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THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

PPP

Public Private Partnership

The way ahead for solving land tenure issues?

Static precise point positioning using triple-constellation GNSS


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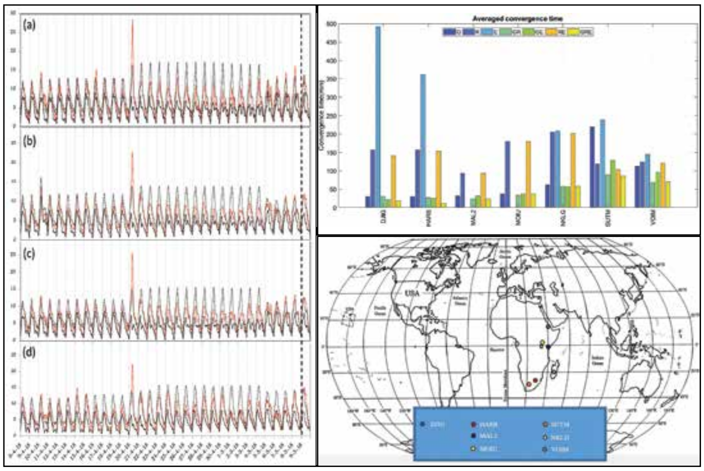

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Editor Bal Krishna
Owner Coordinates Media Pvt Ltd (CMPL)

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'Plastic' concerns

Dead whales with kilograms of plastics in their stomach.

An appalling sight

Increasingly being common in Europe and Asia coast.

In May in coast of Sicilia, in April in Sardinia

And in March in the Philippines.

The list goes on.

We dump million of tonnes of plastic debris in seas and oceans (Read paper on page no. 6)

Causing monumental damage to the marine flora and fauna

Aquatic animals suffer and pay the price

For no faults of theirs.

It's high time that, in concerted effort, we do something about it.

Not only concerned but conscious too!

Bal Krishna, Editor
bal@mycoordinates.org

Overview of marine plastic debris in Vietnam in relation to international context

In order to reduce the quantity of plastic entering the ocean, existing management instruments need to be made more effective and all aspects of waste treatment and disposal need to be improved

Le Dai THANG
Deputy Director, Bureau for resources control and environmental protection of seas and islands. Vietnam Administration of Seas and Islands (VASI). Ministry of Natural Resources and Environment (MONRE), Vietnam

Among the approximately 2.5 billion tonnes of solid waste produced globally in 2010, about 275 million tonnes was mismanaged plastic waste generated from coastal countries, and it is estimated that between 4.8 million tonnes to 12.7 million tonnes of this plastic waste entered the oceans. Inadequate management of plastic waste has led to increased contamination of freshwater, estuarine and marine environments.

Current management plans for solid waste include: open dumps or tips into landfill, incineration, waste to energy and recycling. However, not all plastics are recyclable or recycled which can be the result of insufficient waste streams.

Vietnam with a coastline of more than 3260km runs along the length of the country, with dozens of estuaries flowing into the sea. Plastic waste is really a very serious problem in Vietnam. In the beaches where garbage is regularly collected, plastic still floats a lot in the sea. In some beach areas like mangrove forests, mudflats.... where garbage is not collected, plastic debris forms a thick layer on bottom mud, covering roots and branches, causing great harm to the ecosystem.

However, Vietnam considers strong development of the marine economy must be accompanied with marine environmental protection, do not trade the environment for hot and unsustainable growth. So far, Vietnam has issued and implemented many strategies, policies and regulations on environmental protection to limit marine plastic debris. Therefore, it has achieved many encouraging results, but there are still many difficulties ahead.

In order to reduce the quantity of plastic entering the ocean, existing management instruments need to be made more effective and all aspects of waste treatment and disposal need to be improved. Vietnam needs further cooperation, support and funding from other countries and international organizations.

Introduction

Plastic production has increased exponentially since the early 1950s and reached 322 million tonnes in 2015, this figure does not include synthetic fibres which accounted for an additional 61 million tonnes in 2015. It is expected that production of plastics will continue to increase in the foreseeable future and production levels are likely to double by 2025. [6]

Almost all aspects of daily life involve plastics. One of the most appreciated qualities of plastic products is their durability. Mass production and mass consumption of plastics have led to the accumulation of plastics in natural habitats, and adverse impacts on biota and the economy. Environmental impacts include habitat damage, entanglement and ingestion of marine litter by biota, and the introduction of non-native species, mainly microorganisms, seaweeds and invertebrates, through

It has been estimated that in 2010 between 4.8 million to 12.7 million tonnes of plastic waste entered the oceans. Abandoned, lost or otherwise discarded fishing gears (ALDFG) are considered the main source of plastic waste by the fisheries and aquaculture sectors, but their relative contribution is not well known at regional and global levels

rafting on floating litter (Barnes and Milner, 2005; Calder et al., 2014; Kiessling, Gutow and Thiel, 2015; Kühn, Rebolledo and van Franeker, 2015).

It has been estimated that in 2010 between 4.8 million to 12.7 million tonnes of plastic waste entered the oceans. Abandoned, lost or otherwise discarded fishing gears (ALDFG) are considered the main source of plastic waste by the fisheries and aquaculture sectors, but their relative contribution is not well known at regional and global levels. [6]

Among the approximately 2.5 billion tonnes of solid waste produced globally in 2010, about 275 million tonnes was mismanaged plastic waste generated from coastal countries, and it is estimated that between 4.8 million tonnes to 12.7 million tonnes of this plastic waste entered the oceans (Jambeck et al., 2015).

However, this quality when combined with improper waste management, plastic waste may escape waste streams, enter the environment leads to environmental contamination on land, in freshwater and in marine environments. . Inadequate management of plastic waste has led to increased contamination of freshwater, estuarine and marine environments.

Appropriate waste management strategies are necessary in order to mitigate the effects and impacts of marine plastic debris pollution in coastal and aquatic habitats.

Some figures of marine plastic debris in the world

Nowadays, plastics make up at least 10 percent of solid waste by mass in 58 percent (61 out of 105) of countries with available data (Hoornweg and Bhada-Tata, 2012). Plastics may be buried in landfills, recycled, incinerated (with or without energy generation), accidentally lost or deliberately littered. Except for the incinerated component of waste, it is estimated that all plastics produced since the beginning of mass plastic production remain in the environment in whole or in fragmented forms. The percentage of recycled plastics has increased every year since at least 1990, but it is far behind other materials including paper (58 percent) and iron and steel (between 70 percent and 90 percent) (WEF, 2016).

Several management options have been implemented to manage the waste stream of large plastic items. Current management plans for solid waste include: open dumps or tips into landfill, incineration, waste to energy and recycling (Bernardo, Simões and Pinto, 2016). However, not all plastics are recyclable or recycled which can be the result of insufficient waste streams.

With specific reference to plastic packaging materials (78 million tonnes in 2013), 14 percent was recycled, 14 percent incinerated, 40 percent landfilled and 32 percent reached the environment globally (WEF, 2016). Of the available waste streams, recycling is widely regarded as the preferential treatment option. It allows end of life items to have a value rather than becoming waste.

Treatment of waste is different by country, some rely heavily on landfill, whereas other focus on recycling and energy production (in the form of heat, steam and electricity). However, this requires sophisticated and expensive separation infrastructure which is less available in developing countries. According to estimations, 5 of 192 countries contribute more than 50 percent to the mismanaged plastic waste (Jambeck et al., 2015). These are mainly developing countries, experiencing rapid economic growth, but not yet having efficient waste-management infrastructures.

Defining the marine litter problem is complex as there are many different sources and forms of litter that can enter the oceans. Plastic items are consistently the most abundant type of marine debris identified around the globe, and can amount to more than 80 percent of reported debris (e.g. UNEP, 2016). Both sea and land-based activities are responsible for the continued input of plastic, making it a ubiquitous pollutant as it has been reported globally.

Coastal waters and shorelines often contain a considerable amount of plastics debris. They are subjected to anthropogenic pressures including: land based input of debris, tourism, aquaculture, shipping, fisheries and high coastal population.

Floating marine debris can reach densities over 600 items per km2. Seabed deposition of plastic is very dependent on location and densities range from 0 items to more than 7 700 items per km2 (Galgani, Hanke and Maes, 2015). 80 percent of the floating debris was composed of plastics items (PS, plastic bags and plastic fragments) [Hinojosa and Thiel (2009)].

Overview of marine plastic debris in vietnam

According to some research results, Vietnam is among the top 5 countries in the world with the estimated amount of plastic waste discharged into the sea from 0.28 to 0.73 million tons/year. Plastic waste is really a very serious problem in Vietnam. In the beaches where garbage is regularly collected, plastic still floats a lot in the sea. In some beach areas like mangrove forests, mudflats.... where garbage is not collected,

> According to some research results, Vietnam is among the top 5 countries in the world with the estimated amount of plastic waste discharged into the sea from 0.28 to 0.73 million tons/year. Plastic waste is really a very serious problem in Vietnam. In the beaches where garbage is regularly collected, plastic still floats a lot in the sea. In some beach areas like mangrove forests, mudflats.... where garbage is not collected, plastic debris forms a thick layer on bottom mud, covering roots and branches, causing great harm to the ecosystem

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According to the 2015 National State of Environment Report, about 46% of solid waste in Vietnam is urban solid waste, 17% from industrial production, the rest is rural solid waste, craft villages and health care solid waste. The collection rate of solid waste in urban areas is quite high, about 84% to 85%. The collection rate of domestic solid waste in rural areas is only about 40% and mainly in towns. Solid waste is mainly treated by open dumping or incineration. [11]

Currently, in Vietnam there are about 2,000 plastic enterprises, mainly situate in the South. Among 2,000 enterprises in the plastic industry, most are small and medium enterprises (SMEs), private enterprises (accounting for 90%). With the number of businesses and diverse product categories, Vietnam plastic production in 2008 reached 2.3 million tons, the average growth rate of 15%/year. At present, this number is about 4 million tons/year. In particular, packaging plastic products (including plastic bags, plastic bottles, goods packaging ...) accounted for about 36%; Plastic materials for construction, household appliances and other types for other industries such as electronics, electricity and transportation account for about 16%, 36% and 12%, respectively.

With the proportion of products in the total volume of plastic products produced annually as above, plastic packaging in Vietnam has an average output of about 1 million tons/year. According to previous data, the average consumption of plastic is about 25 - 35kg plastic/person/year. Up to now, with the growth rate of plastic industry of about 15 - 20% / year, at the same time the economic life is growing, the average plastic consumption reaches more than 40kg/person/year.

Along with the increase in domestic solid waste, the amount of plastic waste and plastic bags arises. According to a survey by the Ministry of Natural Resources and Environment, the amount of plastic waste and plastic bags accounts for about 8 - 12% of domestic solid waste. According to the World Bank report, the proportion of plastic waste generated for middle-income countries like Vietnam accounts for about 12% of the generated solid waste. If an average of 10% of the amount of plastic waste and plastic bags is not reused but completely disposed, the amount of plastic waste and plastic bags discharged in Vietnam is approximately 2,500,000 tons/year. Plastic waste and plastic bags is mainly treated together with domestic solid waste mainly in the form of landfill, then incenerating and finally recycling. For plastic waste and plastic bags from industrial activities, most of them are classified and withdrawn for production or sold to other units for recycling.

These types of plastic bags currently used in Vietnam are mainly produced from polyethylene (PE), others are made of polypropylene (PP) or poly vinyl chloride (PVC) ...The products produced from these materials are all of a kind that are difficult to decompose and are likely to cause long-term environmental pollution. The widespread use of plastic products and plastic bags in social activities, mainly and especially ultra-thin bags, shows not only in very popular, number of bags used. but also in the ease of both the supplier and the user: the seller is willing to add one or several plastic bags to the buyer when requested; buyers rarely carry containers (bags, baskets, etc.) because they know for sure that when buying goods, there will be plastic bags attached to carry on.

The responses and achievements

Vietnam considers strong development of the marine economy accompanied with marine environmental protection, do not trade the environment for hot and unsustainable growth. Promoting clean energy, green growth projects and sustainable development; resolutely against pollutant discharge to pollute green, healthy waters.

Resolution No. 09-NQ/TW dated February 9, 2007 "About Vietnam Sea Strategy to 2020", National Strategy on Green Growth (Decision No. 1393/QD-TTg dated September 25, 2012) , National Environmental Protection Strategy to 2020, vision to 2030 (Decision 1216/QD-TTg dated December 5, 2012), Integrated Coastal Management Strategy of Vietnam to 2020, vision by 2030 (Decision No. 2295/QD-TTg dated December 17, 2014), the National Action Plan to implement Chapter 4 of the 2030 Agenda for sustainable development issued under Decision No. 622/QD-TTg dated May 10, 2017. Especially, The strategy of sustainable exploitation and use of marine resources and environmental protection until 2020, vision to 2030 (Decision No. 1570/QD-TTg dated September 6, 2013) provides strategic orientations in resource management and marine environmental protection, in which the strategic tasks is to control the sources of pollution of the marine environment, on islands to achieve the goal of "curbing the rate of increase environmental pollution in coastal areas and on islands ". Decree No. 19/2015/ND-CP dated February 14, 2015 encouraging waste recycling activities, including both plastic waste and plastic bags. Decree No. 155/2016/ND-CP dated November 18, 2016 of stipulating penalties for administrative violations in the field of environmental protection; Decree No. 130/2013/ND-CP dated October 16, 2013 on manufacturing and supplying public products and services. Decree No. 38/2015/ND-CP on waste and scrap management, which requires classification of recycled plastic waste in domestic solid waste and industrial solid waste; The waste must be managed from generation to collection, transportation and handling.

National Environmental Protection Strategy to 2020, vision to 2030 indicates contents and measures aiming to increase the rate of solid waste collected, recycled and reused; gradually reduce the production and use of persistent bags and packages (including plastic and plastic bags); Research, produce various types of easy-to-decompose bags and packages to replace bags, packages that are difficult to decompose.

In order to unify the treatment of environmental pollution due to persistent plastic bags, on April 11, 2013, the Prime Minister issued Decision No. 582/QD-TTg approving the Scheme enhance environmental pollution control due to difficult to degrade plastic bags in daily life until 2020, which identifies groups of tasks, synchronous solutions on economy and society as well as treatment of environmental pollution. The Scheme has set specific objectives: "In 2015, 40% reduction of difficult-to-decompose plastic bags used at supermarkets, commercial centers compared to 2010" and "2020 will reduce 65% of volume difficult-to-decompose plastic bags at supermarkets and commercial centers compared to 2010".

By April 2018, on average, the rate of using non-biodegradable plastic bags in supermarkets by 2017 has basically decreased by 50% compared to 2010. In special urban areas and grade 1 cities, 90%

> In order to unify the treatment of environmental pollution due to persistent plastic bags, on April 11, 2013, the Prime Minister issued Decision No. 582/QD-TTg approving the Scheme enhance environmental pollution

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of supermarkets and commercial centers used environmentally friendly plastic bags to replace difficult-to-decompose plastic bags. However, in grade 2 or lower urban areas, where the number of supermarkets and commercial centers accounts for a low proportion, the use of persistent plastic bags is still relatively common.

+ Enterprises also aim to produce environmentally friendly plastic bags to gradually replace difficult-to-biodegradable plastic bags for consumers. Companies have implemented pollution prevention and control measures according to environmental protection regulations. They have printed labels and product codes so that consumers can identify the types of environmentally friendly plastic bags that are recyclable (thickness > 30 micrometers) or biodegradable plastic bags.

Currently, some domestic solid waste treatment facilities have installed a sorting line to recover recyclable substances, including plastic waste and plastic bags.

Circular No. 07/2012/TT-BTNMT dated July 4, 2012 regulating criteria, order and procedures for recognizing environmentally friendly plastic bags, recognizing all types of environmentally friendly plastic bags through the market to gradually reduce the use of non-biodegradable plastic bags, promote businesses to adopt new technologies to produce recyclable or biodegradable plastic bags. After 5 years of implementation, the country has 43 plastic-bag products of 38 recognized enterprises that are environmentally friendly.

The system of TCVNs for evaluating environmentally friendly plastic bags, including: TCVN 11317:2016 - Guidance on exposure and testing of plastics for decomposition in environments combining oxidation and biodegradable process (ASTM 6954:2004); TCVN 11318:2016 - Determination of complete aerobic biodegradability of plastic materials in water environment - method of measuring oxygen demand in a respiratory meter (respirometer) (ISO 14851:1999); TCVN 11319:2016 - Determination of complete aerobic biodegradability of plastic materials in water environment - method of analyzing the amount of carbon dioxide produced (ISO 14852: 1999); TCVN 11320:2016 - Plastics - cadmium - wet decomposition method (EN 1122: 2001); TCVN 11796:2017 - Method of exposure plastic capable of optical decomposition under the influence of fluorescent UV (UV) (ASTM D5208:2014); TCVN 11797:2017 Labeling requirements for plastics are capable of aerobic composting at municipal or industrial waste treatment facilities (ASTM 6400:2012); TCVN 11798:2017 - Packaging - Requirements for recoverable packaging through composting and biodegradation - Test scheme and evaluation criteria for accepting packaging (EN 13432:2000)

Many localities have carried out the propagation, dissemination of information and education to raise awareness for the community about the harmful effects of plastic bags that are difficult to decompose, organize movements and campaigns such as "day without plastic bags". "Say no to plastic bags"

Decision No. 491/QD-TTg dated May 7, 2018 approving the adjustment of the National Strategy on Integrated Solid Waste Management to 2025, vision to 2050, in which one of the key tasks is to summarize and evaluate the results of the implementation of Decision No 582/QD-TTg dated April 11, 2013 approving the Scheme on strengthening environmental pollution control due to the use of difficult-to-biodegradable plastic bags until 2020; limit and proceed to terminate the import, production and supply of difficult-to-biodegradable plastic bags from 2026 at commercial centers and supermarkets for domestic purposes.

Specific objectives for urban domestic solid waste: (i) All special-class and grade-I urban centers with solid waste recycling facilities appropriate with classification at households; 85% of the remaining cities have solid waste recycling facilities in accordance with household classification; enhance recycling, reuse, and combination of energy recovery; (ii) Using 100% environmentally friendly plastic bags at commercial centers, supermarkets for living purposes to replace difficult-to-biodegradable plastic bags. In the past, one of the efforts to reduce plastic bags waste is to encourage the production and use of environmentally

In the past, one of the efforts to reduce plastic bags waste is to encourage the production and use of environmentally friendly packaging through preferential policies on environmental protection tax. For plastic bags, environmental protection tax is both a tool to increase budget revenue, to limit the production of difficult-to-decompose plastic bags and change consumption habits friendly packaging through preferential policies on environmental protection tax. For plastic bags, environmental protection tax is both a tool to increase budget revenue, to limit the production of difficult-to-decompose plastic bags and change consumption habits (the current level is 40,000 VND/kg). The Law on Environmental Protection Tax stipulates that plastic bags meeting environmental friendly packaging criteria do not have to pay environmental protection tax.

In addition, the Government of Vietnam has participated in many international treaties and conventions related to waste management such as Basel Convention on cross-border waste control and their destruction; United Nations Convention on the Law of the Sea (UNCLOS); 2030 Agenda for sustainable development; United Nations Framework Convention on Climate Change (COP22) and Viet Nam's Paris Implementation Plan on Climate Change; United Nations Environment Program (UNEP).

Difficulties and problems encountered

Scientific and practical understanding of the process of generating, dispersing and transforming plastic waste as well as their impacts on the environment, ecosystems and marine resources is still limited.

Vietnam does not have much practical experience in assessing the status of controlling and managing plastic waste at sea. "Plastic waste" is just regulated (Decree 38/2015/ND-CP) in the group is capable of reusing and recycling, but there are no specific regulations and guidelines on management, collection and handling this waste group to suit the current serious pollution of plastic. Resources for implementing propaganda and dissemination programs to raise awareness as well as implementing tasks and programs in the Scheme on enhancing environmental pollution control due to the use of non-biodegradable plastic bags to 2020 have not been fully allocated, not meeting the practical requirements resulting in the lack of synchronous and inefficient implementation of tasks.

Propaganda, dissemination and public awareness raising have not been continuous and synchronous, leading to low efficiency; Investigation and statistics activities are still limited, leading to incomplete information and data to serve management.

The coordination among relevant agencies in the process of implementing the Scheme on enhancing environmental pollution control due to the use of non-biodegradable plastic bags until 2020 is not continuous and ineffective, especially in inspection and examination of the implementation of policies and remedies for pollution control due to plastic bags, so it has not had a strong impact on difficult-to-biodegradable plastic bag production enterprises.

The Law on Environmental Protection Tax is still not the only solution to change the behavior of the community, plastic bags

Investment policy and application of recycling technology of plastic bag waste is still limited, so it is not attractive to all economic sectors involved in collecting and recycling plastic bags, leading to difficulties in privatizing waste recycling activities in general, plastic bag waste in particular

are still used and disposed at a high level. Currently, in supermarkets and markets, sellers sell plastic bags to buyers free of charge because the prices of these goods are much cheaper than other goods.

Infrastructure for classification, recycling, reuse and waste treatment in general, plastic bags waste has not been invested synchronously. While the demand for using plastic waste in the country is high, but most localities have not done well the classification of waste at source, so the collection for recycling waste plastic bags is not guaranteed to meet the demand of production materials of the plastic industry.

Investment policy and application of recycling technology of plastic bag waste is still limited, so it is not attractive to all economic sectors involved in collecting and recycling plastic bags, leading to difficulties in privatizing waste recycling activities in general, plastic bag waste in particular.

