

H2H leveraging EGNSS for safer maritime navigation

Using EGNSS (EGNOS and Galileo), the Hull to Hull (H2H) project is developing a system that will allow maritime vessels to navigate safely in close proximity to each other and to stationary objects, supporting mariners as they take navigation decisions and creating the fundamental conditions for autonomous maritime navigation.

Funded by the European GNSS Agency (GSA) under Horizon 2020, the H2H system will combine sensor information with 3D models to create digital models of vessels and other objects of interest. This digital model can be visualized by the mariner in 3D, or in 2D format using slices of the 3D model, and used to derive crucial navigation information in real time. The quality of the sensors and the 3D model will drive the quality of the digital model, and consequently the quality of the navigation information that is derived from the model.

Mapbox's new SDK helps developers build smart AR navigation apps

Mapbox, the open source mapping service that competes directly with Google's Maps Platform, has announced a new software development kit (SDK) that will make it easier for developers to build applications that provide AR navigation. That by itself would be cool, but by using ARM's Project Trillium AI platform, the Mapbox Vision SDK can also recognize other vehicles, pedestrians, speed limit signs, construction signs, crosswalks and more, all without having to train their own machine learning models to do so.

Using ARM's Project Trillium platform, the SDK is able to make use of the mobile device's onboard CPUs, GPUs and AI chips (if available) to perform the necessary object recognition. Once new phones launch with ARM's new ML and object detection processors, the SDK will be able to perform all of these functions even faster, but for now, it can extract features from the video feed at a speed of about ten times a second.

Telit launches GNSS integrated antenna receiver modules

Telit, a global enabler of the internet of things (IoT), has debuted its SE878Kx-A series of GPS and GNSS integrated antenna receiver modules for consumer

Galileo update

Four more Galileo satellites launch scheduled for July 25

Four more Galileo satellites will be launched on a customized Ariane 5 on July 25.

The next Arianespace rocket to orbit Galileo satellites has begun taking shape at the spaceport in French Guiana. Build-up of the heavy-lift vehicle is now underway inside the spaceport's Launcher Integration Building.

Once the Ariane 5's basic build-up is completed under the direction of production prime contractor ArianeGroup, it will be moved to the spaceport's Final Assembly Building for installation of its four Galileo FOC (Full Operational Capability) satellite passengers, which are undergoing their own pre-flight preparations at the spaceport.

The Ariane 5 will deploy its satellite passengers at a targeted orbital altitude of 23,222 kilometers in circular medium Earth orbit. The launch is designated Flight VA244 by Arianespace.

In early June, Galileo satellites 25 and 26 landed at Europe's Spaceport in Kourou, French Guiana, joining their two predecessors, satellites 23 and 24, according to the European Space Agency (ESA).

Britain can have access to Galileo after May's threats

Britain could access the European Union's Galileo satellite navigation system after Brexit but will no longer be able to work on developing the project, the bloc's chief Brexit negotiator Michel Barnier said recently.

Britain's Brexit Secretary David Davis said earlier, that Britain had been instrumental in developing Galileo's technology, and blocking it at this stage would delay the project by up to three years and increase the bill by £1billion ($1.2 billion).

Mr Barnier told reporters, referring to the Galileo Public Regulated Service: "The rules as they are today, a third country cannot take part in the development of the PRS signal."

He added the issue should be addressed "in the framework of our future strategic partnership with the UK".

When asked if that meant Britain could not take part in the project's development, however, he said: "Not development. It is a unanimous decision of the 28. "The facts have consequences."

Mr Barnier has previously been clear the UK would lose access to Galileo's PRS service – an encrypted service used by EU member states' militaries and emergency services.

Theresa May blasted the EU has been taking Britain "for a fool" over the situation.

Speaking to Andrew Marr at the weekend, the Prime Mnister said: "Let's just look at Galileo. The UK has been contributing significantly to the Galileo programme so far

"Yes, the EU are saying that in the future, they don't think that not as a member of the EU, we will be able to continue to contribute and have the access as a member of the EU. *www.express.co.uk*

and business applications. As per the company, these modules require high performance, maximum reliability and low power consumption.