Some enterprises still have not really paid attention to environmental protection requirements or technical requirements to ensure their products are environmentally friendly, such as changing the density and composition of raw materials input but not yet informed the certificate issuer, not yet printed the label and product code in accordance with the commitment in the registration profile for recognition of environmentally friendly plastic bags.

The supply of environmentally friendly bag production has not met the demand of designs, has not yet competed on price compared to conventional plastic bags, so it is not encouraging consumers to change their habit of using difficult-to-decompose plastic bags to environmentally friendly bags. Awareness of manufacturing enterprises as well as communities about environmentally friendly plastic bags is confusion, many individuals and enterprises understand rigidly environmentally friendly bags that plastic bags are possible biodegradability, even biodegradable bags, leads to many difficulties in producing and creating markets for biodegradable plastic bags.

Steps to solve marine plastic debris

By Resolution 36-NQ/TW dated October 22, 2018 on the strategy of sustainable development of Vietnam's marine economy to 2030, with a vision to 2045, Vietnam has identified a key task in the coming period is to prevent, control and reduce marine environmental pollution significantly; 100% of hazardous wastes and domestic solid wastes in coastal provinces and cities shall be collected and treated to meet environmental standards; Regional pioneer in reducing ocean plastic waste.

- Develop and implement the National Plan for the management of ocean plastic waste by 2030 with a vision to 2045.

- Promote global cooperation in ocean and ocean data sharing, training and development of human resources, focusing on technology transfer and sustainable use and utilization of marine and ocean resources by establishment an international center for ocean plastic waste located in Vietnam.

- Promote the formation of a global cooperation mechanism for reducing plastic waste that the Prime Minister stated at the G7 Summit in Canada in 2018 and was very welcomed by the Summit.

- Develop a state-level science and technology program framework to solve the problem of ocean plastic waste pollution.

- Develop a regional project on establishing regional partnerships in the East Asia Seas on ocean plastic waste management. This is an initiative of Vietnam presented at the Roundtable of the 6th Meeting of the General Assembly of the Global Environment Fund held in Da Nang on 27-28 June 2018 with the aim of promoting cooperation and increasing, strengthening regional coordination in plastic waste reduction for the East Asia Seas region, creating a driving force for the shift of growth model on the basis of a circular economy on the principle of reducing consumption, increasing recycling and reusing plastic; establishing knowledge base on ocean plastic waste and especially raising community awareness, changing behavior in dealing with plastic products and plastic waste.

Raise awareness of ocean plastic waste. Training on methods of monitoring, sampling and analysis of micro-plastics. Observation and monitoring of micro-plastic on coastal beaches and estuaries (movement of micro-plastic originating from land). Develop common standards for all countries on methods of monitoring, sampling and analysis of micro-plastics.

Support for the media and NGOs in Vietnam as well as a number of ministries, sectors, mass organizations and localities have been conducting necessary activities to prevent and prevent dumping of plastic waste into the ocean.

Increasing the tax rate for non-biodegradable plastic bags, especially thin bags that cannot be recycled. The high taxation aims to increase the price so that sellers will not continue to distribute plastic bags, gradually reducing the single use of difficult to decompose plastic bags. Since then, plastic bag manufacturers must have a conversion plan to produce more environmentally friendly products.

Close inspection and supervision of tax collection/payment activities is an important factor to ensure fairness for environmentally friendly plastic bag manufacturers to limit the production of difficult to decompose bags.

Continuing to propagate in various forms, through the media, newspapers and maintaining propaganda activities on the harmful effects of difficult to decompose plastic bags, raising awareness and disseminating information to community to change community habits from using persistent bags to environmentally friendly products.

Continuing to prioritize the consideration or implementation of national scientific and technological tasks on the development of technologies for treating difficult to decompose plastic bags; strengthen the application and technology transfer program to produce environmentally friendly products to replace the persistent plastic bags.

Organize to guide and supervise activities of sorting waste at source to collect and recycle difficult to decompose plastic bags with high efficiency; building models and self-management programs on environment including contents of minimizing use and classification, collection and recycling of difficult to decompose bags.

Enhance and diversify capital sources to implement environmentally friendly projects on production and recycling the plastic bags; concentrating resources on research, application and transfer of plastic bag recycling technologies and produce low-cost environmentally friendly products that meet the technical criteria for universalization in the market [2]

Conclusion and recomendation

Plastic contamination of marine environment has been increasing since industrial high volume polymer production commenced in the 1950s. As production levels continue to increase, it is likely that plastic related contamination will continue to increase in the foreseeable future.

Currently, ocean plastic debris is a global issue, which is of great concern to many countries and international organizations, including Vietnam. Managing and controlling marine plastic debris pollution is both a challenge for Vietnam and a great opportunity to open a new area of management.

However, at present, Viet Nam has very little information exists on the relative contribution of different types of plastics and associated chemicals, and how this has varied with time. And also, very little information exists on distribution of plastics in the Vietnam waters. And data collection is problematic, especially in deeper waters. There is very limited information on the distribution of plastics in sediment.

In order to prevent, control and reduce marine environmental pollution significantly, especially the regional pioneer in reducing ocean plastic debris as required by Resolution 36-NQ/TW dated October 22, 2018 on The strategy of sustainable development of Vietnam's marine economy up to 2030, with a vision to 2045, apart from implementing the contents mentioned in previous section, Vietnam needs the cooperation and support of countries and financial institutions to solve the problem of ocean plastic debris.

> By Resolution 36-NQ/TW dated October 22, 2018 on the strategy of sustainable development of Vietnam's marine economy to 2030, with a vision to 2045, Vietnam has identified a key task in the coming period is to prevent, control and reduce marine environmental pollution significantly

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Ionosphere TEC anomaly detection prior to Earthquake using GPS observation data

A case study of 2018 Mw 6.2 Tajikistan Earthquake

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Diurnal Total Electron Content (TEC) variations prior to Mw 6.2 Tajikistan Earthquake of 9th May 2018 were investigated for pre earthquake ionosphere anomaly detection and its relationship vis a vis earthquake epicentre distance. Study was carried out using data from International GNSS service (IGS) stations: KIT3, POL2, TASH and CHUM. The TEC time series prior to earthquake indicates anomalies on 10th April, 16th April, 20th April, and these anomalies become continuous from 5th may to 9th May 2018. TEC anomaly time were detected for each anomalous day and was found to be 7.683 UTC on 10 April 2018, 3.55 UTC and 9.783 UTC on 16 April 2018, 9.617 UTC on 20 April 2018, 16.383 UTC on 5 May 2018, 8.45 UTC on 7 May 2018, 8.4 UTC on 8 May 2018 and 5.983 UTC on 9 May 2018. It was inferred that the closest observation station to epicentre showed higher TEC values from rest of the stations which may be attributed to a definite relationship with the epicentre distance of impending earthquake. It was observed that for positive anomaly TEC concentration increases towards the epicentre and it decreases towards the epicentre in case of negative anomaly. It was also seen that the negative anomaly may be observed in the close proximity of earthquake preparation zone. With increasing distance from the radius of the earthquake epicentre area, magnitude of TEC anomaly decreases in all the cases which was completely analogous to the fact that the maximum anomalous values are observed near to the earthquake epicentre. Hence, it is vital to screen TEC variations constantly utilizing GNSS receivers and peculiar anomalies be considered as one of the important parameter for earthquake precursor detection.

Introduction

The prime factor for earthquake occurrences is deformation of the earth crust and strain accumulation. These deformations have certain manifestations in ground as well as the ionosphere. The ionospheric perturbation can be studied by monitoring the behaviour of Total Electron Content (TEC) at the ionosphere by use of dual frequency GPS receiver. TEC is the total number of electrons present between GPS Satellite and receiver in the earth's ionosphere. It is measured in TEC unit (TECU), defined as 1 TECU=electrons/m2. Present study made an attempt to quantify the ionosphere perturbation vis-à-vis Tajikistan earthquake for understanding its precursors. Source of the earthquake is of course deformation on the crust that activates the electronic charge carriers known as positive holes giving rise to peroxy defects in the crystals and minerals of crustal rocks (Freund et al., 2009, Freund, 2011). These positive holes leave the electrons and move to the surface as well as unstressed part of the rock. As the positive holes enter the unstressed rock, they repel electrostatically leading to the ionisation of the lower atmosphere. In this process, positive ions are generated that are free to move through the troposphere up to the lower ionosphere where they join with the electrons. Depending upon the process of ionisation, the electrons may either decrease or increase which was studied in present research. As these are initially pulled by positive ions, the process leads to decrease first, followed by increase due to continuous flow of electrons. Laboratory experiments conducted in support of this mechanism (positive holes) suggest that the number of positive ions produced can reach values of the order of 10^7 sec^{-1}. cm^{-2} (Freund et al., 2009) indicating regional high concentrations of positive air ions, often lasting tens of hours. This mechanism states that the air at ground level becomes positively ionized, leading to the development of a vertical ion current, which is expected to produce an ionospheric disturbance. Since the ionosphere is a dispersive medium for electromagnetic waves, it induces a time delay in radio signals during the transmission of the GPS satellite signals (Davies, 1990, Garner et al., 2008, Olwendo et al., 2016) that can be estimated by differencing the two frequencies of GPS satellites signals. Thus in present study, total electron content (TEC) values were estimated using dual-frequency GPS receivers.

Numerous study has been carried out to understand the ionosphere TEC variation prior to earthquakes (Calais and Minster, 1998, Liu et al., 2001, Liu et al., 2002, Liu et al., 2004, Pulinets, 2004, Pulinets et al., 2005, Hegai et al., 2006, Pulinets, 2009, Dogan et al., 2011, Liu et al., 2011, Ouzounov et al., 2011, Kumar and Singh, 2012, Yao et al., 2012, Grant et al., 2015, Shah and Jin, 2015, Sharma et al., 2017, Sharma et al., 2017) which indicates TEC as one of the important parameter to be considered in precursor study. It was also shown that the electron density may decreased upto 51% from its typical incentive between 12:00-17:00 LT, that was observed 3 to 4 days prior to event as shown in case of e Chi-Chi earthquake (Liu et al., 2001). In this study, Tajikistan Earthquake of 9th may 2018 was analyzed as an example, the epicentre of which was 32 km North West of Ishkhashim, occurred at 10:41:45 UTC (USGS). The radius of the earthquake preparation zone was estimated as per Dobrovolsky equation (Dobrovolsky et al., 1979) and was found to be 467.70 km. Global Positioning System (GPS) permanent station (IGS Stations) within this zone was identified and selected for analysis in present study. The results showed anomalies in ionosphere TEC variations at regular intervals prior to the event and are discussed in detail.

Methodology and Datasets

Every GNSS observations are inherent with an errors because of the dispersions in the ionosphere, primary cause for which are the electron concentration or Total electron content (TEC) along the line of sight in the ionosphere between the observation station and Navigation satellite (GPS). TEC processing were carried out using GPS-TEC analysis application software (Ma and Maruyama, 2003, Seemala and Valladares, 2011). Slant TEC (sTEC) were computed using both phase and code values for L1 and L2 GPS frequencies in the software in order to eliminate the effect of tropospheric water vapor and clock errors (Sardon et al., 1994, Sardón and Zarraoa, 1997, Arikan et al., 2008). The absolute values of TEC was then obtained by including the differential code and receiver biases from the University of Bern (Valladares et al., 2009). However, for precursor analysis, it is crucial to compute ionospheric variations in vertical direction known as Vertical TEC or vTEC (Pulinets et al., 2005). Therefore, based on the assumption of thin-shell ionosphere at a fixed height, slant TEC is converted into equivalent vertical TEC (Kersley et al., 2004). In the presence of the EIA, there occurs a large spatiotemporal gradient in TEC which poses a great challenge on the accuracy of the TEC owing to the mapping function while converting the slant TEC (STEC) to vertical TEC (vTEC). To minimize this effect in the computed TEC values, an elevation threshold angle of 30° was used for all the vTEC computed.

The geomagnetic storm index (Dst) data from World Data Centre for Geomagnetism and Space magnetism (WDC) were utilised in assessing geomagnetically disturbed day during the TEC observation window. The data used in this research were obtained from the IGS receivers KIT3 (Kitab), TASH (Uzbekistan), POL2 (Kyrgyzstan) and CHUM (Kazakhstan) for the period of April-May 2018 in receiver-independent exchange (RINEX) format. Various statistical analysis were carried out in order to identify the precursors and its signatures as discussed in the result and discussion section. The anomaly in the TEC observations were detected using the statistical approach as below (Sharma et al., 2017, Sharma et al., 2017)

Boundary limit = X ± 1.34σ

Where, X is 15-day running mean and σ is 15 days running standard deviation for particular time of observation. These act as a boundary limit for TEC variations, i.e., TEC values crossing these limits are considered anomaly. Hence, a mathematical model was constructed that give the anomalous behaviour of ionospheric TEC where vTEC must lie between the upper and lower boundary limit in normal ionosphere condition.

Result and Discussion

To have a better understanding of seismic precursor in the Middle East, an attempt was made to analyse the ionospheric TEC anomalies by continuous operating GNSS receivers of International GNSS service (IGS). Since the earthquake is of large magnitude Mw 6.2, anomalous behaviour of TEC is more likely to be expected and are explored in present study. It was seen that TEC variations preceding the Tajikistan earthquake started almost a month prior to event with number of anomalies occurring 0 to 29 days and are discussed in detail in the present section.

TEC anomaly and anomaly time detection

Seismic perturbation on the ionosphere caused by Tajikistan Earthquake of 9th may 2018 were analysed, epicentre of which lies 32 km North West of Ishkhashim and occurred at 10:41:45 UTC. Ionospheric perturbation was studied through TEC monitoring using GNSS observations at IGS stations KIT3, POL2, TASH and CHUM before the earthquake. The TEC time series of month prior to earthquake indicates strong anomalies (crossing upper boundary) on 10th April, 16th April, 20th April, and these anomalies become continuous from 5th may to 9th may (figure 1). Since these values has crossed upper boundary limit, they are named as positive anomalies. Similarly, a negative anomaly (values crossing lower boundary) was seen on 16th April 2018 as shown in figure 1, which is a characteristic feature of earthquake and has also been observed in earlier studies as well (Sharma et al 2017). The anomaly on 16th April is observed by the nearest site (KIT3) only and the magnitude of TEC is also smaller on other stations as compared to KIT3. It is rather interesting to note that all stations showed a positive anomaly on 20th April, 5th May and 9th May (the day of earthquake). In addition, at observation station CHUM, positive anomalies was observed on 14-15th April which was not seen or was minimal in other observation stations. These irregularities observed at CHUM station are attributed to a nearby earthquake of 4.6 magnitude, the epicentre of which was 96 km south of Urzhar, Kazakhstan on 21st May 2018. The time at which the TEC deviation is maximum and minimum was noted and was named as anomaly time. It is also known that a geomagnetic storm can cause significant changes in ionospheric TEC and needs to be assessed to rule out its influence. Three indices give a good measure of geomagnetic storm: Dst index, Ap index, Kp index. In present study, anomalies are checked

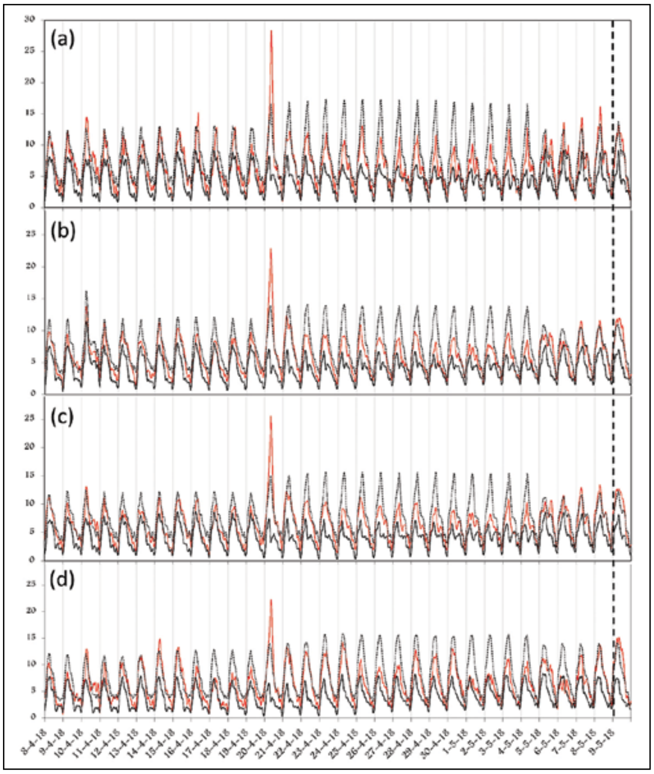

Fig 1. Shows the TEC observations for the period of one month prior to the occurrence of earthquake. (a) TEC observation at IGS Station KIT3. (b) TEC observation at IGS Station POLI2. (c) TEC observation at IGS Station TASH. (d) TEC observation at IGS Station CHUM. Black dotted line is the upper limit constructed as described in the text, black solid line is the lower limit whereas red solid line is the daily TEC variations observed. Dotted black vertical line represent the earthquake day.

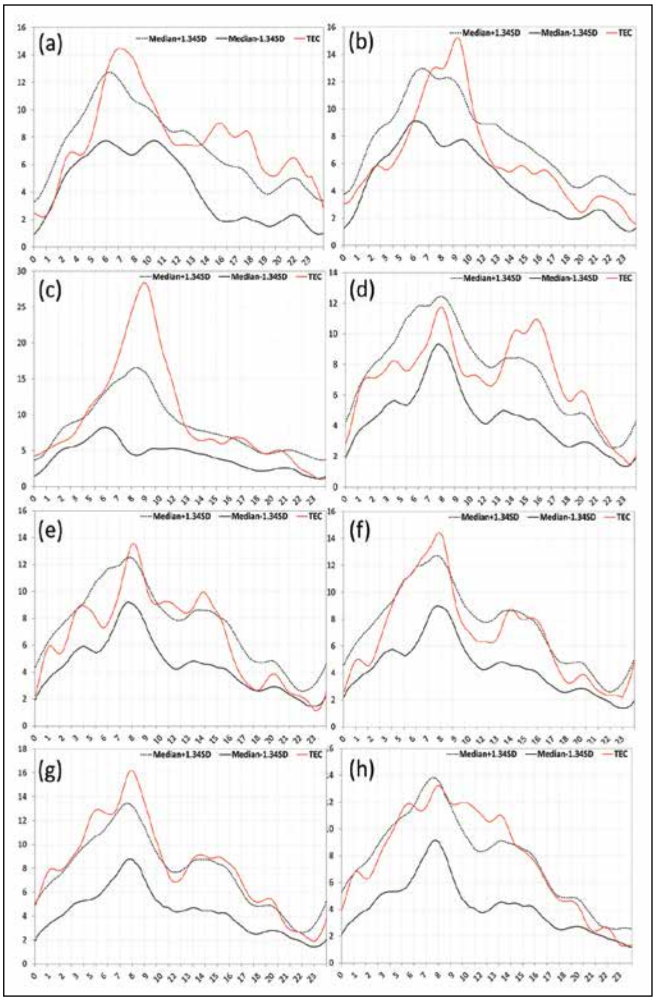

Fig 2. Shows TEC observations for anomalous days and detected anomaly time observed at nearest station KIT3. Y axis is the TEC observations whereas X axis is the time in UTC for anomalous day. Dotted and solid black lines are upper and lower limits (a) TEC observation on 10 April 2018, anomaly time: 7.683 UTC. (b) TEC observation on 16 April 2018, anomaly time: 3.55 and 9.783 UTC. (c) TEC observation on 20 April 2018, anomaly time: 9.617 UTC. (d) TEC observation on 5 May 2018, anomaly time: 16.383 UTC. (f) TEC observation on 7 May 2018, anomaly time: 8.45 UTC. (g) TEC observation on 8 May 2018, anomaly time: 8.4 UTC. (g) TEC observation on 9 May 2018, anomaly time: 5.983 UTC.

Table 1. Shows anomaly time detected for each anomalous day and nature of anomaly observed vis a vis Geomagnetic storm condition during the observation period

Anomaly date	Anomaly Time (UTC)	Nature of anomaly	Geomagnetic storm condition	Days before earthquake
10-Apr-18	7.683	crossing upper boundary	Quiet	30
16-Apr-18	9.783	crossing upper boundary	Quiet	24
16-Apr-18	3.55	crossing lower boundary	Quiet	24
20-Apr-18	9.617	crossing upper boundary	Quiet	19
5-May-18	16.383	crossing upper boundary	Quiet	4
6-May-18	8.433	crossing upper boundary	storm	3
7-May-18	8.45	crossing upper boundary	Quiet	2
8-May-18	8.4	crossing upper boundary	Quiet	1
9-May-18	5.983	crossing upper boundary	Quiet	0

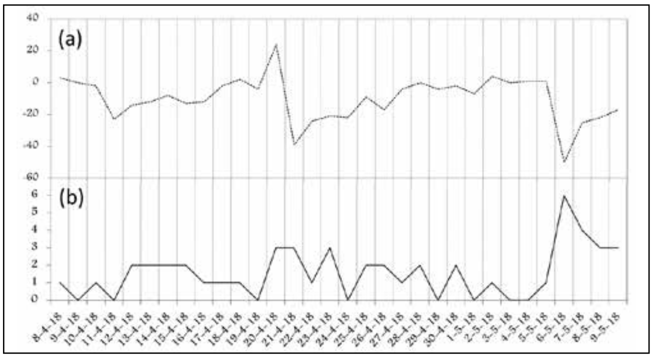

Fig 3. Shows day wise Dst values from World Data Centre for Geomagnetism and Space magnetism. Very high negative values are observed on 21th April and on 6th May 2018.

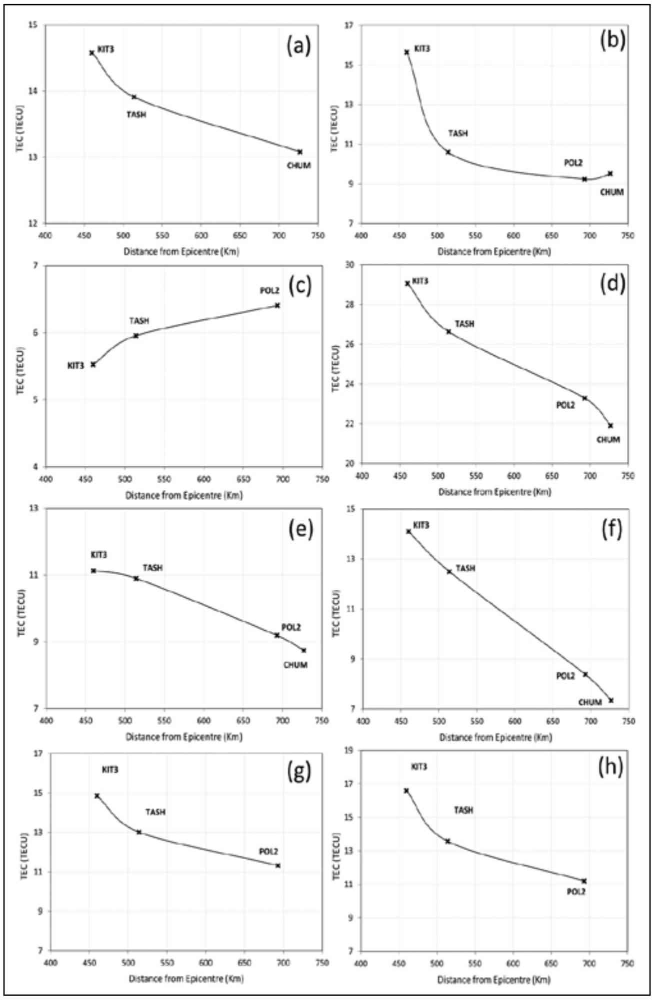

Fig 4. Shows TEC observations versus epicentre distance from 3-4 stations for the anomalous days at detected anomaly time. Y axis represent the actual TEC observed whereas X axis is the distance from epicentre. KIT3, TASH, POL2 and CHUM are the IGS stations (a) TEC observation on 10 April 2018 at 7.638 UTC. (b) TEC observation on 16 April 2018 at 9.738 UTC. (c) TEC observation on 16 April 2018 at 3.55 UTC. (d) TEC observation on 20 April 2018 at 9.617 UTC. (e) TEC observation on 5 May 2018 at 16.383 UTC. (f) TEC observation on 6 May 2018 at 8.433 UTC. (g) TEC observation on 7 May 2018 at 8.45 UTC. (h) TEC observation on 8 May 2018 at 8.4 UTC.

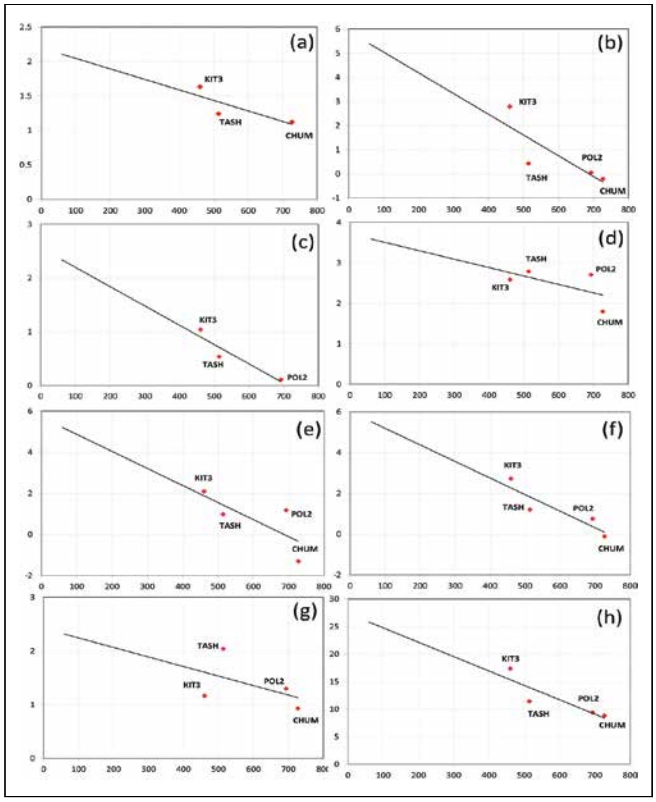

Fig 5. Shows magnitude of TEC anomaly versus epicentre distance from 3-4 stations for the anomalous days at detected anomaly time. Y axis represent the magnitude of TEC anomaly in TEC UNIT whereas X axis is the distance from epicentre. KIT3, TASH, POL2 and CHUM are the IGS stations (a) Amount of TEC anomaly on 10 April 2018 at 7.638 UTC. (b) Amount of TEC anomaly on 16 April 2018 at 9.738 UTC. (c) Amount of TEC anomaly on 16 April 2018 at 3.55 UTC. (d) Amount of TEC anomaly on 5 May 2018 at 16.383 UTC. (e) Amount of TEC anomaly on 7 May 2018 at 8.45 UTC. (f) Amount of TEC anomaly on 8 May 2018 at 8.4 UTC. (g) Amount of TEC anomaly on 9 May 2018 at 5.983 UTC. (h) Amount of TEC anomaly on 20 April 2018 at 9.617 UTC

using Dst data from World Data Centre for Geomagnetism and Space magnetism (WDC). Dst index shows negative values for a geomagnetic storm. A geomagnetic storm is marked by a value crossing -30 unit, where as severe geomagnetic storm is marked by values crossing about -50 unit. Further TEC anomalies for geomagnetic storm was also checked with Kp indices. Kp indices shows positive values crossing 5 unit in the case of geomagnetic storm. Any anomaly observed on day other than that on geomagnetically disturbed day defined by Dst and Kp as discussed above may be seismic in origin and are considered as anomaly. In present analysis Dst index shows values less than -30 on 21 April 2018 and 6th May 2018 which could be the signature for geomagnetic storm (fig 3). The Kp on 6th may 2018 also shows values more than 5 units indication storm. Both positive (crossing upper limit) and negative (crossing lower limit) anomalies were observed on 16th April 2018 and its corresponding anomaly time was 9.783 UTC and 3.55 UTC respectively. The TEC observation for all the anomalous days are shown in figure 2 and the anomaly time detected for these anomalous days are shown in table 1**.**

TEC variation with distance from the epicentre

Anomaly observed at different stations on 20th April 2018 showed maximum anomalous behaviour at observation station KIT3, which lies inside the radius of earthquake preparation zone (figure 1). TASH also showed high values in some cases as it lies near to the radius of earthquake preparation zone (40km from KIT3).

A huge decrement was observed in the magnitude of TEC anomaly when moved just 30 km towards TASH and further towards POL2 (i.e., away from epicentre). 7th and 8th May 2018 showed a steep decreasing trend from KIT3 to TASH and slightly linear change between TASH and POL2 observation stations as shown in figure 4. From the plot, it is inferred that the closest observation station (KIT3) to epicentre showed slight higher TEC values from rest of the stations which may be attributed to a definite relationship with the epicentre distance of impending earthquake.

The next closest observation station (TASH) also showed slight higher TEC observation but lower than KIT3 which is expected as both lies close to each other. The rest stations showed minimal variation. Hence a general decreasing trend was observed as we go farther from the epicentre. It was observed that the Tajikistan earthquake of magnitude 6.2 has major effect up to 500 km from the epicentre. Minor effects were seen at 500 to 600 km from epicentre and from 600 km to 700 km, the seismogenic effects was seen minimal. Therefore it is observed that for positive anomaly TEC concentration increases towards the epicentre. Negative anomaly on 16th April 2018 at 3.55 UTC shows completely opposite trend to that of positive anomalies which is rather expected. For negative anomaly, TEC concentration decreases towards the epicentre as shown in figure 4 (c). KIT3 showed very prominent negative anomaly which was not prominent with rest of the stations. This may infer that the negative anomaly may be observed in the close proximity of earthquake preparation zone.

Magnitude of TEC anomaly versus epicentre distance

4 IGS stations data was analysed in making a general relationship of TEC anomaly with respect to the distance from the epicentre. This relationship can explain why it is important to take stations within the preparation zone and give a rough idea about the extent up to which ionosphere can get disturbed due to the impending earthquake of certain magnitude. The relationship was established by computing the TEC anomaly values i.e., TEC minus upper limit in case of positive anomaly and lower limit minus TEC for negative anomaly.

The idea is to compute the magnitude of TEC anomaly as we move towards the epicentre. As the distance of one station to other is not regular, a linear plot is not expected but a general trend must be achieved if the anomaly was of seismic origin. KIT3, TASH and POL2 lies within the earthquake preparation zone where as the fourth station considered in present analysis was slightly outside the radius of earthquake preparation zone. Behaviour of anomalies with distance from the epicentre was also being checked for getting an insight of the extent of the seismogenic effect on the ionospheric TEC.

Anomalies observed at KIT3 station was taken as a reference for determining anomalous day and exact anomaly time of the anomalous day was computed as described in above section (TEC anomaly and anomaly time detection). Keeping time fixed, the magnitude of anomaly was computed for all other stations. It was observed that with increasing distance, the magnitude of TEC anomaly decreases in all the cases which is completely analogous to the fact that the maximum anomalous values was observed near to the earthquake epicentre (figure 5). The magnitude of anomaly on the day of earthquake showed rather a complex behaviour. TASH shows the maximum anomaly at 5.983 UTC followed by POL2 and KIT3. However the overall trend increases towards the epicentre.

Conclusion

The study has revealed that Total Electron Content may be used as one of the parameter for seismic precursor. The analysis also suggest the degree and distance up to which ionospheric TEC can be exasperated because of the impending earthquake. The TEC anomaly (1 to 3 TEC units) can be considered as antecedents to gentle seismic tremors, while higher TEC varieties may encountered before larger magnitude earthquakes. These unpretentious changes are effectively recorded by close-by GNSS receivers and can be considered for testing, assessment, and general portrayal of seismo-tectonics and ionospheric coupling.

Behaviour of anomalies with distance from epicentre was also analysed which showed a downward trend indicating that the GNNS stations are not able to detect anomalies efficiently as we move away from the earthquake epicentre which suggests possibilities of epicentre detection with large GNSS stations. Hence, it is vital to screen constantly TEC utilizing GNSS receivers, and, at whatever point there is peculiar anomalies, which could be high or low. However, the challenge lies in data accessibility from ground stations (CORS/GNSS) and their analysis in real time on a daily basis which is the way forward and urgent need for earthquake precursor research

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PPP: the way ahead for solving land tenure issues and contribute to sustainable development?

In this article, I propose strategies for practitioners to involve the private sector in land administration services while at the same time ensuring there is a contribution to the achievement of the SDGs

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For over 20 years, governments in developing and developed countries have invested worldwide on improving the certainty of rights, restrictions and responsibilities by implementing land tenure reform projects. Traditionally efforts have been focused primarily on digitalization of land right registry and cadastre systems and - more recently - spatial planning and natural resources systems. Most of the investments are focused on large scale systematic registration activities aimed at improving coverage, building information technology (IT) systems, reviewing and reforming institutions, technical capacity building and improving the regulatory framework.

There is an increasing trend across most developed and developing countries to involve the private sector in the delivery of land cadastre and registration services. This trend follows significant results in the infrastructure sector (in areas such as ports, roads and hospitals) where many developed and developing countries have leveraged new investment by making the private sector and active partner that takes risks, invest resources and achieve social results under what is known as a public-private partnership (PPP) model.

Results from other sectors have demonstrated that under a PPP arrangement, better financial options and distribution of risks could be achieved. However, we have also learnt that PPPs need to be well designed to achieve value-for-money for society as the private sector always would expert revenue out of a PPP.

Learning from experiences as the supervisor of a large e-governance PPP in Colombia; as financial analyst and designer of a PPP proposal in Africa and after supporting the policy efforts of the World Bank in the field; I have clear in my mind that land PPPs are not a silver bullet to solve current funding challenges and lack of innovation many countries around the world are facing in their cadastre and land management systems.

Are PPP part of the future? Yes, with no doubts as we already have seen is happening for over 20 years in Canada and it is significantly used today in Australia, the country

Multiple studies have reviewed approaches conducted in developed and developing studies. However, after over 30 years of investment in developing countries land administration systems, it is difficult to identify approaches that are likely to work in all context with probably the best cadastre and land titling system in the World.

So, in a future in where PPPs are broadly used in the land administration sector, how we ensure these projects are not just profitable for the private sector but primarily support the achievement of the United Nations Sustainable Development Goals (SDGs)?

In this article, I propose strategies for practitioners to involve the private sector in land administration services while at the same time ensuring there is a contribution to the achievement of the SDGs. Many of these strategies I have writtenS them after understanding what has worked well (like in Switzerland) and what lessons we have learnt from challenging land PPPS (like in the Philippines). Although most of the strategies focus on helping the government design good land PPPs. However, the private sector interested in be an active part of these coming opportunities, will benefit from these strategies when bidding or submitting an unsolicited proposal.

Strategy 1: Use what has proven to work

Multiple studies have reviewed approaches conducted in developed and developing studies. However, after over 30 years of investment in developing countries land administration systems, it is difficult to identify approaches that are likely to work in all context.

In any case, there are some general views in the international community of crucial principles most land reform projects should follow to be successful and contribute to sustainable development.

Acknowledging this space is always changing; the following list presents some principles today for land reform projects that are considered to be in line with the private participation focus of land PPPs:

- Fit-for-purpose: improve land tenure rights by fostering innovation in approaches and new technologies in land administration with the objective of optimising resources by investing in the collection and processing of land information in a way that best fits the specific conditions
- Data and process standardisation: standardisation of data topology and processes within a particular jurisdiction to improve information sharing, optimising resources and reduce errors and duplication
- Community mapping and crowdsourcing methodologies: the use of technologies and methods, particularly portable devices and open public participation, to collect information with the community as an active participating party with roles and responsibilities

Based on the cases in Switzerland and Australia in where the private participation is segmented to where it best suits the local and national needs, land reform project designers should consider involving the private sector only in segments or areas where it can better help the government in achieving SDGs

Strategy 2: Involve the private sector in the area where it can best perform

Based on the cases in Switzerland and Australia in where the private participation is segmented to where it best suits the local and national needs, land reform project designers should consider involving the private sector only in segments or areas where it can better help the government in achieving SDGs.

These areas of segmentation could be either geographical or institutional. In Switzerland, the roles of surveyors vary depending on the canton while in Australia (both in NSW and Victoria) the privatisation occurred on the land registry and not the cadastre.

When doing this segmentation, project designers could better identify if which of the related SDGs could be better addressed. In many cases, cross-subsidies in the form of packages in the land PPP where highly profitable areas are bounded with those that might not raise revenue but could table better gender equality (SDG5) and title for the poor (SDG1).

Strategy 3: Cross-service approaches

One of the most significant advantages of the Karnataka in India is the delegation of multiple land administration services into one PPP. Designing cross-service approaches in land PPP and other projects could better allow supporting the achievement of SDGs. In particular, joining the land tax collection service with land registry and cadastre services opens the opportunity for the private operator to invest in low-income areas (SDG1) with the prospectus of generating wealth in the long term and improve tax collection. Similarly, like in Karnataka, titling activities could be directly related to other fees such as crop registration, building and development permits and forest licenses, creating additional sources of income to expand land tenure systems.

Strategy 4: Work with the trusted part of the private sector

Success in Switzerland of its delegation of cadastre services to the private sector is underpinned by the trust that exists on the

Success in Switzerland of its delegation of cadastre services to the private sector is underpinned by the trust that exists on the surveyor's registration system. Similarly, privatisations in Australia are considering very successful from a financial point of view because the government has created mechanisms to trust private investment banks

surveyor's registration system. Similarly, privatisations in Australia are considering very successful from a financial point of view because the government has created mechanisms to trust private investment banks and pension funds as owners of land administration services.

Therefore, project designer should consider delegating the land administration services on those segments of the private sector that are well trusted by society. In some cases, it might be the financial sector, the insurance sector, certain professions (lawyers, surveyors) or private associations (such as the chambers of commerce).

Strategy 5: Result-based revenue

A key opportunity politicians have is to define the objective of a project they are willing to support which in most cases should be aligned to the SDGs.

Therefore, project designers should ensure that revenue received by the private sector is achieved when these objectives are met. The case in the Philippine demonstrates a situation where this strategy was not used and cause the opposite effect: revenue conditions limit achieving better land tenure systems.

Result-based revenue would be a particularly useful strategy for projects focusing on gender equality. For example, extra revenue could be negotiated with a private operator of a land system to those titling registration that includes women, encouraging this private operator to invest and prioritize equal land ownership in the areas covered by the project.

In conclusion, a future with many land PPP projects across the world is possible (this is the reality in many other sectors). Examples around the world where the private sector plays a significant role in running land administration systems have provided valuable lessons. Notably, all future projects need for government to have the right financial, administrative, legal and regulatory framework in place to ensure private participation under a partnership arrangement and not just transfer the problem.

I hope strategies proposed open conversations between different parties and allow to shape this land PPP trend into a future full of strong land tenure in all continents.

4th JISDM, Athens, 2019

The 4th *Joint International Symposium on Deformation Monitoring* (JISDM) was held on May 15th – 17th in Athens, Greece. JISDM carries the 40 years long tradition of the FIG and IAG joint symposia in the field of deformation monitoring and more recently the active sponsorship of ISPRS. The symposium aimed to connect research in deformation measurement / techniques, analysis and interpretation with advanced practice. The *School of Rural and Surveying Engineering (SRSE)* of the *National Technical University of Athens (NTUA)* was the host institution of this event.

During the three days of the symposium 95 oral and 37 poster presentations were given originating from 27 countries from 5 continents. Conference topics were related to core methodological, technical and practical achievements in the field of deformation monitoring. Technical sessions were organized in 13 thematic areas that include: QC/QA and optimization techniques in deformation analysis; new concepts for GNSS-based monitoring; point cloud-based space-temporal deformations; reference frames and geodynamics; vibration monitoring and dynamics; ground and spaceborne radar; monitoring of cultural heritage; deformation monitoring for construction engineering; bridge monitoring; dam monitoring; multi-sensor systems and new concepts for deformation measurements; UAV for change detection and deformation monitoring; monitoring of geohazards. *https://jisdm2019.org*

Total solution

Sun as backsight

- The Best 6-Engines RTK system of GPS, GLONASS, Galileo and BeiDou with verification features.
- “J-Mate”; The Best Optical, Laser, and Angular Encoders to mate with the TRIUMPH-LS where there is no GNSS signal. And Sun Seek feature for Backsight.
- J-Tip a tiny but powerful magnetic locator.
- Free DPOS to process your date with COR Stations.

“While I had the J-Mate running, I performed a solar observation for orientation. That was about the sweetest execution I could imagine. I see so much potential here.”

John Evers, PLS

Auto Verify...
Auto Validate...

RTK V6+

GPS, GLONASS, Galileo, BeiDou

six engines plus one support

J-Tip

“I don’t know how the other surveyors do it without Javad ! I’ll back my data up all day long with the confidence of the Javad system.”

see full letter in the last page

Introduction to J-Mate

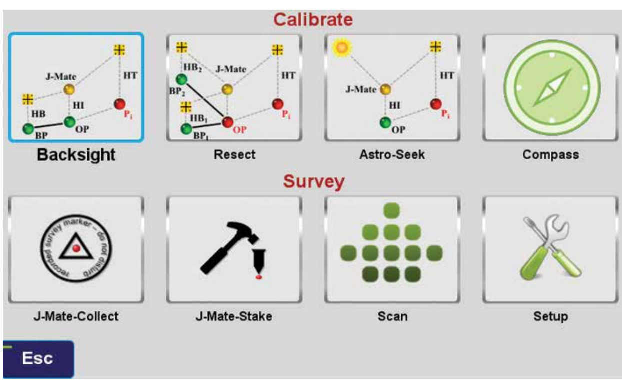
Let's set the record straight: J-Mate is not a total-station. **J-Mate and TRIUMPH-LS together** make the **"Total Solution"** which is a combination of GNSS, encoder and laser range measurements that **together do a lot more than a total station**. For long distances you use GNSS and for short distances (maximum of 100 meters) you use the J-Mate along with the TRIUMPH-LS. Together they provide RTK level accuracy (few centimeters) in ranges **from zero to infinity**.

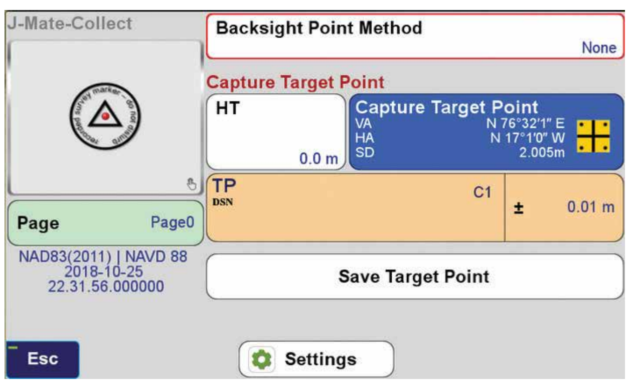
As with the TRIUMPH-LS, with the J-Mate we also provide software improvement updates regularly and free of charge. Download the J-Mate update in your TRIUMPH-LS and then inject it to the J-Mate. The J-Mate SSID will be in this format JMatexxx, where xxx is your J-Mate's serial number. After a Wi-Fi connection is established, click the J-Mate icon and then click Setup. When you are prompted to connect to the J-Mate, click yes and then follow the remaining prompts.