Moreover, the SE878K3-A and SE878K7-A are compatible with GPS, GLONASS, Beidou and Galileo and also enable device vendors to develop quickly and cost-effectively location-based IoT solutions for use in virtually any country worldwide. The SE878Kx-A series supports dual internal-external antennas to ensure connectivity when one is broken or compromised, along with a SAW filter to maximize jamming immunity. According to Telit, these features make the modules ideal for mission-critical applications and other use cases where reliability is key, such as alarms, stolen cars or high-end asset tracking.

Harris Corporation delivers fifth GPS III satellite navigation payload

Harris Corporation has provided Lockheed Martin (with its fifth of ten advanced navigation payloads contracted for the U.S. Air Force GPS III satellite program.

The GPS III navigation payload features a Mission Data Unit (MDU) with a unique 70-percent digital design that links atomic clocks, radiation-hardened computers and powerful transmitters – enabling signals three times more accurate than those on current GPS satellites. The payload also boosts satellite signal power, increases jamming resistance by eight times and helps extend the satellite's lifespan. Lockheed Martin successfully integrated the navigation payload into the fifth GPS III space vehicle (GPS III SV05). Harris is committed to delivering three more payloads by the first quarter of calendar year 2019 for GPS III SVs 06-08.

Concept3D interactive map and virtual tour platform

Concept3D, a leader in creating immersive online experiences with 3D modeling, interactive maps and virtual tour software recently announced that The University of Maine in the USA is the latest major university to launch on the Concept3D platform. With the platform, richly detailed

3D models are built atop Concept3Ds interactive map system, making it easy and fun to explore the campus and surroundings from a mobile device on campus or anywhere in the world. The platform also enables the ability to offer 360-degree panorama images, giving map visitors the ability to feel as if they have jumped right into a specific campus location.

Mapping for the city of the future

The Land Survey Division within the Singapore Land Authority (SLA) develops mapping and positioning data and administers the cadastre and mapping framework for Singapore.

The purpose of mapping is to capture landscapes and streetscapes, digitize these data and make them available for other uses. In its first phase of mapping, an airborne laser scanning and imaging equipment was flown over Singapore to collect 3D point cloud and imagery data of the whole nation.

Phase two of the national 3D mapping project involved a comprehensive mobile mapping project that was carried out to collect a ground-based laser scanning and 360 panoramic imagery dataset on approximately 6,000 km of roads. The data collected was used to create 3D models of road and street furniture. These data sets would be used to create the first nation-wide 3D maps of Singapore, which will contribute to the development of a Smart Nation. The 3D digital models are taken into Virtual Singapore to be used by the public, private and people (3P) and research sectors.

UAVs for island management

In support of the Whole-of-Government push for a Future Ready Public Service, the Singapore Land Authority (SLA) has been actively driving innovation in land management regime. SLA recently conducted an Unmanned Aerial Vehicle (UAV) proof of concept (POC) at Pulau Seringat.

The objective of the POC was to establish whether fully-autonomous UAVs operating beyond visual line of sight (BVLOS) were effective for the inspection and automatic detection of maintenance issues on offshore islands managed by SLA. The offshore islands were identified as an ideal test-bed for the POC as they provided a conducive environment to test the remote deployment of UAVs, as a pre-cursor to full-scale deployment on these islands.

Safran reveals Geonyx inertial navigation system for assured PNT

Safran has developed a new family of inertial navigation and pointing systems for land vehicles, called Geonyx. It provides alternative assured position, navigation, and timing (APNT) if GNSS such as GPS or Galileo are unavailable due to physical constraints, jamming, or spoofing. It can be used autonomously or in a hybrid configuration in conjunction with GNSS. The system is based on Safran's Crystal hemispherical resonator gyro (HRG) that has been used in a range of applications in multiple domains for several years, such as in missile guidance and space navigation. The HRG measures the rotation of a platform to calculate its exact position and attitude. A stationary resonance wave is maintained electronically inside a silica hemisphere (a resonator).

This wave remains fixed in relation to an inertial reference, such as stars. By measuring the relative angle between the vibration plane and the resonator, the rotation of the platform can be calculated and its position and orientation deduced. *ihs.com*

SamyoungPNT to provide applanix products and solutions in S. Korea

SamyoungPNT has been selected to provide products, support, and service for Applanix air and land customers in South Korea. Working with Applanix, SamyoungPNT increases its range of products with the addition of Applanix Position and Orientation Solutions for airborne and land vehicles, including: industry-leading POS AV and POSTrack, POS LV, DG for UAV OEM board sets, and POSPac MMS software.