Connecting the TRIUMPH-LS to the J-Mate

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

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





VB-RTK

Get on the Grid with VB-RTK. For over a decade American surveyors have been using the National Geodetic Survey's Online Positioning User Service. Surveyors employing RTK have been a significant share of the user segment of OPUS.

A significant share of OPUS users are surveyors using RTK. Often a surveyor will set up his base on a new, unknown position and allow an autonomous (or standalone) position to be used for the base coordinates. While he is performing his RTK work with fixed vectors between his base and rover, he stores data at the base to be submitted at a later time to OPUS. Once he is finished with his work, he downloads this file to his computer, converts the file if necessary, and submits it to OPUS. He then receives an email response back with a precisely determined coordinate for his base station. He then must take this coordinate, relate the coordinate to his project coordinate system, and then translate the work from the autonomous (or standalone) position he used in the field to this new coordinate. This procedure can produce excellent results and anchors the survey to the NSRS. The down side to this is that there are several steps that must be carefully observed and each of these error prone steps costs time.

With J-Field data collection software, JAVAD has been automating many tasks that surveyors have been doing for years, making the tasks more efficient and reducing sources of potential error. One example, **"Verify RTK with V6 Resets"**, is being recognized by surveyors across the country as the most accurate and efficient way to confidently determine RTK positions. Rather than taking a shot, manually resetting (or dumping) the receiver and taking a second shot for comparison, Verify RTK does this automatically with a user defined number of reset iterations.

JAVAD has continued this automation philosophy by dramatically simplifying the process of translating a survey from an autonomous base position to precise geodetic coordinates with **VB-RTK (Verify Base – RTK)**. Using the JAVAD GNSS, Data Processing Online Service (DPOS), which is powered by the proven JAVAD GNSS Justin processing engine. **This multi-level process is done in J-Field completely automatically.**

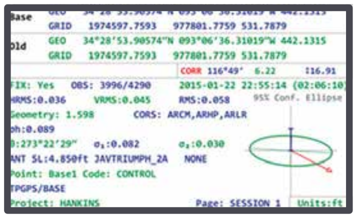
Once an RTK session has been completed, the user returns to his JAVAD base receiver and presses "Stop Base" on the TRIUMPH-LS. **At this point, the raw data file that has been recording at the base during the session, is wirelessly downloaded from the base to the TRIUMPH-LS. When the download is complete, the user returns to his office and connects the TRIUMPH-LS to the internet.**

When internet connection is made, the file is automatically transmitted to one of the JAVAD GNSS servers for post processing. Once data and ephemerides are available for the session, **DPOS** processes the file and returns results to the waiting TRIUMPH-LS. This all takes place within minutes.

Once results are returned, the new coordinates for the base are shown related to your coordinate system (including localization systems).

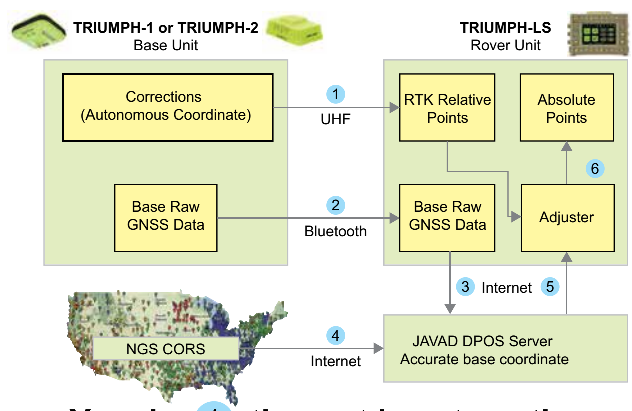
The horizontal and vertical differences between the base coordinates used and the DPOS determined coordinates are shown. **This provides for an instant check of the base coordinates and instrument height** if the base were set up on a known position.

All rover points associated with that base session translate automatically in seconds. Only those rover points associated with that base session translate.



If the user is not satisfied with the results of the DPOS solution and wants to revert back to the original RTK positions, he simply clicks **"Undo"**.This process is immune to base instrument height errors because the internal vectors between base to rover are related to the antenna, not the ground point. So, an accidental entry for the base height of 543' instead of 5.43' can be resolved by VB-RTK.

In addition to the advantages of having your RTK base station near your work area, which gives you much more accurate and faster fixes, especially in difficult areas, and saving you the RTN fees; perhaps most important of all, your work is now precisely related to one of the most accurate geodetic control networks in history – the NGS CORS. Every rover point is only two vectors removed from the CORS (CORS to base, base to rover). This means that you can return again someday to find your monuments easily and accurately. This makes your records incredibly more valuable to both you and future surveyors. J-Field also has the unique ability to load and view every point you have ever surveyed from all the projects in its system. By combining this feature with a **distance filter** in its advanced set of filters, you can easily view all the points you have previously surveyed within a given distance of a point in your current project. Having an easily accessible record of nearby georeferenced coordinates is very beneficial as you may have previously located monuments in past surveys that are beneficial in your current project. J-Field allows you to easily copy these selected points into your current project, eliminating the need for you to resurvey them. All of this is available automatically on the world's most advanced RTK rover – **the TRIUMPH-LS**.



You do 1, the rest is automatic

Concepts Behind RTK Verification

Fundamental in the determination of GNSS solutions is calculating the correct number of full wavelengths (so-called ***fixing ambiguities***) in order to figure out the distances from the satellites to the receiver. In doing Real Time Kinematic (RTK) surveying, we need it fast and we need it to be correct.

Multipath, the reflections of GNSS signals from ground and nearby objects and structures create their own indirect measurements from the satellites to the GNSS receiver. It's as if your measuring tape is bent around an obstacle such as a tree instead of a free and clear line of sight between two points. No calculator is going to improve this result.

TRIUMPH-LS has sophisticated hardware to distinguish between the direct and indirect signals and remove most of the indirect signals. It also reports the amount of indirect signal that has been removed. The worst case is when the receiver doesn't see the direct signal at all; e.g., the satellite is behind a building, but it's still receiving the signal reflected off of the nearby structure. It is the task of the RTK engines to isolate such indirect signals and then exclude them from the calculations.

If too many of the signals are affected by severe multipath or indirect signals, no solution may be found. Remember, indirect signals are analogous to the bent measuring tape! When you're preforming RTK surveying, observe your environment and come to recognize that the structures around you are like mirrors for GNSS signals.

The other aspect impacting the veracity of a fixed solution is when there are weak GNSS signals. Frequently, weak signals are due to their penetration directly through tree canopy.

While the **TRIUMPH-LS** can't move the obstacles that are creating multipath out of the way, its sophisticated hardware has advanced multipath reduction sub-system, its tracking software is designed to handle even the weakest signals, and its **J-Field** software provides reliable RTK solutions like no other system with its **Automatic RTK Verification System**. J-Field also has ample tools to demonstrate the reliability of the solution or warn against questionable results. You can readily see that without such tools other systems can provide you wrong and misleading solutions.

J-Field uses six RTK engines (Figure 1) running in parallel plus a support engine to monitor and aid the six engines. Each engine uses a different criteria and mathematical method tailored to resolve ambiguities in different conditions. These six parallel engines not only verify robust solutions but also maximize the possibility of providing solutions in all conditions.

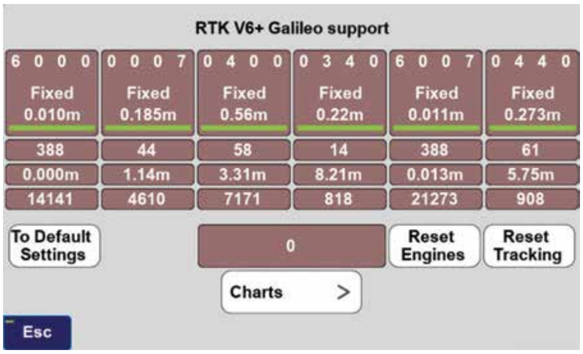


Figure 1 *V6+ six RTK Engines*

User Defined Verification Tools

J-Field provides the option for you to specify the **Minimum Number of Fixed RTK Engines** in verifying solutions **N** times before a position is automatically accepted where **N** is a user defined value.

J-Field employs two metrics to evaluate the performance of its RTK system of six engines: **1) Confidence Counter, and 2) Consistency Counter.** (Figure 2)

Confidence Counter

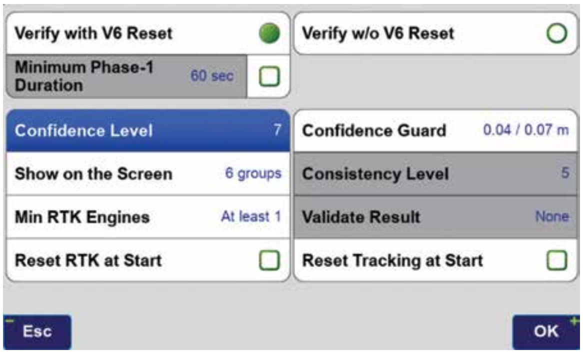


Figure 2 *Verify Settings*

This metric is incremented each time an engine is reset, ambiguities are recalculated, and the solution is in agreement with the previous ones (as defined by the **Confidence Guard (CG)**, default value 5 cm) is achieved. The Confidence Counter increments by 1, 1.25, 1.5, 1.75, 2.0, and 2.5 depending on the number of reset engines that fix in that epoch.

Consistency Counter

The Consistency Counter is incremented each time a solution is in agreement with the previous ones (as defined by the Confidence Guard) irrespective of engines being reset or not. The Consistency Counter is incremented by 0.0, 0.1, 0.25, 0.5, 1.0 and 1.5 depending on the number of fixed engines used in that epoch. Note that one fixed engine gets no credit and 6 fixed engines gets a **Consistency Credit** of 1.5.

Using these Confidence and Consistency verification tools, J-Field has two options to achieve reliable RTK solutions: **1) Verify With Automatic RTK Engines Resets** and **2) Verify Without Automatic RTK Engines Resets.**

Verify with Automatic RTK Engines Resets

This method has two steps: **1) Confidence Building** and **2) Smoothing and verifying**.

- **Step One.** In Step One, fixed engines are reset and solutions are collected into groups. Each group contains all the epochs located within a specified radius (the CG value) from its center and new groups are created as necessary so that all epochs fall into at least one group. Each group has its own Epoch Counter, Confidence Level and Elapsed Time. A point may fall into more than one group. The groups are sorted from best to last by the sum of their Time and Confidence with the current best group being shown within [ ] and others within ( ). Step One continues until a group reaches the Confidence Level. (Figure 3)
- **Step Two.** During Step Two the engines are

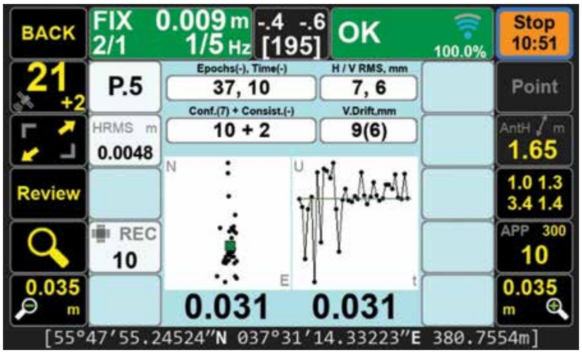


***Figure 3** End of Step one*

not reset and solutions which are located inside the CG of the selected Group are added to that Group for the remaining number of epochs that user has requested (Epoch Number, EN) in the How to Stop screen. Epochs which are outside the CG of the selected Group will be stored in a new (or previously created) group; the RTK engines are reset if the epoch falls outside a sphere with a radius twice that of the CG and the process will then revert back to Step One and the Confidence Level of the current group will be reset to 0.

If the number of epochs falling outside of the current group (but less than 2X outside it) reaches 33% of epochs collected so far, the process will revert back to Step One. Previously created groups will remain intact and once an existing or previously created group meets the Step One criteria, it will pass to Step Two. (Figure 4)

In both steps the Consistency Counter is also incremented as mentioned earlier.

You can manually reset all RTK engines via the V6-RTK engines screen (Figure 1), or assign this

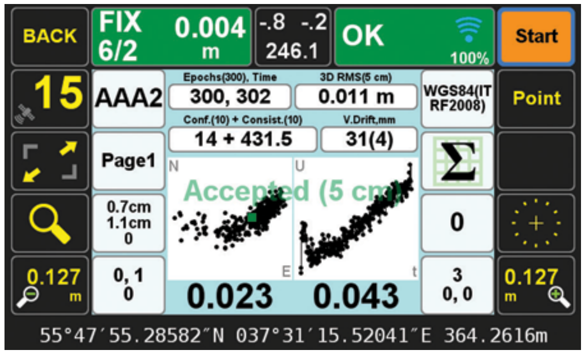


***Figure 4** End of Step 2*

reset function to any one of the U1 to U4 hardware buttons in front of the TRIUMPH-LS for easy access.

Verify without Automatic RTK Engines Resets:

In this method we don't force the RTK engines to reset but rely mostly on the Consistency Counter. There will be only one group as selected by the first epoch. Solutions that are not within the Guard band of the current average will be thrown out. If more than 30% of solutions are thrown out, the process will restart.

The horizontal and vertical graphs presented in both approaches also help the surveyor to evaluate the final solution. The linear drift of the vertical solution and its drift RMS are also shown above the vertical graph. A high linear drift (more than few centimeters) reveals severe multipath or, in rare cases, a wrong ambiguity fix. Pay close attention to the vertical drift and the horizontal and vertical scatter plots of epochs. Consider the scatter plots as doctors examine X-rays to determine anomalies.

The desired **Confidence Level** and **Consistency Level** are user selectable. Default values are 10. These parameters along with the desired number of epochs must be reached before a solution is provided.

In either case there is also a **Validate** option which, when selected, will reset all engines at the end of the collection and continues with 10 more epochs to validate if the solution is within the desired boundary of the Confidence Guard. (Figure 2) Minimum number of engines for the Validation Phase is user selectable.

***Figure 5** How to Start*

Figure 6 *How to Stop*

In either case, if Auto-Accept is activated, the position will be automatically accepted if the RMS of the final solution is less than what user has selected in the Auto-Accept screen. (Figure 6)

You can also use **Auto-Restart** if you want to monitor structures or test the RTK system unattended. (Figure 6)

Screen Shots of Action Screen

Action Screen shows detailed information about each point collected. Screen shots can automatically be attached to each point and saved at the end of each collection (Figure 7). In **Verify with Automatic RTK Engines Resets** screen shots at the end of both Step One and Step Two are saved (Figures 3

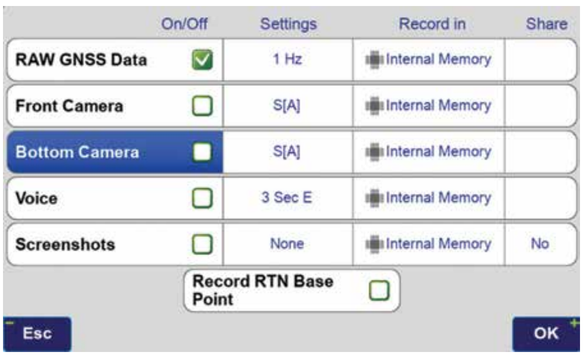


Figure 7 *What to record screen*

and 4). In Action screen there are 8 white boxes that selected items can be viewed on them.

Review Screen

View cluster of all points. Select the desired point to see its point cluster (Figure 8). Click the icons to see additional details about that point (Figure 9) including the distance and direction to the current point (Figure 10).

The effects of multipath, ionosphere, orbit, and other sources of problems somewhat exponentially increase as the baseline length increases. In a VRS/RTN scheme your **actual** baseline length is the actual distance to the nearest base station. The **virtual** base station that is mathematically created is not the actual length. We strongly recommend using your own base station near your job site in a

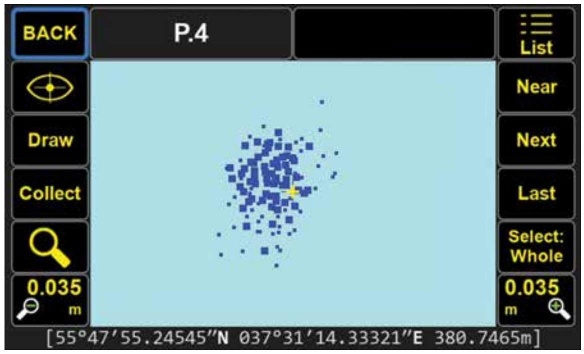


Figure 8 *Review screen shows cluster of 386 points*

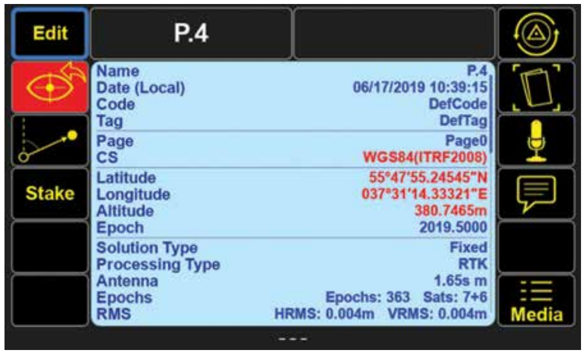


Figure 9 *Detailed information on selected point (scroll to see all information)*

Figure 10 *Distance and direction from the current point to the selected point*

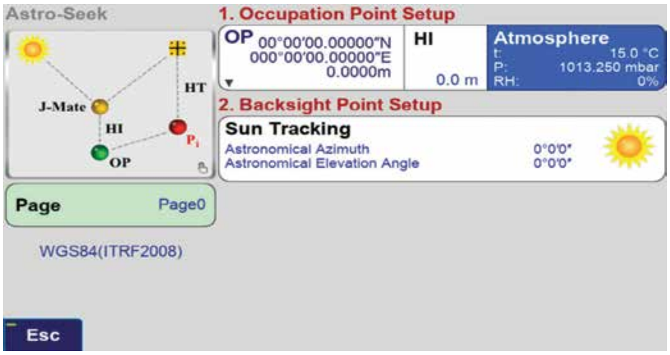
Verified-Base RTK (VB-RTK) scheme.

In addition to providing you with the most reliable RTK solutions (especially true in remote areas where cell coverage is hit or miss), using your own base receiver allows you to easily tie your solutions to well-established IGS/NGS spatial reference systems through Javad's exclusive Data Processing Online Service (DPOS) and J-Field's user-friendly Base/Rover Setup. Note that post-processed results returned to the TRIUMPH-LS using DPOS are dependent on the availability of orbital data from NGS and may require several hours. Alternatively, if you don't have access to IGS-type stations to use DPOS, you can select an open area near your job site and use TRIUMPH-LS to obtain its position via RTN networks for about 5 minutes.

Backsight point and the Sun

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

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



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

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

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

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

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

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

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

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

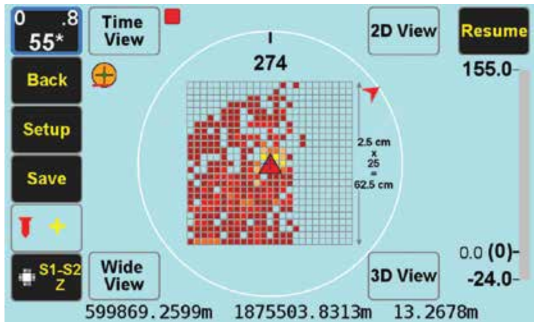
If GNSS signals are not available at the Occupation Point, click the “J-Mate-Resect” icon to shoot two known points to establish its accurate position and calibrate its encoders. Then continue to shoot the unknown points.

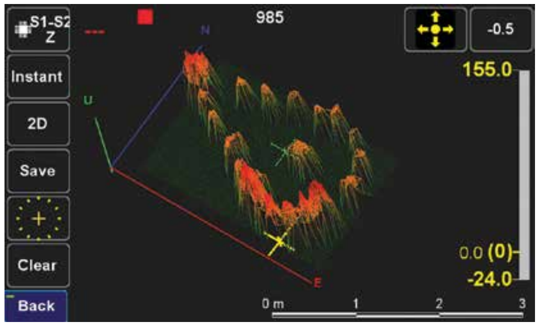
Astro-Seek feature: Sun as the Backsight point!

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

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

J-Tip





TRIUMPH-LS tags coordinates with magnetic values, It also guides you to top of the item to survey it.

The Mag View focuses only on the mag object with the highest mag value.

The audio and graphical bar show the magnitude of the magnetic object.

In “Setup” you can select the cell size and the size of the field you want to scan.

2D and 3D views of the field show the magnetic objects that have been scanned.

Zooming the 2D and 3D screens can show the shape of the magnetic objects under the ground.

For many sophisticated features of the J-Tip see its Users Manual in www.javad.com

What a great little system! I’ve been using it a good bit in the last few months since purchased controller back in November. Really appreciate all that I’ve learned here on the forum from folks like Nate the Surveyor, Shawn Billings, Matthew Sibole, others and all the developers on the Javad Team. Although this system has only a quarter of the channels as the Triumph-LS, it still amazes me in high multi-path areas using the RTN. Once you read the manual several times, especially on RTK Verification, everything falls into place. There is so many ways to verify your position if there’s any doubt; i.e., distance to last point, confidence and consistency levels, verification with selected # engines, saving of raw data to post process, etc.

Last project was cutting out 33 acres, part of the boundary was at the corner of a 150 acre tract. Located all the existing corners and the proposed corners with the owner (1 day field work). Computed the acreage (1/2 day office) and then staked out the corners and staked a few lines using my brothers Triumph-LS with radio RTK (1 day field work). This site was very bad with multi-path (pine forests and hardwood lands). I don’t think I could have used the Victor-LS/Triumph-2 in these conditions for stake out (I didn’t try). The Triumph-LS ruled in these conditions and minimal time was spent on station, staking out the actual new corners. Verification of my original locations performed with the Victor-LS/Triumph-2 checked < 0.1’ both horizontal and vertically. Also re-measured all staked points for verification while on station. Surveying is so much fun again when I can get out of the office!!!

I don’t know how the other surveyors do it without Javad! I’ll back my data up all day long with the confidence of the Javad system.

Bryan Enfinger

Thanks a lot Bryan. If you don’t mind, I would like to share your experience in our publications.

Javad Ashjaee

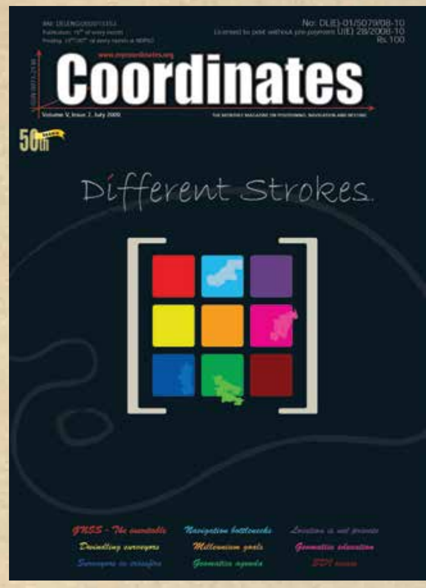
I just get excited using the equipment, it’s light years beyond anything available! I really enjoy finding time to keep learning on this machine, I’ve always enjoyed learning new things and this is the greatest yet. We were part of the trial team originally, my brother Buck really loves the Triumph-LS/Triumph-2 system.

Here’s an attached pic from the collect screen. I was verifying PT23 with two additional shots with the EPOCH count set at 10, time set at 180 secs and the APP set at 3600 secs (1 hour) for raw data logging if I didn’t get any fixed positions. This was in a wooded area with 25 year old pines and hardwoods with many leaves. I was amazed I got a fix with 5 engines within approx 1 minute and met the confidence and consistency levels set. Notice the “distance to last” measurement, all this with the Victor-LS/Triumph-2 system. While I know this won’t occur in all situations in the time frame shown here, even if it didn’t get a fix I had the raw data to post process using short baselines (i.e., another base <1.0 mile away).

Bryan Enfinger ENFINGER & ASSOCIATES PROFESSIONAL LAND SURVEYORS

In Coordinates

10 years before...



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Different strokes

The article presents views and opinion about current issues and priorities surrounding Geomatics and GNSS by experts in their repective domain.

GNSS: The international cooperation is inevitable

Akio Yasuda
Professor Emeritus
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Navigation: Accuracy, availability, infrastructure and cost of deployment

Dr. Naser El-Sheimy
University of Calgary, Canada

Dr. Chris Goodall
Trusted Positioning Inc, Calgary, Canada

Surveyors are caught in the crossfi re

Brent A. Jones
PE, PLS Industry Manager, ESRI Survey/Cadastre/Engineering

SDI: Human issues are most critical

Al Stevens
GSDI Secretariat

Remote Sensing: Contributing to Millennium Development Goals

Orhan ALTAN
President of ISPRS Istanbul Technical University, Turkey

Knowing where you are is no longer a private matter

Professor George Cho
University of Canberra, Australia

Geomatics education: from specialist to generalist

Prof Dr-Ing Dietrich Schröder
University of Applied Sciences Stuttgart, Germany

Geomatics in India - A Proposed Agenda

Prof P Misra
Consultant in Land Information Technologies

Surveying: Dwindling number of qualifi ed surveying professionals

Frank Derby
Ph.D., Associate Professor of Surveying and GIS The Pennsylvania State University, USA

Malaysia precise positioning

Norsuzila Ya'acob, Mardina Abdullah and Mahamod Ismail
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An ionospheric delay model was developed using modifi ed Jones 3-D ray tracing program to accurately determine the difference in ionospheric delay expected over a short baseline so that a more accurate differential GPS correction could be made

Static precise point positioning using triple-constellation GNSS

This paper evaluates the static PPP solutions using triple-constellation GNSS in seven different modes. The evaluation is done in terms of positioning accuracy, convergence time and Positional Dilution of Precision (PDOP)

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Precise Point Positioning (PPP) is a versatile tool that has drawn attention among researchers in processing static and kinematic Global Navigation Satellite System (GNSS) datasets (Choy et al. 2013; Gao and Chen 2004; Zhang et al. 2015; Zumberge et al. 1997). PPP requires long observation period to attain a desired positioning accuracy (Bisnath and Gao 2009). To achieve ten centimetres (10 cm) or better two-dimensional (2D) positioning accuracy, PPP needs a convergence time of about 50 minutes (50 min)(Choy, Bisnath, and Rizos 2017). The convergence time of a PPP solution vary based on receiver position dynamics, observation quality, sampling rate, number and satellite vehicles (SVs) in view (Héroux et al. 2004).

The continuously changing satellite configuration in space with time compromises the PPP performance (Geng et al. 2009). The fusion of different GNSS constellations improves PPP positioning accuracy, convergence time (Cai and Gao 2013; Ceylan et al. 2015), reliability, and availability (Ge et al. 2012; Li et al. 2015). This improvement is attributed to increased number of visible satellites (Pan et al. 2017) that consequently maximises signal power-level (Shen and Gao 2006). This consequently widens the spectrum of PPP application in GNSS-denied environments (Schönemann, Becker, and Springer 2011) namely: urban canyons, heavily forested areas, and mountain valleys.

Before the modernization of Galileo and BeiDou, the integration of multi-GNSS PPP incorporated only GPS and GLONASS constellations (Melgard et al. 2009). Today, with the benefits accrued from multi-GNSS constellation, studies have been undertaken in different GNSS combinations. Lou et al. (2016) analyse the contribution of Multi-GNSS PPP solution to single and dual-frequency raw observations based on 105 MGEX stations. Pan, Chai, and Kong (2017); Zhao et al. (2017) gather improved average convergence in three-dimensional (3D) based on different combinations of GPS, GLONASS, Galileo, and BeiDou constellations. Rabbou and El-Rabbany (2015) assesses the contribution of Galileo to GPS PPP performance. Pan et al. (2017) extend the study by evaluating Galileo PDOP values on a global scale. Recently, Xia et al. (2018) carry out a similar study but by comparing the Galileo input to multi-GNSS PPP solution.

In analysing PPP with respect to conventional GNSS positioning, Soycan and Ata (2011) yield better positioning accuracy in PPP of 10 mm and 20 mm in 2D and vertical components, respectively, from one week daily observations obtained from 60 Ordinance Survey (OS) stations. In a separate study from 24-hour datasets, Soycan (2012) comes up with a better 2D positional accuracy of 6.6 mm and 9 mm in the elevation dimension with a very high precision in the north coordinates of 3.1 mm.

Furthermore, Abd-Rabbou and El-Rabbany (2017) come up with positional accuracies of 18%, 20% and 13% in dual-constellation of GPS+BDS, GPS+Galileo and in quad-GNSS PPP, respectively. Tegedor et al. (2016) yield improved results in PPP positioning and convergence time in four-system constellation of GPS, GLONAS, Galileo and BeiDou. Yu and Gao (2017b) obtain better results in triple-GNSS constellation of GPS+GLONASS+BDS from receivers on a vehicle with an improvement in PDOP values. Afifi and El-Rabbany (2016) develop a between-satellite single-difference (BSSD) undifferenced model and obtain an improvement in convergence period in triple constellation of GPS+Galileo and BeiDou. Lou et al. (2016) witness a reduction in convergence time in GPS PPP over GLONASS PPP and BDS PPP solutions in both single and dual-frequency approaches except in high altitude areas where GLONASS dual frequency PPP outperforms GPS single-frequency PPP solution. Odolinski, Teunissen, and Odijk (2014) and Abd Rabbou, El-Shazly, and Ahmed (2017) gather better improvement in convergence time in dual-constellation of GPS+Galileo than in single-system constellation of GPS-only PPP.

Triple-constellation PPP has become possible due to improvement in Galileo satellite orbit and clock products (Rizos et al. 2013). Most studies on multi-GNSS PPP do not provide a fair evaluation of different combinations of GNSS. In this study, static PPP with triple-constellation GNSS of GPS, GLONASS and Galileo is evaluated in seven combinations: GPS-only, GLONASS-only, Galileo-only, GPS+GLONASS, GPS+Galileo, GLONASS+ Galileo, and the combined PPP solution of GPS, GLONASS and Galileo. The single and combined PPP static solutions are evaluated in terms of positioning performance, convergence period and PDOP.

Multi-GNSS constellation PPP models

Basic carrier phase and pseudorange observation models

The GNSS observation models for carrier phase (L) and pseudorange (P) from the satellite (s) to the receiver (r) at carrier frequency (j) are expressed as follows:

$$L^s_{r,j} = \rho^s_r g - t^s + t_r + \lambda_j\left(b_{r,j} - b^s_j\right) + \lambda_j N^s_{r,j} - I^s_{r,j} + m^s_r.Z_r + \varepsilon^s_{r,j} \quad [1]$$

$$P^s_{r,j} = \rho^s_r g - t^s + t_r + c\left(d_{r,j} - d^s_j\right) + I^s_{r,j} + m^s_r.Z_r + e^s_{r,j} \quad [2]$$

$$\begin{cases} I^s_{r,j} = \kappa_j.I^s_{r,1} \\ \kappa_j = \lambda^2_j / \lambda^2_1 \end{cases} \quad [3]$$

where the symbol ρg is the geometric distance from the satellite to the receiver antennae phase centres at the time of signal transmission and reception, respectively; t^s and t_r denote the satellite and clock biases, respectively; λ_j denotes the wavelength; c is the speed of light in vacuo; b_{rj} and b^s_j denote the receiver- and satellite-dependent uncalibrated phase delay (UPD) (Ge et al. 2008); $d_{r,j}$ and d^s_j denote receiver and satellite code biases, respectively; $N^s_{r,j}$ denotes the carrier phase ambiguity between satellite s and receiver r; denotes the ionospheric delay at carrier frequency j (Equation 3 presents the same at different frequencies); m^s_r is the wet mapping function from satellite s to receiver r; Z_r denotes the tropospheric zenith wet delay at station r; $\varepsilon^s_{r,j}$ and $e^s_{r,j}$ are the sum of measurement noise and multipath error for the carrier phase and pseudorange observation models, respectively.

Linearized phase and code observation models

The slant tropospheric delay is the sum of the wet and dry components and are estimated as unknown parameters (Li et al., 2013). Ionosphere-free combination observations are normally employed in PPP to mitigate the first-order ionospheric delay (Kouba and Héroux 2001; Yu and Gao 2017a). From the basic carrier phase and pseudorange observation equations [1] and [2], the associated linearized observation models are expressed as follows:

$$l^s_{r,j} = -u^s_r.r_r - t^s + t_r + \lambda_j\left(b_{r,j} - b^s_j\right) + \lambda_j N^s_{r,j} - \kappa_j.I^s_{r,1} + m^s_r.Z_r + \varepsilon^s_{r,j} \quad [4]$$

$$p^s_{r,j} = -u^s_r.r_r - t^s + t_r + c\left(d_{r,j} - d^s_j\right) + \kappa_j.I^s_{r,1} + m^s_r.Z_r + e^s_{r,j} \quad [5]$$

To mitigate the first-order ionospheric delay, the squares of the residuals are minimised according to [4] and [5]. The mitigation involves consideration of the observed minus computed (OMC) carrier phase and pseudorange observables. In [4] and [5], $l^s_{r,j}$ and $p^s_{r,j}$ denote the OMC phase and pseudorange observables from satellite s to receiver r at carrier frequency j, respectively; u_r is a unit vector from receiver r to satellite s ; r_r is the vector of receiver position increments with respect to a priori position used for linearization.

Triple-GNSS constellation PPP models

In [4] and [5], the index s can be any GNSS constellation. This can be GPS (G), GLONASS (R), Galileo (E) or BeiDou (C) satellites. In this contribution, the triple-GNSS constellation involving G, R and E are employed. Thus, [4] and [5] are re-written in terms of G, R and E constellations as follows:

$$\begin{cases} l^G_{r,j} = -u^G_r.r_r - t^G + t_r + \lambda_{jG}\left(b_{rG,j} - b^G_j\right) + \lambda_{jG} N^G_{r,j} - \kappa_{jG}.I^G_{r,1} + m^G_r.Z_r + \varepsilon^G_{r,j} \\ l^R_{r,j} = -u^R_r.r_r - t^R + t_r + \lambda_{jR}\left(b_{rR_k,j} - b^R_j\right) + \lambda_{jR_k} N^R_{r,j} - \kappa_{jR} I^R_{r,1} + m^R_r.Z_r + \varepsilon^R_{r,j} \\ l^E_{r,j} = -u^E_r.r_r - t^E + t_r + \lambda_{jE}\left(b_{rE,j} - b^E_j\right) + \lambda_{jE} N^E_{r,j} - \kappa_{jE} I^E_{r,1} + m^E_r.Z_r + \varepsilon^E_{r,j} \end{cases} \quad [6]$$

$$\begin{cases} p^G_{r,j} = -u^G_r.r_r - t^G + t_r + c\left(d_{rG,j} - d^G_j\right) + \kappa_{jG}.I^G_{r,1} + m^G_r.Z_r + e^G_{r,j} \\ p^R_{r,j} = -u^R_r.r_r - t^R + t_r + c\left(d_{rR_k,j} - d^R_j\right) + \kappa_{jR_k}.I^R_{r,1} + m^R_r.Z_r + e^R_{r,j} \\ p^E_{r,j} = -u^E_r.r_r - t^E + t_r + c\left(d_{rE,j} - d^E_j\right) + \kappa_{jE}.I^E_{r,1} + m^E_r.Z_r + e^E_{r,j} \end{cases} \quad [7]$$

In the linearized multi-constellation models [6] and [7], R_k is the GLONASS satellite with frequency factor k for carrier phase frequency computation for the satellites; d_{rG}, d_{rR}, d_{rE} and are the code biases of the receiver rfor G-, R-, and E-satellites, respectively.

The G- and E-satellites use Code Division Multiple Access (CDMA) whereas R-satellites use Frequency Division Multiple Access (FDMA). In CDMA, each satellite transmits a Coarse/Acquisition (C/A)-code and a Precision-code (P-code) (Kaplan, 2006).Unlike the modernised GLONASS satellites which can transmit a CDMA signal on a new L3 frequency, originally the system transmitted signals within L1 and L2 bands (Teunissen and Montenbruck 2017). Notwithstanding this, it should be mentioned that individual satellites differ in frequency and signal structure. This calls for the application of Differential Code Biases (DCBs) in order to achieve precise positioning performance.

Simplified Triple-GNSS Constellation PPP Models

Multi-GNSS constellation brings about an increased number of biases that need to be accounted for in a PPP algorithm (Schaer 2017). Even though, precise ephemeris eliminates the biases in coordinates and time, receiver and satellite hardware biases need to be accounted for (Cai and Gao 2013). The implementation of multi-GNSS DCB products alongside precise satellite orbits, clocks from IGS multi-GNSS Experiment (MGEX) becomes necessary (Montenbruck, Hauschild, and Steigenberger 2014). Equations [6] and [7] simplify to [8] and [9] when the MGEX products are implemented.

$$\begin{cases} l_{r,j}^{G} = -u_r^{G}.r_r + t_r + \lambda_{jG}\left(b_{rG,j} - b_j^{G}\right) + \lambda_{jG}N_{r,j}^{G} - \kappa_{jG}.I_{r,1}^{G} + m_r^{G}.Z_r + \varepsilon_{r,j}^{G} \\ l_{r,j}^{R} = -u_r^{R}.r_r + t_r + \lambda_{jR}\left(b_{rR_k,j} - b_j^{R}\right) + \lambda_{jR_k}N_{r,j}^{R} - \kappa_{jR}I_{r,1}^{R} + m_r^{R}.Z_r + \varepsilon_{r,j}^{R} \\ l_{r,j}^{E} = -u_r^{E}.r_r + t_r + \lambda_{jE}\left(b_{rE,j} - b_j^{E}\right) + \lambda_{jE}N_{r,j}^{E} - \kappa_{jE}I_{r,1}^{E} + m_r^{E}.Z_r + \varepsilon_{r,j}^{E} \end{cases} \quad [8]$$

$$\begin{cases} p_{r,j}^{G} = -u_r^{G}.r_r + t_r + c.d_{rG} + \kappa_{jG}.I_{r,1}^{G} + m_r^{G}.Z_r + e_{r,j}^{G} \\ p_{r,j}^{R} = -u_r^{R}.r_r + t_r + c.d_{rR_k} + \kappa_{jR_k}.I_{r,1}^{R} + m_r^{R}.Z_r + e_{r,j}^{R} \\ p_{r,j}^{E} = -u_r^{E}.r_r + t_r + c.d_{rE} + \kappa_{jE}.I_{r,1}^{E} + m_r^{E}.Z_r + e_{r,j}^{E} \end{cases} \quad [9]$$

Only the phase delays are absorbed by phase ambiguity parameters out of all the parameters in [8] and [9], the rest are estimated and are presented in [10]:

$$\Phi = \begin{bmatrix} r_r \\ t_r \\ Z_r \\ d_{rE} \\ d_{rR_k} \\ I_{r,1}^{s} \\ \bar{N}_r^{s} \end{bmatrix} \quad [10]$$

with

$$\left\{ \bar{N}_r^{s} = N_r^{s} + b_r + b^{s} \right. \quad [11]$$

PDOP model

The tips of the receiver-satellite unit vectors form a polyhedron whose volume assists in defining DOP values. Geometric Dilution of Precision (GDOP) defines the precision and accuracy GNSS observations from satellites (Azami, Azarbad, and Sanei 2013). From Altamimi & Gross (2017), PDOP is simply the GDOP without the contribution of the receiver clock (q_ξ). For the sake of clarity, PDOP (σ_P) [13] is deduced from the diagonal elements (q_x, q_y and q_z) of a co-factor matrix of receiver position [12] as expressed in Leick, Rapoport, and Tatarnikov (2015):

$$Q_x = \left(A^T A\right)^{-1} = \begin{bmatrix} q_x & q_{xy} & q_{xz} & q_{x\xi} \\ & q_y & q_{yz} & q_{y\xi} \\ & & q_z & q_{z\xi} \\ sym & & & q_\xi \end{bmatrix} \quad [12]$$

Equation [12] is transformed using the law of variance-covariance propagation to yield a similar matrix but in a local geodetic coordinate frame of East (E), North (N) and Up (U). If $r(t)=[N, E, U]^T$ denotes a receiver position in the local geodetic coordinate system, then PDOP is expressed as (Teunissen and Montenbruck 2017):

$$\sigma_P = \sqrt{c_{\hat{N}}^2 + c_{\hat{E}}^2 + c_{\hat{U}}^2} \quad [13]$$

Here, ($c_{\hat{E}}^2$, $c_{\hat{N}}^2$ and $c_{\hat{U}}^2$) are equivalent to (q_x, q_y and q_z).

Triple-GNSS static PPP data processing

Datasets

The MGEX stations selected in this study are illustrated in Figure 1. The selection criterion was based on the fact that

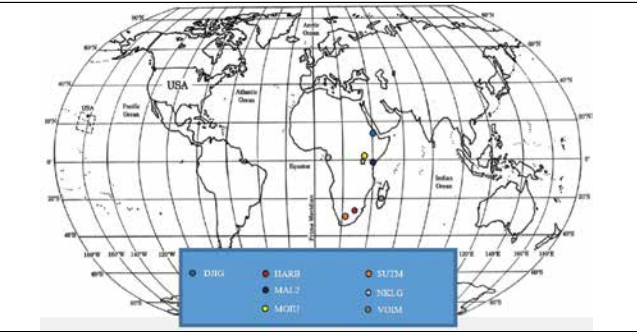

Figure 1: Geographical distribution of MGEX station selected in the study

Table 1: Multi-GNSS Orbits and Clocks from MGEX

Provider	Identity	Constellation	GNSS Product
CODE	com	G + R + E + C + J	sp3, clk, erp, bia
	COD0MGXFIN	G + R + E + C + J	
GFZ	gfm / gbm	G + R + E + C + J	sp3, clk, erp, bia
TUM	tum	E + J	sp3, clk, erp
Wuhan University	wum	G + R + E + C + J	sp3, clk, erp
CNES	grm	G + R + E	sp3, clk, snx
JAXA	qzf	G + J	sp3
	JAX0MGXFIN	G + R + J	sp3

Key: The bia, erp, snx, and sp3 denote biases, earth rotation parameters, sinex (containing site coordinates), and standard product 3, respectively (http://mgex.igs.org/IGS_MGEX_Products.php). G, R, E and C stand for GPS, GLONASS, Galileo, BeiDou and Japanese Quasi-Zenith Satellite System (QZSS) navigation systems, respectively.

Table 2: Data processing parameters

Parameter	Description
Position Mode	Static PPP
Filter Processing Mode	Forward
Constellation	[G]; [R]; [E]; [G + R]; [G + E]; [R + E] and [G + R + E]
Elevation Cut-Off Angle	7º
Data Sampling	30 Seconds
Frequencies	Dual
Coordinate Estimation	Constant
Ionospheric Delay Correction	Ionosphere-free combined observables
Ionospheric Delay Estimation	Random Walk
Tropspheric Delay Estimation	ZTD-estimated
Tropospheric Mappng Function	GMF
Tide Correction	Solid earth Tide, Ocean Loading Tide and Pole Tide

Key: G, R, and E stand for GPS, GLONASS, and Galileo navigation systems. ZTD and GMF denote Zenith Tropspheric Delay and Global Mapping Function, respectively.

each of these stations tracks at least GPS, GLONASS, and Galileo satellites. In this study, one week observations were used for the year 2017 from DOY 060 to DOY 066.