TRIMBLE - NEWS

Trimble's new tunnel solutions

Tunneling for miles underground is a costly business, requiring the utmost dependence on surveyors to ensure tunnel breakthroughs occur at the exact location (within millimeters). To ensure accuracy, surveyors rely on precise measurements from high-accuracy total stations, such as the Trimble® S9 HP. With the new Trimble TSC7 data collector and Trimble Access™ field software, surveyors can easily control the total station and manage tunnel information.

The combined solution improves the ease of use and data visibility in challenging tunnel environments. The 7-inch data collector display, backlit keypad and optimized software makes it easier than ever to capture control data efficiently and accurately. In the office, traverse and network adjustments can be processed with Trimble Business Center software to ensure high-level accuracy. *https://geospatial.trimble.com*

Trimble catalyst now supports glonass

Trimble has announced that its Trimble® Catalyst™ software-defined GNSS receiver for Android phones and tablets has been updated to support GLONASS. The update demonstrates the advantages of software. GNSS for delivering new functionality faster and easier

Trimble Catalyst provides users with Positioning-as-a-Service to collect highly accurate location data with Trimble or third-party apps on Android smartphones and tablets.

When combined with a small, lightweight, plug-and-play DA1 digital antenna and Catalyst subscription, the receiver provides on-demand GNSS positioning capabilities, and transforms consumer devices into centimeter-accurate mobile data collection systems. *https://geospatial.trimble.com.*

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Dortmund, Germany
http://urs.earsel.org

International Symposium and Workshop on A smart sustainable future for all
24 - 26 September
Melbourne, Australia
ssf2018.com

ION GNSS+ 2018
24 - 28 September
Miami, USA
www.ion.org

The 8th China Surveying and Mapping GI Tech Equipment Expo
26 - 28 September
Deqing, Zhejiang, PR China
www.tleerw.com/en/

October 2018

Joint Geo Delft Conference
The 6th International FIG 3D Cadastre Workshop
The 3D GeoInfo Conference
1- 5 October
Delft, the Netherlands
www.tudelft.nl/geodelft2018

39th Asian Conference on Remote Sensing (ACRS 2018)
15 - 19 October
Kuala Lumpur, Malaysia
http://acrs2018.mrsa.gov

Intergeo 2018
17 - 18 October
Frankfurt, Germany
www.intergeo.de

November 2018

Trimble Dimensions 2018
5 - 7 November
Las Vegas, USA
www.trimbledimensions.com

CHINTERGEO2018
7 - 9 November
Chengdu, Sichuan Province
PR China
www.chintergeo.com

International Navigation Conference 2018
12 - 15 November
Bristol, UK
www.rin.org.uk

ITSNT 2018
13 - 16 November
Toulouse, France
www.itsnt.fr

Commercial UAV Show
14 - 15 November 2018
London, UK
www.terrapinn.com/exhibition/the-commercial-uav-show/

United Nations World Geospatial Information Congress
19 - 21 November
Deqing, China

International Symposium on GNSS (ISGNSS 2018)
21 - 23 November
Bali, Indonesia
www.isgnss2018.com

CHINTERGEO 2018
November
ChengDu, PR China
www.chintergeo.com/en/index.html

The Pacific GIS and Remote Sensing User Conference
26 - 30 November 2018
SUVA, Fiji
www.picgisrs.org

The 16th IAIN World Congress 2018
28 November – 1 December
Chiba, Japan
https://iain2018.org

BeiDou Satellite Navigation Application Expo & Smart City Expo
30 November - 02 December
Nanjing, PR China
www.tleer.cn/enbdsexpo

China 2018 BDS Expo
30 Nov - 02 Dec
Nanjing, PR China
www.tleer.cn/enbdsexpo/About/Introduction/

record • replay • simulate

LabSat3 WIDEBAND

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

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

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

LabSat 3 WIDEBAND can record and replay the following signals:

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

www.labsat.co.uk