Data processing parameters

Pseudorange differences corrected for ionosphere path delays are a source of DCBs for multi-GNSS constellation (Montenbruck et al. 2014). Processing Triple-GNSS constellations in different combinations utilises DCBs from MGEX provided in Bias SINEX (Solution Software/technique INdependent EXchange) format which is simply an exchange of code and phase bias information. The prototype DCBs are generated by the Center for Orbit Determination in Europe (CODE) (Prange et al., 2015); Centre National d'Etudes Spatiales (CNES) (Loyer et al. 2012); GeoForschungsZentrum Potsdam (GFZ) (Uhlemann et al., 2015; Deng et al., 2014); Technische Universität München (TUM) (Steigenberger et al. 2013); Wuhan University (Guo et al. 2016) and Japan Aerospace Exploration Agency (JAXA) are all convenient for implementation in multi-GNSS PPP algorithm. Table 1 summarises these DCBs.

Guo et al. (2017a) and Guo et al. (2017b) identify minor differences between precise ephemeris generated in analysis centres (ACs) and those provided by the Deutsches GeoForschungsZentrum (GFZ). This paper takes advantage of the DCBs computed by GFZ in evaluating the triple-GNSS static PPP performance.

To thoroughly evaluate triple-GNSS static PPP performance in different combinations, a state-of-the-art GAMP was used. GAMP is a command line software capable of handling multi-constellation and multi-session data processing written by Zhou et al. (2018). Table 2 depicts the data processing parameters implemented in this study.

In this contribution, three output files from GAMP are considered: positioning root mean square error (RMSE) values, convergence time, and PDOP. The position errors are estimated with respect to a priori coordinates for the stations contained in the SINEX files from the IGS (International GNSS Service). The convergence time is estimated as the time interval from the start epoch to the convergence epoch (Xia et al. 2018). In this study, PDOP values are used to demonstrate the influence of the receiver-satellite instantaneous geometry of the visible satellites on station positioning.

Results and analysis

Positioning accuracy

The positioning RMSE values in North, East, Up and 3D for the seven (7) stations for the selected DOY are averaged and are depicted in Figure 2. The averaged RMS values for the triple PPP solution of GRE yield the best results in N, E, Up and 3D out of all the seven PPP scenarios. The statistical evaluation of the 3D positions is presented in Table 3. The averaged PPP positioning performance was the best in GRE (11.6 cm) combination among the seven PPP solutions. The performance of dual-constellation of GR (15.4 cm) ranks second, followed by GPS-only PPP with an average of about 19.7 cm. Here, it can be seen that there was no meaningful difference between GPS-only PPP and GPS+Galileo PPP solutions. This slight difference is attributed to insufficient number of visible Galileo satellites contributed to the GPS-only PPP solution (Xia et al. 2018). For the same reason, the static PPP for Galileo was not possible for MAL2 and MOIU stations. This is indicated with zeros (0s) in Table 3.

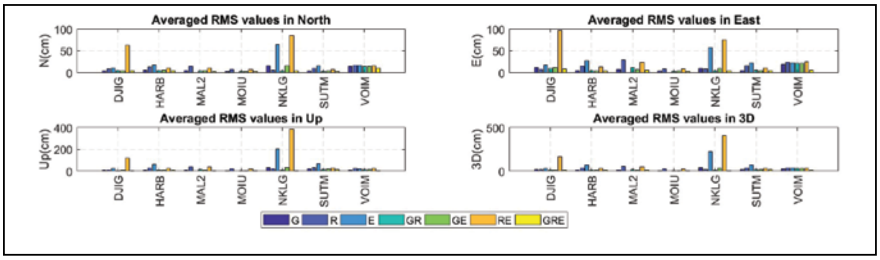

Figure 2: Averaged 3D RMS values in North, East, Up and 3D for PPP scenarios

Furthermore, the combined solution of GE falls on the fourth of the seven different combinations with an average of 19.8 cm. The GLONASS-only (31.6 cm), Galileo-only (61.9 cm) and GLONASS+Galileo (105.4 cm) fall on the fifth, sixth and seventh positions, respectively in terms of positioning accuracy. The combined solution of GPS+GLONASS is necessary in cases of few visible satellites in either of them (Tolman et al. 2010; Li, Zhang, and Guo 2009).

Table 3: Averaged 3D RMS values for the PPP scenarios

Station	G	R	E	GR		GE		RE		GRE	
DJIG	16.2	16.0	31.6	12.4	[23.9%]	15.0	[7.8%]	167.0	-	12.2	[25.0%]
HARB	13.8	33.8	72.1	13.1	[4.9%]	13.1	[4.9%]	29.0	[14.2%]	12.5	[9.4%]
MAL2	12.7	51.3	0.0	18.9	-	13.6	-	45.9	[10.6%]	10.1	[20.8%]
MOIU	8.9	23.4	0.0	6.9	[22.0%]	8.9	-	23.4	-	6.9	[22.0%]
NKLG	39.6	21.0	222.3	9.7	[75.5%]	38.4	[2.9%]	404.5	-	8.9	[77.5%]
SUTM	20.8	38.4	72.4	17.5	[15.7%]	20.6	[1.2%]	30.5	[20.5%]	15.7	[24.3%]
VOIM	25.6	37.3	34.8	29.2	-	28.9	-	37.3	[0.1%]	14.6	[43.0%]

Key: G, R, E, GR, GE, RE, and GRE are the PPP scenarios for GPS, GLONASS, Galileo, GPS+GLONASS, GPS+Galileo, GLONASS+Galileo, and GPS+GLONASS+Galileo, respectively. The numbers in brankets denote the improvement in averaged RMS values with respect to GPS (for GR,GE, and GRE) and GLONASS (for RE), respectively. The symbol (-) means no improvement.

The statistical results indicates better performance for GLONASS-only static PPP solution than that of GLONASS and Galileo combined solution. The poor static PPP solution in the GLONASS+Galileo PPP combined solution may be attributed to both reduced number of Galileo visible satellites and poor orbit and clock accuracy of Galileo (Xia et al. 2018). As can be seen in Table 3, the positioning accuracy improves with increase in number of GNSS-constellations. The averaged 3D RMS value for NKLG was the most outstanding with an improvement of 77.5% in the triple-constellation.

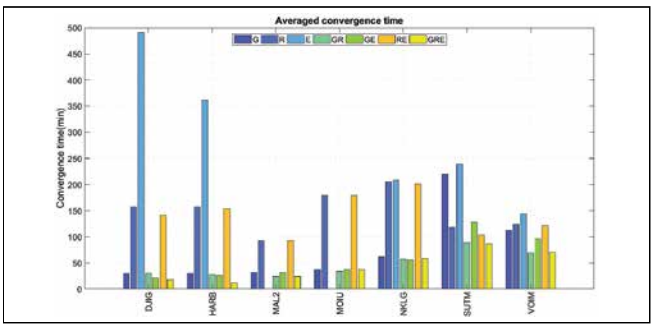

Figure 3: Averaged convergence time for the stations for each PPP scenario

Convergence time

The contribution of triple-GNSS constellation to PPP performance was also evaluated in terms of convergence period. Figure 3 and Table 4 present the averaged convergence time for seven PPP scenarios. As can be seen in Figure 3 and Table 4, no Galileo satellites were tracked for MAL2 and MOIU stations. For all selected DOYs, Galileo-only PPP solution had the poorest convergence time with that of DJIG station reaching up to about eight (8) hours.

Table 4: Averaged convergence time for the PPP scenarios

Station	G	R	E	GR		GE		RE		GRE	
DJIG	30.1	157.0	491.4	29.8	[1.0%]	21.3	[29.4%]	141.4	[9.9%]	18.1	[39.9%]
HARB	29.5	157.0	361.4	27.1	[8.0%]	26.1	[11.4%]	154.6	[1.5%]	12.2	[58.6%]
MAL2	31.6	93.7	-	23.8	[24.7%]	31.6	-	93.7	-	23.8	[24.7%]
MOIU	37.1	179.8	-	33.8	[8.8%]	37.1	-	179.8	-	36.8	[0.7%]
NKLG	61.9	205.2	208.3	57.1	[7.7%]	56.3	[9.0%]	201.7	[1.7%]	58.4	[5.5%]
SUTM	220.1	118.8	238.6	88.5	[59.8%]	128.6	[41.5%]	103.5	[12.8%]	86.0	[60.9%]
VOIM	112.6	123.9	144.3	68.5	[39.1%]	96.1	[14.6%]	121.8	[1.7%]	69.8	[38.0%]

Key: G, R, E, GR, GE, RE, and GRE are the PPP scenarios for GPS, GLONASS, Galileo, GPS+GLONASS, GPS+Galileo, GLONASS+Galileo, and GPS+GLONASS+Galileo, respectively. The numbers in brankets denote the improvement in convergence time with respect to GPS (for GR,GE, and GRE) and GLONASS (for RE), respectively. The symbol (-) means no improvement.

In both Figure 3 and Table 4, it is apparent that the addition of any other GNSS constellation to GPS considerably improves the convergence time. The average improvement in the dual- and triple-constellation PPP solutions is presented in square blankets (Table 4). SUTM station had the best average improvement in convergence time of about 61% (from 220.1 min to 86.0 min) in the triple-GNSS PPP solution whereas MOIU has the worst (0.7%). For this station (SUTM), the dual-GNSS constellation of GPS+GLONASS convergence period was not different from that of the triple-GNSS constellation. This may be attributed to reduced number of satellites contributed by Galileo in the three-system GNSS PPP static solution. It is noticeable that the convergence time vary for each station. However, the average convergence time is the best in the triple-GNSS PPP.

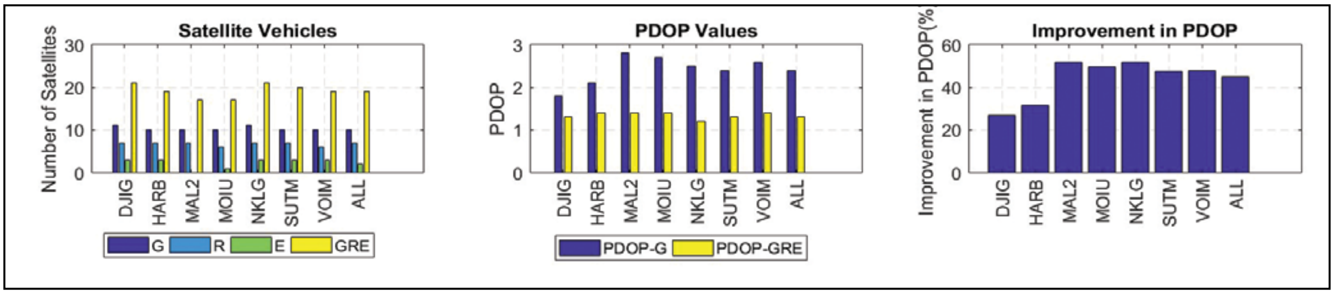

Figure 4: Numbers of satellites, PDOP values and improvement in PDOP

Table 5: Average numbers of satellites, PDOP values and improvement in PDOP

	DJIG	HARB	MAL2	MOIU	NKLG	SUTM	VOIM	All Stations
G	11	10	10	10	11	10	10	10
R	7	7	7	6	7	7	6	7
E	3	3	0	1	3	3	3	2
GRE	21	20	17	17	21	20	19	19
PDOP-G	1.8	2.1	2.8	2.7	2.5	2.4	2.6	2.4
PDOP-GRE	1.3	1.4	1.4	1.4	1.2	1.3	1.4	1.3
Improvement [%]	27.0	31.4	52.0	49.8	51.9	47.4	47.8	45.1

Key: G,R,E and GRE are the GPS, GLONASS, Galileo and GPS+GLONASS+Galileo constellations. PDOP-G and PDOP denote the PDOP for GPS and the triple-constellation, respectively.

PDOP

The number of satellites, average PDOP and improvement in PDOP are presented in Figure 4. The average number of GPS satellites vary between 10 and 11 per day for the selected stations. The average number of GLONASS satellites vary between 6 and 7 per day whereas Galileo satellites in view vary between 0 and 3 as can be seen in Table 5. GNSS positioning requires at least four satellites to perform an autonomous positioning. For the selected stations, the average number of Galileo satellites are not enough for a GNSS survey.

DJIG has the least improvement in PDOP of about 27% as a result of the addition of GLONASS and Galileo satellites to GPS-only static PPP. MAL2 and NKLG station have PDOP improvements of about 52.0% (from 2.8 to 1.4) and 51.9% (from 2.5 to 1.2), respectively. The PDOP values in GPS-only static PPP improves by about 45% (from 2.4 to 1.3) for all stations. All other improvements in PDOP with respect to GPS-only static PPP are presented in Table 5. The triple-GNSS static PPP has better satellite visibility and precision factor (PDOP) than the single-GNSS system of GPS. This is indicated by much less PDOP values which are in the range of 1.2 to 1.4 in the triple-GNSS static PPP than that of GPS-only static PPP (which are in the range of 1.8 to 2.8). It can be verified that triple-GNSS static PPP can significantly improve the spatial distribution of satellite.

Conclusion

In this contribution, static PPP using triple-constellation GNSS was assessed in terms of positioning performance, convergence time, and PDOP. GNSS observations from seven (7) MGEX stations spread over Africa were analysed for DOY 060 to DOY 066 for year 2017 in GAMP.

The observations were analysed in seven different GNSS PPP solutions. Based on the results, the following conclusion are drawn:

1. The positioning performance of triple-constellation static PPP was greater than that of GPS-only, GLONASS-only, and Galileo-only static PPP. Besides that, the performance was also better than that of the dual-system static PPP.
2. The convergence performance of triple-GNSS PPP was the best for all seven different static-PPP scenarios.
3. The number of satellites for the triple-constellation static PPP was significantly better than that of GPS-only PPP. GPS-only PPP had better satellite visibility than GLONASS and Galileo-only PPP.
4. The integration of GPS, GLONASS and Galileo static PPP solutions significantly lowers PDOP values.

This paper was limited to stations geographically distributed over Africa and incorporated Galileo other than BeiDou in the triple-GNSS static PPP solution. Thus, future research prospects will increase the number of stations and integrate BeiDou in the triple-GNSS static PPP solution.

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Where to plant a trillion trees to save planet Earth?

Restoration of forests has long been seen as a potential measure to combat climate change. The latest special report by the Intergovernmental Panel on Climate Change suggests that an increase of 1 billion hectares of forest will be necessary to limit global warming to 1.5°C by 2050. What has so far been unclear, however, is how much of this tree cover might be actually possible in the existing conditions on the planet.

Now, researchers have quantified how much land around the world is available for reforestation, as well as the extent of carbon emissions these would prevent from being released into the atmosphere. The study, by researchers with the Crowther Lab of ETH Zurich university, has been published in the journal Science.

On the basis of nearly 80,000 images from around the world, they calculated that around 0.9 billion hectares of land would be suitable for reforestation. "We are trying to restore a trillion trees," according to Thomas Crowther, co-author of the paper and founder of the Crowther Lab. If an area of 0.9 billion hectares is indeed reforested, the researchers calculated, it could ultimately capture two-thirds of human-made carbon emissions.

"One aspect was of particular importance to us as we did the calculations: we excluded cities or agricultural areas from the total restoration potential as these areas are needed for human life," lead author Jean-François Bastin said.

Earth's continuous tree cover is currently 2.8 billion hectares, and the researchers calculated that the land available could support 4.4 billion hectares, or an additional 1.6 billion hectares. Out of this, 0.9 billion hectares — an area the size of the US — fulfil the criterion of not being used by humans, according to the paper. These new forests, once mature, could store 205 billion tonnes of carbon, the researchers calculated. That is about two-thirds of the 300 billion tonnes of carbon that has been released into the atmosphere as a result of human activity since the industrial age. "But we must act quickly, as new forests will take decades to mature and achieve their full potential as a source of natural carbon storage," Crowther said.

The study found that the six countries with the greatest reforestation potential are Russia (151 million hectares); the US (103 million hectares); Canada (78.4 million hectares); Australia (58 million hectares); Brazil (49.7 million hectares); and China (40.2 million hectares).

In a post on the website of Legal Planet, a joint initiative of University of California's Berkeley and Los Angeles law faculties, Jesse Reynolds of UCLA described the new research as "misleading, if not false, as well as potentially dangerous". Among various arguments, Reynolds noted that the authors do not consider how such reforestation might come about when the land proposed to be reforested is owned and managed by many private persons, companies, nongovernmental organisations, and governments. Reynolds also found the authors' estimate of carbon removal per area "remarkably high". *https://indianexpress.com*

Army Signs Woolpert–Black & Veatch JV

The U.S. Army has selected the Woolpert and Black & Veatch joint venture and Quantum Spatial Inc. to a $49 million contract to provide surveying and mapping services. Work locations and funding will be determined with each task order. The U.S. Army Corps of Engineers (USACE), Wiesbaden, Germany, is the contracting activity. The USACE received 10 bids via an online solicitation process for the firm-fixed-price contract, according to the U.S. Department of Defense. *woolpert.com*

YellowScan releases Point Cloud Data Software CloudStation

YellowScan has announced the release of CloudStation, its new software providing a complete solution to create and manipulate point cloud data. It allows the user to extract, process and display data immediately after flight acquisition. The auto-generation of flight lines and the production of LAS files are now done in a few clicks. *www.yellowscan-lidar.com*

$10 Million approval for Geospatial Mapping

MAPPS reports the U.S. House Appropriations Committee has approved an additional $10 million above FY19 funding of $37.6 million as part its U.S. Department of Interior Fiscal Year 2020 bill for fundamental mapping work to be managed by the U.S. Geological Survey (USGS). These funds, described as an essential underpinning of the USGS 3D Elevation Program (3DEP), will support and enhance drinking water protection, hazards resilience, infrastructure design, natural resource management and fundamental research applications.

Of this funding, the Committee allocated $5 million for 3DEP to accelerate the achievement of 100 percent coverage of the Great Lakes region. The Great Lakes have nearly 11,000 miles of coastline and, with associated lakes and tributaries, make up the largest surface freshwater system on Earth. The 3DEP initiative will provide data that will enable scientists to address these critically advancing concerns.

Alphabet unveils Toronto smart city plans

Google parent company Alphabet has announced the release of a detailed smart city development plan for the city of Toronto in a 1,500-page document.

According to the Master Plan, The development of Quayside is planned to occupy 12 acres land, the Villiers West is planned to take 19 acres of land and the rest of the IDEA District would take 159 acres of land. This plan would create at least 93,000 more jobs, with 44,000 permanent and direct jobs by 2040. At least half out of the 44,000 jobs would be in manufacturing and cultural sectors, around a quarter of jobs in the administrative support, retail and transit. It is expected that at least 10,000 jobs would be created in finance, real estate and management sectors.

The smart city proposal also specifies that the Quayside would be able to emit 85% fewer greenhouse gases. Downtown Toronto's development model called IDEA District would emit 89% lesser greenhouse emissions. Projects like energy efficient houses, facilities to convert organic food waste into biogas and a clean thermal grid for heating and cooling are being considered. *https://venturebeat.com*

Highest level of precision with new Airbus ground control points

Airbus has launched a new series of Ground Control Points (GCPs) to give centimetre level accuracy and higher points density. These highly precise 3D coordinates are automatically extracted from Airbus' high-resolution stereo radar imagery, using an innovative geodesy processor. GCPs are essential for accurate orthorectification of aerial, optical satellite and drone data, as well as precise localisation of ground features, landmark detection and target recognition. Furthermore, GCPs are used to calibrate and validate all types of map data.

As radar satellite acquires data 24 hours a day regardless of darkness and or weather conditions, they allow rapid imagery collection whatever the location. Combined with this new automatic geodesy processor, radar data enables prompter processing and delivery of GCPs. Airbus GCPs are able to complement and even substitute in-situ measurements. This enables time and cost savings while providing a homogeneous data source. *www.airbus.com*

NASA launches a Deep Space Atomic Clock

NASA launches Deep Space Atomic Clock on the SpaceX Falcon Heavy rocket launched on June 24. It is similar to the atomic clocks found in GPS satellites but 50 times more stable. The technology will be a critical part of onboard navigation systems for future spacecraft and will work like the GPS you have in your car.

This represents a leap forward from today's space travel, which doesn't benefit from the GPS system used to navigate on Earth. Instead, human navigators guide spacecraft using signals that can take from minutes to hours to deliver directions. If the clock's one-year technology demonstration goes well, future Deep Space Atomic Clocks could guide humans to Mars, even providing them GPS on the surface.

The Deep Space Atomic Clock is hosted on a spacecraft provided by General Atomics Electromagnetic Systems of Englewood, Colorado. It is sponsored by the Technology Demonstration Missions program within NASA's Space Technology Mission Directorate and the Space Communications and Navigations program within NASA's Human Exploration and Operations Mission Directorate. JPL manages the project. *www.jpl.nasa.gov*

China launches latest Beidou satellite

A Long March 3B lifted off from the Xichang Satellite Launch Center in southwest China sending a Beidou satellite toward an inclined geosynchronous orbit. The launch occurred within a window indicated by the issuance of an airspace closure notice days earlier. The mission involved the 21st satellite of the Beidou-3 rollout and the second to be placed in an inclined geosynchronous orbit.

Beidou-3 satellites form the third phase of construction of the Beidou Navigation Satellite System, which expands service coverage from regional to global. The new satellites also adopt inter-satellite link capabilities, new-generation rubidium atomic clocks and passive hydrogen maser clocks. *www.space.com*

Permanent GNSS reference station at GLB, Burdwan, India

A permanent GNSS reference Station with Leica GR50 Multi-GNSS receiver (with NavIC L5) and AR25 Antenna has been established at GNSS Laboratory Burdwan (GLB), Department of Physics, The University of Burdwan, INDIA. This facility is also being used as a NTRIP caster transmitting RTCM 3.0 MSM 7 messages. The facility has been developed using financial support from All India Council of Technical Education (AICTE) and support from The University of Burdwan. The infrastructure would be used for GNSS research and GLB would also provide support to the industry.

Tesla Model S and Model 3 Prove Vulnerable to GPS Spoofing

Tesla Model S and Model 3, electric cars built for speed and safety, are vulnerable to cyber attacks aimed at their navigation systems, according to recent research from Regulus Cyber. During a test drive using Tesla's Navigate on Autopilot feature, a staged attack caused the car to suddenly slow down and unexpectedly veer off the main road. The research discovered the Tesla vulnerability during its ongoing study of the threat that easily accessible spoofing technology poses to GNSS receivers. It was found that spoofing attacks on the Tesla GNSS (GPS) receiver could easily be carried out wirelessly and remotely, exploiting security vulnerabilities in mission-critical telematics, sensor fusion, and navigation capabilities.

Regulus Cyber experts traveled to Europe as well to test-drive the Tesla Model 3 using Navigate on Autopilot. An active guidance feature for its Enhanced Autopilot platform, it's meant to make following the route to a destination easier, which includes suggesting and making lane changes and taking interchange exits, all with driver supervision. While it initially required drivers to confirm lane changes using the turn signals before the car moved into an adjacent lane, current versions of Navigate on Autopilot allow drivers to waive the confirmation requirement if they choose, meaning the car can activate the turn signal and start turning on its own. Tesla emphasizes that “in both of these scenarios until truly driverless cars are validated and approved by regulators, drivers are responsible for and must remain ready to take manual control of their car at all times.” *www.regulus.com*

Weird, bendy GPS signals for weather forecast

A new cluster of satellites will harness the GPS to help predict weather patterns, long-term climate change, and even crippling interference from solar flares. The same GPS signals we rely on to navigate through rush-hour traffic, find a restaurant, or track your kids can also be used to forecast when hurricanes form in tropical waters.

Known as the Constellation Observing System for Meteorology, Ionosphere and Climate (or COSMIC-2), the mission takes advantage of a weird property of GPS radio signals: They actually bend and slow down slightly as they travel through the atmosphere. This bending doesn’t affect the accuracy of navigation on the ground; it’s only visible from the side by something else in orbit. It’s a bit like what when you dip a pencil in a half-full glass of water and the image refracts slightly through the denser liquid.

The denser the atmosphere, the more the GPS radio wave bends. Once scientists get this information about density, they can figure out atmospheric moisture, pressure, and temperature at one-kilometer intervals. Getting this kind of granular information about what’s happening up and down the atmosphere is key to making weather prediction models more accurate.

Compared to other weather satellites, COSMIC-2 is a relative bargain at a cost of $250 million, half of which was paid by Taiwan, according to Schreiner. “It’s an order of magnitude less expensive,” he says. In comparison, NOAA’s four GOES geostationary weather satellites, the first of which launched in 2016, are costing taxpayers $11 billion and have had a few hiccups in space since then. *www.wired.com*

Navigation system problem compel regional airlines to ground flights

Regional airlines in the U.S. canceled flights after receiving error messages from navigation systems aboard some of their planes, the Federal Aviation Administration said recently. Mesa Airlines, which flies for American Airlines and United Airlines, as well as Delta Air Lines’ subsidiary Endeavor Air, United contractor GoJet, American Airlines-owned PSA Airlines and SkyWest are affected by the issue. *www.cnbc.com*

The US Army will soon test a new GPS that's resistant to jamming

The US Army will soon test a jam-resistant GPS to try and overcome the problem. GPS jamming can also be a major liability for US and allied forces, which depend on the system for everything from troop movement to missile and drone guidance. Last fall, the US and NATO allies launched a major joint exercise in Norway called Trident Juncture, to test the joint readiness and training of a large, multinational coalition. Over the course of the exercise, the military noticed that GPS signals were being jammed. In April 2018, US officials said that the Russian military had been jamming the GPS systems for is drones operating in Syria.

Members of the 2nd Cavalry Regiment located in Germany will get the devices this fall, and the Army is reportedly looking into developing a new generation of Inertial Navigational Systems that could be used as a back up. *www.theverge.com*

Galileo tests its new urban mobility scheme

New urban mobility schemes are rapidly evolving due to social, economic and technological changes. Against this backdrop, the Galileo navigation system, can deliver new accuracy and reliability for location-dependent services that get people where they need to go.
The Hellenic Institute of Transport is part of the Center for Research and Technology Hellas. Under the Galileo project, which encompasses a number of “Mobility as a Service”-oriented pilots, the institute is coordinating a pilot study in Thessaloniki, where citizens have the option to share a taxi with the help of a mobile phone app. *www.neweurope.eu*

Galileo Masters 2019 announces submission phase

The 2019 edition of Galileo Masters has announced its submission phase on May 1. Since it began in 2004, the Galileo Masters has searched for the most progressive thinking applications based on satellite navigations and the desire to set benchmarks in space-related inventions across Europe. The last day for the submissions of applications is 31st July 2019. The Galileo Masters seeks to award applications, services and new ideas from healthcare and leisure to traffic management and other rails, sea, and air transport logistics, individuals and entire industries alike can benefit from satellite navigation. *www.gsa.europa.eu*

Glonass to be used for railway fault detection in Lithuania

Lithuania’s state-run railway company Lietuvos Gelezinkeliai (Lithuanian Railways) is buying an autonomous inspection vehicle whose technical specifications state it must be compatible with the Russian satellite navigation system Glonass.

Experts warns about possible threat to national security, but the company says the choice was made to ensure swift and accurate identification of a fault place and that needs technology whose receivers are capable of accepting and calculating the location from two satellites networks, GPS and Glonass.

Russia may create Glonass ground stations in Africa and Asia-Pacific region

Russia may place ground stations of its Glonass satellite navigation system on the territory of African and Asia-Pacific countries, State Space Corporation Roscosmos Deputy CEO for International Cooperation Sergei Savelyev said recently.

In June this year, Russia completed the procedure of approving an inter-governmental agreement on outer space with Argentina. After it is signed, Roscosmos will be able to switch to the practical implementation of the project for placing a Glonass ground station on the territory of Argentina, he added. *https://tass.com*

Transit of Ukrainian Goods using Glonass

Transportation of Ukrainian goods by road and by rail via Russia is allowed again after Russian President Vladimir Putin amended a corresponding decree. However, Ukrainian trucks and railcars will be allowed through Russia only if they carry seals on vehicles and goods using the GLONASS technology only.

Drivers must have registration coupons, which will be canceled if the seal use procedure is violated. Seals are required for tracking goods so that they are not shipped to Russia. The new decree comes into force on July 1. *https://russiabusinesstoday.com*

Glonass navigation satellites to switch to domestic components by 2023

Russia's program of fully replacing foreign components in Glonass navigation satellites is due to be implemented before 2023, Chairman of the Roscosmos State Space Corporation's Scientific and Technical Council Yuri Koptev told recently.

"A four-year program exists for the Reshetnev Information Satellite Systems Company as the developer of Glonass satellites. The program has been agreed upon with the developers of the components base. Each year, the program defines a specific set of Russian components to replace foreign analogues," Koptev said, adding that the program was designed for a period until 2023.

The program of replacing foreign components with domestic items was launched in 2018. It stipulates that Glonass satellites will carry no foreign components in the future, he noted. *https://tass.com*

Russia to transfer satellite that outlived original lifespan

A Russian Glonass-M navigation satellite that was launched in 2007 and has already exceeded its expected service life by 50 percent will be transferred to the orbital reserve A Russian Glonass-M navigation satellite that was launched in 2007 and has already exceeded its expected service life by 50 percent will be transferred to the orbital reserve on Wednesday, the Information and Analysis Center for Positioning, Navigation and Timing run by the Russian Central Research Institute of Machine Building said on Tuesday in a statement. *www.urdupoint.com*

International resolution against Jamming & Spoofing

Fourteen maritime organizations have petitioned the U.S. Coast Guard to seek a resolution by the International Maritime Organization (IMO) to address disruption of GNSS signals.

In a letter to U.S. Coast Guard Commandant Admiral Karl Schultz the groups said: "GNSS signals have become an important part of all maritime operations. Interfering with them places the efficiency and safety of maritime operations at risk and can impact the safety of life."

A recent report on Russian jamming and spoofing by the non-profit C4ADS, and work by the German Aerospace Center were cited as evidence GNSS interference is a global problem. The letter makes the point that when vessels in innocent passage through territorial seas are impacted, or a disruption is also felt in international waters, it becomes a multi-national concern.

Also, jamming and spoofing GNSS signals seems a clear violation of International Telecommunications Union (ITU) provisions to many. ITU Radio Regulation 19.2 states, "All transmissions with false or misleading identification are prohibited." This could mean jamming and spoofing by a signatory nation is also a treaty violation. Recognizing that some nations are compelled for security reasons to disrupt GNSS signals upon occasion, the group called for warnings to vessels that might be impacted.

The letter called for a resolution by the International Maritime Organization that would include language to the effect that:

- GNSS signals are important to safety of navigation
- Member states should enact measures to prevent unauthorized transmissions on GNSS frequencies
- Member states should refrain from interfering with GNSS signals as much as possible, except when required for security reasons.
- Member states interfering with GNSS signals for security reasons should issue notices to mariners specifying the time periods and areas impacted to help minimize negative effects on maritime operations.

The letter was coordinated by the Resilient Navigation and Timing Foundation.

$45B is the cost for a 30-day GPS outage

In the event of a 30-day GPS outage, the United States could face up to $35 billion in economic losses, and that number could increase to $45 billion during prime planting seasons for farmers, according to a report written by RTI International and sponsored by the National Institute of Standards of Technology.

The report, the "Economic Benefits of the Global Positioning System (GPS)," estimates the potential impact of a GPS outage over a 30-day period, as specified by the Department of Commerce.

The report focuses on 10 industries: electricity, finance, location-bases services, mining, maritime, oil and gas, surveying, telecommunications, telematics, and agriculture. Government officials have warned of threats to GPS and how a successful attack on that technology would impact national security. Those threats include the ability of adversaries to jam or spoof radio frequency signals, disrupting military operations. *www.c4isrnet.com*

Cybersecurity from Space: Canada Invests in Quantum Technology

The Canadian Space Agency's Quantum EncrYption and Science Satellite (QEYSSat) mission will test quantum technology that protects communications in space. The Canadian Space Agency (CSA) is awarding a contract worth $30 million to Honeywell for the design and implementation phases of the QEYSSat mission, according to press release issued by the CSA.

Current encryption methods are expected to be rendered obsolete within the next decade by the exceptional processing power of quantum computers. Slated for launch in 2022, QEYSSat will demonstrate quantum key distribution (QKD) technology in space. This emerging encryption technology will offer Canada a new, more effective method of securing the transfer of information.

Cyient announces strategic investment in Cylus

Cyient has announced a corporate venture investment in Cylus, a global leader in cybersecurity solutions for the rail industry. This investment is in line with the company's focus on developing smarter and safer mobility solutions for the rail industry. It brings together Cyient's leadership position in engineering solutions for rail and focus on digitalization, with Cylus' cybersecurity solutions developed specifically for the rail industry. Israel-based Cylus is the developer of CylusOne, a cybersecurity software product, designed for mainline and urban rail systems. The solution detects cyber threats in the signaling and control networks, both trackside and onboard, facilitating a timely and effective response. *www.cyient.com*

New AI system makes autonomous vehicle navigation more humanlike

A paper delivered by MIT researchers at the International Conference on Robotics and Automation recently described a novel approach to AI for driverless vehicles. Their new system will draw on the fact that human drivers tend to be quite adept at negotiating never-before-seen terrain from behind the wheel.

A departure from most current self-driving tech, this fledgling model uses visual cues and easy-to-follow maps rather than rigorous computation of all the new roads in the area. Using a machine learning model called a convolutional neural network (CNN), the AI "observes" the way human drivers handle new environments as they travel about a fresh (albeit confined) area. It can then mimic what it learned from the human's responses to take a self-driving car along a brand new route, provided the trip shares certain similarities with the trial run. As incongruities between its basic layout and the actual trip it's making emerge en route, it can take simple corrective measures similar to the responses of the human driver.

In live testing, a human took a Toyota Prius (complete with a self-driving camera and navigation system) through a residential area. The CNN collected data on the steering patterns of the driver through this area in response to obstacles and other stimuli and correlated them to sensory inputs. Over time, a pattern of the most likely steering responses to various driving situations emerged. Then, given only a basic map of an entirely different area, the control system took the car safely through the test zone. *www.engineering.com*

O2 and ESA to explore connectivity solutions for autonomous vehicles

O2 and the European Space Agency will be supporting 'Project Darwin', an ambitious four year trial programme designed to pave the way for next generation connectivity solutions for connected and autonomous vehicles (CAVs). The project aims to test new technology and end-to-end connectivity solutions including 5G and satellite communications to ultimately create a new CAV industry vertical.

Based in the Harwell Science and Innovation Campus in Oxfordshire, 'Project Darwin' will bring together Oxford and Glasgow Universities, Spanish satellite operator Hispasat, start-ups specialised in self-driving mobility solutions and Darwin Innovation Group Oxford – a cutting edge innovation company connecting terrestrial and satellite communications. *https://news.o2.co.uk*

Analog Devices and First Sensor to accelerate the future of Autonomous Driving

Analog Devices, Inc. has announced a collaboration with First Sensor AG to develop products aimed at speeding the launch of autonomous sensing technology serving unmanned automotive, aerial and underwater vehicles in transportation, smart agriculture, industrial manufacturing and other industries. As part of the collaboration, Analog Devices and First Sensor are developing offerings that shrink the LIDAR signal chain to enable higher system performance as well as reduce size, weight, power and cost for manufacturers designing sensing and perception technology into their autonomous safety systems. *www.analog.com*

BlackBerry and LG partnership to drive autonomous vehicle technology

BlackBerry Limited has announced that it is expanding its partnership with LG Electronics Inc. to accelerate the deployment of connected and autonomous vehicle technology for automotive OEMs and suppliers around the world.

As part of the agreement, LG Electronics will use a range of BlackBerry QNX software and services to build next generation digital consolidated cockpits, including infotainment systems, digital instrument clusters, and telematics systems for multiple OEMs.

Toyota plans to sign Baidu's self-driving platform Apollo

Toyota Motor plans to sign Chinese internet search provider Baidu's autonomous driving platform Apollo. Launched in 2017, it is an open platform that is driven by Machine Learning through which companies can develop their own autonomous systems. Through this expertise, Toyota plans to develop its autonomous vehicles in China. *https://asia.nikkei.com*

Intel launches project to help Israeli tech startups in AI

Intel Corporation has announced a program to advance open innovation and accelerate early-stage startup companies in Israel targeting key industry inflection points, including artificial intelligence (AI), autonomous systems and other data-centric technologies and business models.

Based in Tel Aviv, the program called Ignite will leverage Intel's global market access and business and technology leadership to provide early-stage startups with unique advantages on their paths to disrupt the future.

Following a rigorous selection process, Intel will host 10 to 15 top pre-seed to seed startups through a 20-week program where they will receive hands-on mentorship from Intel and industry experts in a variety of product, business, management and technical areas. Intel is committed to accelerate their growth and scale their ideas for greater impact. *https://telecom.economictimes.indiatimes.com*

South Korea tests first 5G enabled autonomous bus

An autonomous bus carrying passengers demonstrated self-driving technology by using 5G networks for the first time in Seoul.

The bus has a three-level drive capability. This means it can run on its own on pre-defined routes. The bus doesn't need any drivers but there is a driver's seat that has been allocated. This is because at least one manpower is needed in case of any mishap.

Vehicles and roads were connected using 5G network with various traffic signals. Vehicles and road facilities were connected with a 5G network to respond to various traffic signal information and unexpected situations on roads. The autonomous bus was able to recognize traffic signals, pedestrians and would also slow down or stop in case of any interruption. *www.news18.com*

ISRO establishes new public sector company

Indian Space Organisation ISRO establishes NewSpace India Limited (NSIL), a new public sector undertaking (PSU) to exploit the research and development work of the space agency, co-produce PSLV and launch satellites through SSLVs, reports PTI.

The main task of this PSU will involve the transfer of small technology to industry, manufacture of Small Satellite Launch Vehicle (SSLV) that being developed jointly by the private sector and productionisation of Polar Satellite Launch Vehicle (PSLV) through Indian industry.

The new venture will not only look after the mass production and marketing of space-based products and services but also launch an application developed by the space organization's centers and the constituent units of the Department of Space and marketing spin-off technologies and products and services both in India and abroad.

Airbus strengthens its imagery capabilities with Vision – 1

Airbus has enlarged its high-resolution imagery portfolio following an agreement to leverage capacity from the S1-4 satellite built by Surrey Satellite Technology Limited (SSTL). This new imagery offer called Vision-1 delivers full end-to-end imaging operations to Airbus' customers.

Vision-1 provides 0.9m resolution imagery in the panchromatic band and 3.5m in the multispectral bands (NIR, RGB), with a 20.8km swath width. These specifications are ideal for defence, security and agriculture applications, while this extra revisit opportunity further strengthens Airbus' satellite fleet.

Vision-1 operations will be coordinated by Airbus in the UK, following integration into the UK Mission Operation Centre, which already operates the commercial imaging of the DMC Constellation. *www.airbus.com*

Phase One Industrial introduces three high performance lenses

Phase One Industrial has expanded its RS and RSM lens offering with three new high performance lenses for high-altitude aerial photography and long-range aerial and ground inspection applications.

The 300mm AF, 180mm, and 150mm MK II lenses are designed to enhance the performance and flexibility of Phase One Industrial's iXM-RS and iXM aerial camera series. Each offers precision imagery, taking advantage of the cameras' ultra-high resolution backside-illuminated (BSI) CMOS sensors, to maintain a smaller ground sample distance (GSD) while flying at higher altitudes.

With the longest focal length in the line-up, this lens offers a 5 cm GSD from 13,000 ft. It fits both iXM and iXM-RS camera models and produces superb image quality by enhancing the cameras' ultra-high resolution BSI CMOS sensors (3.76 µm pixels). *https://industrial.phaseone.com*

Luxembourg Space Agency approves EUR 1 million grant to Kleos Space

Kleos Space S.A. has announced that the Luxembourg Space Agency (LSA) has approved an additional EUR €1,000,000 financial grant (non-equity) support for data product development.

The Grand Duchy of Luxembourg is home to approximately 50 space companies and research labs. The space sector's contribution to the nation's GDP is among the highest ratios in Europe.

With the funding support approval from the Luxembourg Space Agency, Kleos has entered the European Space Agency Business Applications programme process and aims to be on contract with initial funding receipts by the end of 2019. *www.spacedaily.com*

New drone laws for European Union

Common European rules on drones, Commission Delegated Regulation (EU) 2019/945 and Commission Implementing Regulation (EU) 2019/947, have been published to ensure drone operations across Europe are safe and secure. The rules will amongst others help to protect the safety and the privacy of EU citizens while enabling the free circulation of drones and a level playing field within the European Union.

The common rules will help drone operators, whether professional or recreational, to have a clear understanding of what is allowed or not. At the same time it enables them to operate across borders. Once drone operators have received an authorization in the state of registration, they are allowed to freely circulate in the European Union. This means that they can operate their drones seamlessly when travelling across the EU or when developing a business involving drones around Europe.

The new rules include technical as well as operational requirements for drones. On one hand they define the capabilities a drone must have to be flown safely. For instance, new drones will have to be individually identifiable, allowing the authorities to trace a particular drone if necessary. This will help to better prevent events similar to the ones which happened in 2018 at Gatwick and Heathrow airports. On the other hand the rules cover each operation type, from those not requiring prior authorisation, to those involving certified aircraft and operators, as well as minimum remote pilot training requirements. The new rules will replace existing national rules in EU Member States.

EASA will soon publish guidance material and a proposal for two "standard scenarios" to support drone operators to comply with the adopted rules. Towards the end of the year EASA will make a proposal to the European Commission for U-space service regulation to enable complex drone operations with a high degree of automation.

LIDARUSA puts safety first with drone rescue systems

LiDARUSA has announced the option of the Drone Rescue Systems parachute system with all DJI M600 UAV sales. As UAV's become increasingly common for mapping applications the likelihood of a crash increases. Any mapping equipped drone will have enough weight to potentially harm a person even if falling from a low altitude flight. The Drone Rescue system greatly mitigates this danger.

The DRS- M600 is designed to auto-release using a patented, airplane-friendly ejection mechanism within milliseconds of detecting a system failure. Effective as low as 10m with a descent of 3m/s, the equipment will land without a hard impact yet quickly enough to keep from being dragged far away. *lidarusa.com*

Terra Drone Europe aids Djibouti in flood damage mitigation

Terra Drone Europe has successfully completed a high-resolution photogrammetric pavement assessment using a multi-rotor drone at Djibouti's key port of Doraleh. The 5-day aerial survey was accompanied by detailed inspections of the quay walls and the sea defense revetments at the Doraleh harbor.

The data acquired will be used in conjunction with previously-collected bathymetric data, by Deep B.V., to offer a holistic view of the condition of the port – both above and below the waterline. With this survey, Djibouti will be able to identify the high and low spots of the harbor pavements – an important aspect since the port has proven to be susceptible to flooding. The topographic data will further be used to plan and propose a new drainage scheme to the port owners. *https://terra-drone.eu/en/*

Terra Drone introduces Terra Mapper software in India

Terra Drone India (TDI) has introduced all-in-one drone data processing and photogrammetric software Terra Mapper in the Indian market. The new, updated version of Terra Mapper simplifies aerial data analytics and eliminates the need for enterprises and organizations to outsource drone data processing jobs.

DJI Government Edition's rigorous data controls are validated by U.S. Federal

DJI has introduced DJI Government Edition, a new comprehensive drone solution created specifically for use in high-security situations by government agencies around the world. Government Edition's unique architecture ensures that drone data – including photos and videos captured during flight – never leave the drone and therefore can never be shared with unauthorized parties including DJI. This architecture ensures it meets the stringent requirements of the government sector for data management, risk mitigation, and enterprise-level data sharing control. *www.dji.com*

SimActive launches new drone processing service

SimActive Inc. has announced a new drone data processing service based on Correlator3D™. Clients can now upload full projects and have SimActive experts generate optimal results from their imagery, including DSMs, DTMs, 3D models and orthomosaics. *www.simactive.com.*

Altitude Angel partners with FOCA

Altitude Angel is to join the Swiss civil aviation authority (FOCA) development programme to establish a U-Space regulatory framework.

FOCA established the Swiss U-Space Implementation (SUSI) platform and invited businesses from across the globe to help advance its understanding and regulatory model around the integration of unmanned aircraft systems (UAS) into the airspace. Skyguide, the Swiss ANSP, is commissioned to implement the applicable legislation and to develop and implement the FIMS (flight information management system). Skyguide will provide different FIMS functionalities and interfaces over time in accordance with the overall SUSI project. *www.altitudeangel.com*

Drone management integrates business and technical tools

Dronecloud has announced the launch of its Drone Management, cloud-based software platform. The platform can halve project overheads by simplifying end-to-end workflow. It integrates all drone operations; from client communications to flight planning and it automatically creates a regulation-compliant audit trail through partnerships with global leaders in drone and air traffic data analytics. *www.dronestagr.am*

AIRT and APD partnership to promote disaster resiliency via drones

The Airborne International Response Team (AIRT) has announced a new partnership with the Asociación de Profesionales de Drones (APD) to promote the use and standardization of unmanned aircraft systems (UAS) and associated technologies throughout the Caribbean and Latin America for emergencies and disasters.

The memorandum of understanding also calls for mutual-aid and support capabilities for disaster preparedness, response, and recovery capabilities for complex incidents and significant emergencies such as hurricanes, earthquakes, mudslides, and a range of other disasters.

Two Indian drone startups get certified under new drone policy

Two drone startups in the Indian city of Bengaluru, Skylark Drones and Throttle Aerospace Systems get certified drones from the Directorate General of Civil Aviation (DGCA) after they complied with the NP-NT (no permission, no takeoff) protocol under the new drone policy. This is the first time such certifications has been given under India's new drone law that came into effect on December 1, 2018.

Under the NP-NT procedure, drone operators needs to get prior permission to fly drones through mobile applications. Those drones that don't have the permission from Digital Sky platform will not be able to operate. These two startups got the permission as their drones fall under the category of visual line of sight (VLOS) – which means drones have to be within the viewing limits of the operator.*https://tech.economictimes.indiatimes.com*

Hyderabad, India to use drones for mapping urban properties

The Indian city of Hyderabad'sGreater Hyderabad Municipal Corporation (GHMC) has sent a proposal to conduct a GIS mapping survey via drones.

The Municipal Corporation plans to use this new technology to map urban properties and other conveniences in the town. The mapping project is estimated to make an important impression on unauthorized constructions and illegal infringement.

This technology might be used for the first time in Hyderabad, other cities that have already implemented this mapping survey for urban properties and other facilities are Chennai, Bangalore, and Mumbai. *www.newindianexpress.com*

GeoCue launches True View, first drone LiDAR/imagery fusion sensor

GeoCue Group has unveiled its new True View line of drone sensors. It offer surveyors an innovative lidar + dual oblique mapping camera configuration integrated in a single lightweight payload for use on commercial drone platforms. It allows for fast, easy automated generation of true 3D colorized point clouds, oblique imagery and orthophotos from a single flight.

Raytheon and Black Sage team to deliver counter-drone tech

Raytheon Company and Black Sage are now partnering to provide an integrated drone detection and mitigation system for civil authorities, critical infrastructure and military organizations around the world.To defend urban environments, like airports and cities, against drones, Black Sage's sensors, AI, and radio-frequency jammers have been integrated into Raytheon's Windshear command and control system. This combined system allows a single operator to control a network of sensors and effectors that safely and quickly track, take over or land drones flying where they shouldn't. *www.raytheon.com*

Raytheon and AirMap collaborate on safe drone integration

Raytheon Company has signed a strategic agreement with AirMap, the leading global airspace intelligence platform for drones, to collaborate on future projects to safely integrate unmanned aerial systems, into the national airspace system and unlock the positive economic and social benefits of expanded commercial drone operations. *www.airmap.com*

Flock launches 'real-time' insurance and risk-management product for drone fleets

Flock, the London-based insurtech startup has unveiled 'Flock Enterprise', a first-of-its-kind insurance and risk management solution for drone fleets.The product leverages real-time data to provide highly bespoke insurance policies for enterprises using drones. This data-driven approach transforms how organisations insure their connected drone fleets, offering greater visibility into flight risk and rewarding safer flights with cheaper insurance premiums. *https://dronelife.com*

Virtual Surveyor unveils terrain lenses in drone mapping software

Virtual Surveyor has unveiled Terrain Lenses in Version 6.3 of its drone surveying and mapping software. Overlaid on a LiDAR point cloud or orthophoto, the six lenses enhance different aspects of the terrain in 3D to give users a better understanding of the topography in the area they mapped with UAV. *www.virtual-surveyor.com*

CHC Navigation introduces LT700 Android tablet

CHC Navigation (CHCNAV) has announced the availability of the latest LT700 rugged Android tablet designed to increase efficiency and productivity of mobile workforce in different industries and applications. Featuring an 8-inch sunlight-viewable screen in direct sunshine and high-bright areas, the it perfectly displays any GIS data tables, complex vector and raster maps or high-resolution pictures.

The integrated GNSS module (GPS/GLONASS/BDS/SBAS) provides robust positioning performances. The LT700 dual-SIM 4G modem ensures fast and reliable connection with mobile teams. *www.chcnav.com*

Low-power GNSS processing for tracking devices

A new solution developed by Ubiscale enables low-power GNSS sensing and position determination for applications such as asset tracking, where the tracking device does not need to know its own position.

The Ubiscale solution consists of an embedded software core that pre-process signals and a simple Application Programming Interface (API) to the 'Ubi.cloud' platform, which then delivers the effective device coordinates to the end user. Smart algorithms increase the reliability of the positioning. The solution is designed to enable close integration with 'Internet of Things' (IoT) and 'System on a Chip' (SoC) technologies. *www.gsa.europa.eu*

Royal Navy Developing AI Mine-Hunting Submersible

The Royal Navy is using artificial intelligence to task autonomous submersibles with hunting underwater mines. British geospatial and data company Envitia, which has expertise around applying AI and machine learning to complex data problems, along with its partner BAE Systems Applied Intelligence, has been selected to deliver this, one of the first AI projects for the Royal Navy. Mine-hunting is currently carried out by a fleet of mine-hunter ships using sonar to survey seabeds looking for anomalies. But these new AI-enabled submersibles will be much quicker in being able to scan an object, identify the threat, and make decisions about what to do with it. *www.envitia.com*

First Galileo Batch-3-Payload "Patrick" reaches OHB

The first of the Batch 3 contract navigation payloads was delivered at the beginning of June by SSTL according to schedule and satellite series production for Galileo is in full swing again at OHB System AG in Bremen. OHB System AG will deliver a further twelve satellites for the European Satellite Navigation System Galileo. *www.sstl.co.uk*

Detection of fatigue and distraction in operators of light vehicles

Hexagon AB has introduced HxGN MineProtect Operator Alertness System Light Vehicle (OAS-LV) . It expands Hexagon's portfolio for operator safety solutions, filling a gap to protect light-vehicle operators from falling asleep at the wheel, crashing or other fatigue-related incidents. The product is based on the proven technology used in HxGN MineProtect Operator Alertness System Heavy Vehicle (OAS-HV), which protects operators of haul trucks.

The solution's in-cab device is easy to install and scans the operator's face to detect any sign of fatigue or distraction, such as a microsleep. A machine-learning algorithm leverages this facial-feature analysis data to-determine whether or not an alert should be triggered. OAS-LV works in both light and dark conditions, and through prescription glasses and/or sunglasses. hexagon.com

NovAtel's SMART2 Antenna offers scalable positioning solutions

NovAtel unveiled the new SMART2™ family of antennas, adding robust entry-level options to their SMART Antenna portfolio that meets the needs of users requiring scalable accuracy in a single compact enclosure. With dual-frequency, multi-constellation signal tracking, the SMART2 is designed to deliver optimized position reliability and accuracy for the precision agriculture market.

Access to TerraStar™ Correction Services is also offered with the SMART2, providing users with improved accuracy and pass-to-pass performance. It delivers flexible positioning solutions that grow with users' needs.

Safran, Orolia announce global resilient PNT partnership

Safran and Orolia announced the signing of a strategic partnership to offer the latest resilient positioning, navigation and timing (PNT) solutions for military forces, especially in GNSS denied environments.

This partnership will provide mission-critical equipment for air, land, sea and space programs in environments where GNSS signals are not available or degraded. Whether the outage is unintentional (environments where GNSS signals are unavailable like underground locations, jungles, etc.) or intentional (jamming, meaconing or spoofing), the Safran-Orolia partnership will provide an alternative to GNSS-dependent military systems.

Hemisphere GNSS offers new OEM Positioning & Heading Boards

Hemisphere GNSS recently announced its next-generation digital and RF (radio frequency) ASIC (application-specific integrated circuit) platforms, and the release of three all-new positioning and heading OEM (original equipment manufacturer) boards– the first products incorporating these technological advancements.

Hemisphere's new (Lyra II) digital ASIC and (Aquila) wideband RF ASIC designs optimize performance and provide the ability to track and process more than 700 channels from all GNSS constellations and signals including GPS, GLONASS, Galileo, BeiDou, QZSS, SBAS, and L-Band Signal support and tracking for AltBOC and BS-ACEBOC, BeiDou

Phase 3, L5, and QZSS/LEX CLAS-D and CLAS-E are also available. This new ASIC technology is designed to offer scalable access to every modern GNSS signal available. Also, the Lyra and Aquila ASIC technology provide the foundation for a new GNSS receiver chipset architecture that significantly reduces the number of board components required, thereby reducing complexity, improving reliability, and lowering power consumption, according to Hemisphere. *www.hemispheregnss.com*

Allystar offers dual-antenna GNSS-aided INS platform

The Allystar INS Platform is a dual-antenna, multi-frequency, multi-GNSS inertial navigation system (INS) that delivers accurate and reliable position, velocity and orientation. It is designed for a wide range of autonomous vehicle applications under the most demanding conditions. *www.allystar.com*

"Tiny" GNSS Module for Tracking and Navigation by STMicroelectronics

STMicro's newest module is ROM-based. The module provides simultaneous access to the Glonass, Beidou, and QZSS constellations in addition to GPS. The Teseo-LIV3R is available in a 9.7 mm x 10.1 mm LCC 18 pin package. It responds to proprietary NMEA (National Marine Electronics Association) commands, and it has a tacking sensitivity of –163dBm. The module incorporates STM's Teseo lll positioning receiver IC. *www.st.com*

Harris delivers Navigation Payload for GPS III Satellite

Harris Corporation HRS recently announced that it has delivered the seventh of 10 leading-edge navigation payload to Lockheed Martin Corporation LMT, contracted for the U.S. Air Force's GPS III satellite program.

Markedly, the GPS III navigation payload features a Mission Data Unit (MDU) with 70% digital design that links atomic clocks, radiation-hardened processors and powerful transmitters. This enables signals up to three times more accurate than any other GPS satellites currently in operation. Reportedly, the payload improves signal power, which helps to increase jamming resistance by eight times and extend the satellite's lifespan. *www.harris.com*

Orolia's new aircraft emergency beacon uses Galileo service

The Kannad Ultima-S is designed to be installed in the cabin of commercial aircraft or in its life raft. It is capable of notifying the crew about the launch of a search-and-rescue operation via Galileo Return Link Service (RLS).

For passengers, installation of the Kannad Ultima-S means their flight can located accurately, with rescue following if an aircraft evacuation is needed. Orolia's Kannad Ultima-S ELT was developed under a two-year contract through the European GNSS Agency's Tauceti Project. It is the first beacon to use the Galileo RLS.

Microsemi qualifies ViaLite high-performance GNSS/GPS fiber extension kit

Carrying timing signals over optical fiber links to 10+ km, ViaLite's new GNSS/GPS Fiber Extension Kit has been successfully qualified for use with Microsemi's timing and synchronization products. Included in the kit is the ViaLiteHD GPS Link, which is designed for providing a remote GNSS/GPS signal or derived timing reference to equipment located where there is no reception, such as inside buildings, tunnels and mines.

The kit is suitable for GPS, Galileo, GLONASS and BeiDou bands, and the links provide a wide dynamic range with negligible signal degradation from noise or interference.

The TDC600 – handheld GNSS receiver from Trimble

The TDC600, a newly introduced product of Trimble Data Collectors' lineup, is a rugged, slim, lightweight and ergonomic pocket-size form factor Android smartphone with a built-in professional GNSS receiver. While allowing to perform the standard tasks of a consumer smartphone, reducing the number of devices needed in the field, the TDC600 integrates with other Trimble's hardware and software solutions.

These include the Trimble R2 and R1, two separate external GNSS receivers for GIS and survey professionals; the Trimble Penmap and Terraflex, which are software solutions to collect attribute rich and accurate geo-located GIS and asset information; and Trimble's software-based receiver, Catalyst, a small, lightweight antenna that plugs directly into an Android phone or tablet's USB port to collect on-demand high-accuracy data. *www.trimble.com*

Dual-frequency GNSS smartphone supports BDS phase III signal

The latest Lenovo smartphone offers dual-frequency GNSS capable of tracking the latest BDS phase III signal, the Z6 SE, using an Allystar chipset. It is the first time a smartphone supports the new BeiDou signal.

Abom launches military/industrial goggles with GNSS/INS

Abom, a company that designs sophisticated commercial goggles, has launched new augmented reality (AR) goggles. Designed for safety, industrial and military markets, it feature accurate tracking of orientation, velocity and positioning using IMU/GPS-GNSS/INS receiver capability. *www.abom.com*

Septentrio Releases New High-precision GNSS Module

Septentrio has announced that the Mosaic development kit is available for testing and integration. It is Septentrio's most compact next-generation, high-precision multi-frequency GPS/GNSS module. This receiver brings precision and reliability of high-end multi-frequency GNSS to mass-market applications. It is designed to fit into the assembly line process, which allows Mosaic to be favourably priced for high volumes.

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

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

57th Photogrammetric Week
9 - 13 September 2019
Stuttgart, Germany
https://phowo.ifp.uni-stuttgart.de

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

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

MRSS19 – Munich Remote Sensing Symposium 2019
18 - 20 September
Munich, Germany
www.mrss.tum.de

PIA19 – Photogrammetric Image Analysis 2019
September 18 - 20
Munich, Germany
www.pia.tum.de

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

October 2019

The 8th FIG Land Administration Domain Model Workshop (LADM 2019)
4th International Conferenceon Smart Data and Smart Cities (SDSC2019)
Geomatics Geospatial Technology (GGT2019)
1 - 3 October
Kuala Lumpur, Malaysia,
http://isoladm.org
www.geoinfo.utm

40th Asian Conference on Remote Sensing (ACRS)
13 - 18 October
Deajuong City, Korea
www.acrs2019.org

Commercial UAV Expo Americas
28 - 30 October
Las Vegas, USA
www.expouav.com

ISGNSS 2019
29 October - 1 November
Jeju Island, South Korea
www.ipnt.or.kr/isgnss2019

November 2019

GEO Week 2019 and the GEO Ministerial Summit
4-9 November
Canberra, Australia
www.earthobservations.org

International Navigation Conference 2019
18 - 21 November
Edinburgh, Scotland
https://rin.org.uk/events

March 2020

Munich Satellite Navigation Summit
16 - 18 March
Munich, Germany
www.munich-satellite-navigation-summit.org

May 2020

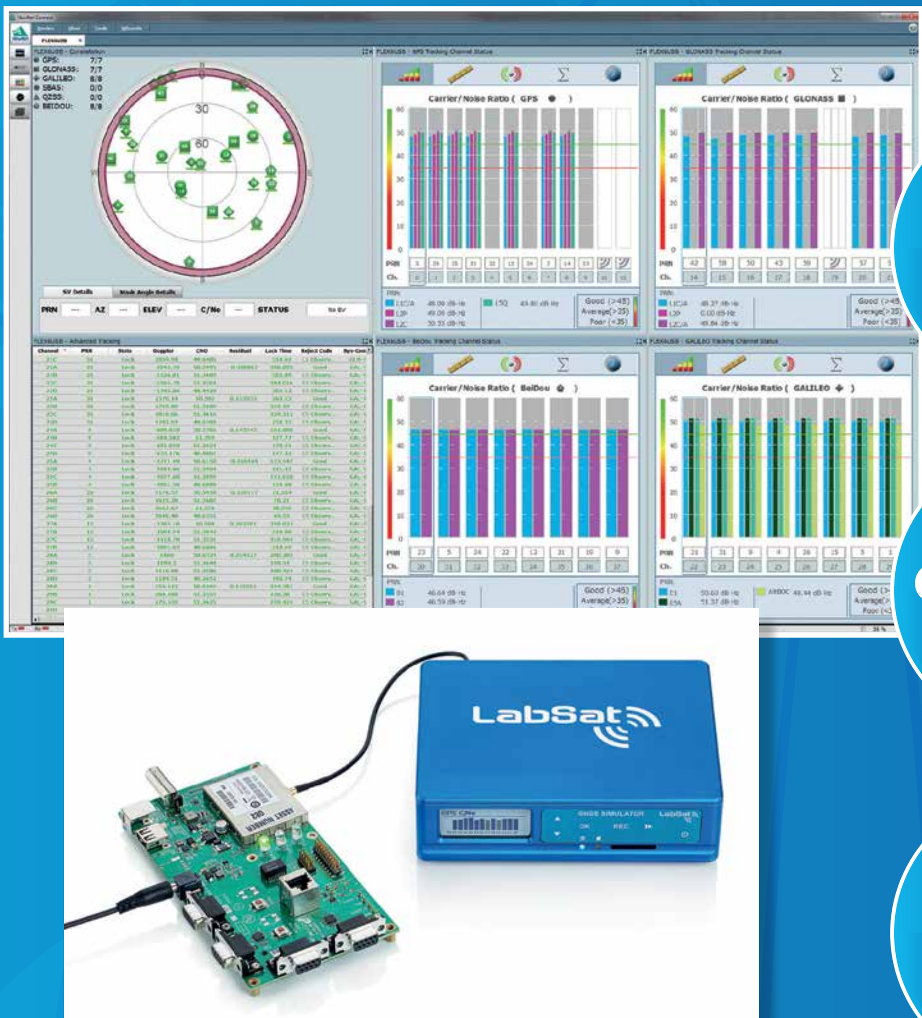
FIG Working Week 2020
10 -14 May
Amsterdam, the Netherlands
www.fig.net

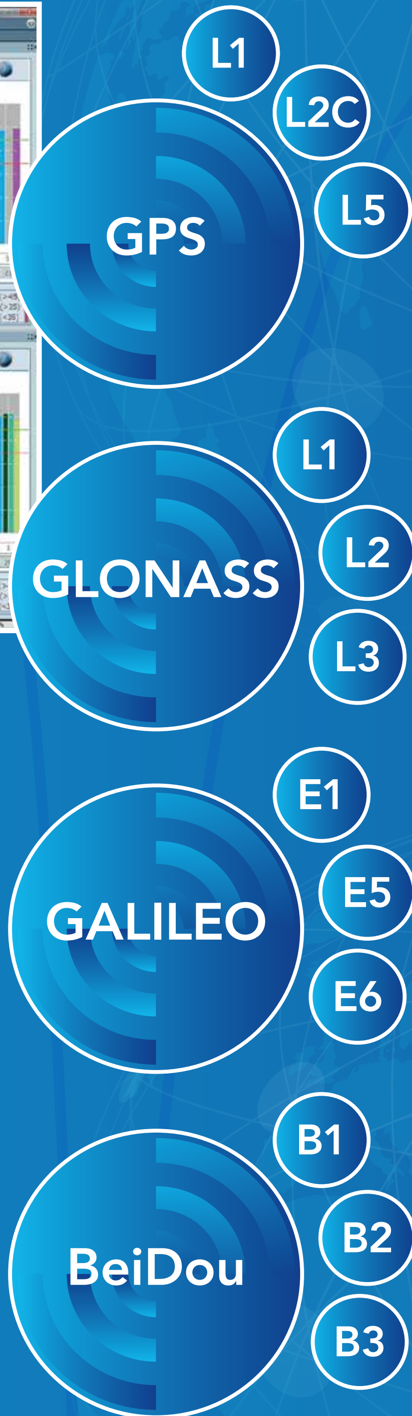
GeoBusiness 2020
20 - 21 May
London, UK
www.geobusinessshow.com

June2020

XXIVth ISPRS Congress
14 – 20 June 2020
Nice, France
www.isprs2020-nice.com

SatGen Signal Simulation Software





SatGen signal simulation

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

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

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