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THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

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L5 ☑	L3[1] ☑		

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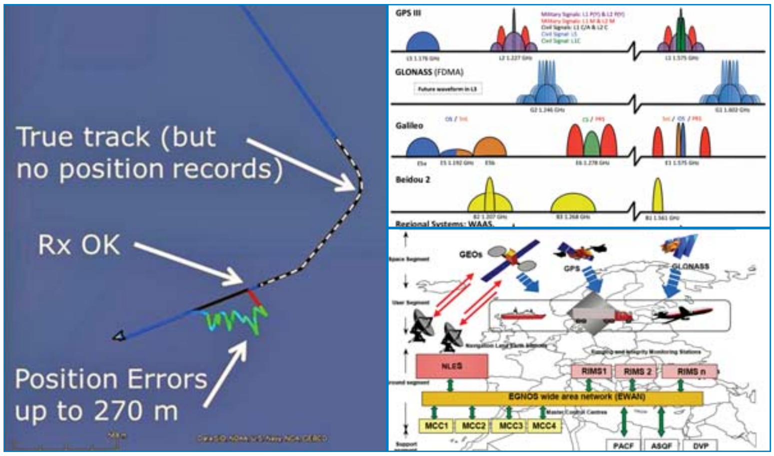
[1]There is no public GLONASS L3 CDMA ICD. Trimble cannot guarantee full compatibility.



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Mailing Address
A 002, Mansara Apartments
C 9, Vasundhara Enclave
Delhi 110 096, India.
Phones +91 11 22632607, 98102 33422, 98107 24567
Fax +91 11 22632607

Email
[information] talktous@mycoordinates.org
[editorial] bal@mycoordinates.org
[advertising] sam@mycoordinates.org
[subscriptions] iwant@mycoordinates.org

Web www.mycoordinates.org

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Editor Bal Krishna

Owner Centre for Geoinformation Technologies

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Mission Mars

After Moon, it is now Mars.

With the launch of its first interplanetary spacecraft

on November 5, 2013.

Indian Space Research Organization has demonstrated,

Not only its capabilities of carrying such a venture at a low cost

But also its priorities for interplanetary missions.

Mars orbiter spacecraft is scheduled to reach to Mars' orbit in September 2014.

Though, the eventual success of such missions

May ultimately be measured by their contributions

To the domain knowledge of space science.

They do add to the pride

And the confidence of a developing nation.

Bal Krishna, Editor
bal@mycoordinates.org

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EUROPE, MIDDLE EAST AND AFRICA

Spectra Precision Division
Rue Thomas Edison
ZAC de la Fleuriaye - BP 60433
44474 Carquefou (Nantes), France

+33 (0)2 28 09 38 00 Phone

ASIA-PACIFIC

Spectra Precision Division
80 Marine Parade Road
#22-06, Parkway Parade
Singapore 449269, Singapore

+65-6348-2212 Phone

"Member States are obliged to implement INSPIRE"

Says Alessandro Annoni, Head of the Digital Earth and Reference Data Unit, European Commission, Joint Research Centre, Institute for Environment and Sustainability in an interview with Coordinates

How is INSPIRE useful for Europe?

INSPIRE stands for Infrastructure for Spatial Information in Europe. It is a European framework legislation that aims to create a European Spatial Data Infrastructure (SDI) that is built on the top on National SDI developed and operated by the European Member States.

Through INSPIRE, we ensure the access to existing information in various Member States (MS). Through common rules and protocols and interoperable services (for discovery, view and download) we can access MS harmonised data at the European level. That means it would be possible to support cross border applications between two or more countries, by working with harmonised data set and interoperable services.

How much time did it take to implement this system, and has it been implemented fully and to your satisfaction?

The work for INSPIRE started in 2001, including an Impact Assessment in which we had to analyse the different options to create a European Spatial Data Infrastructure. Considering that there were different policies in place in the different Member States, the clear solution was that a European legislation was needed. For this reason in 2001 an INSPIRE expert group composed by representatives of the Member States and the European Commission jointly started the preparation of a proposal for the INSPIRE Directive (European legal framework). The INSPIRE Directive was adopted by the EU Council and Parliament in 2007. As any other European Directive the legislation has been transposed in all national legislations. This process took a couple of years.

INSPIRE is a framework legislation so all technical details are not necessarily described there. They are defined by additional legal acts called implementing rules. These implementing rules are additional legal acts that cover Metadata, Network Services, Data Sharing and Interoperability of Data and Services. The implementing rule on Network services in particular establishes common protocols for discovery, view and download data. The implementing rules have been developed across several years. The first one was developed in 2009 on Metadata and the last one was developed on data specifications on interoperability for Annex II and III data and was adopted on 21st October this year. Only one implementing rule is missing on Spatial Data Services and Invoke Services. This is expected to be adopted early next year. At that stage the INSPIRE legal framework will be complete.

INSPIRE implementation started at the time the directive was adopted in 2007, and progresses when additional implementing rules are adopted (for example the obligation to provide metadata is by 2010 following the adoption of the Metadata implementing rule). As far concern data interoperability (use of common data models), we should wait till 2015 for Annex I data, and then till 2020 for Annex II and III.

These dates are deadlines to be legally respected but some Member States could decide to anticipate the implementation. That is what is already happening in some Member States. The decision to anticipate implementation is related to various factors: i) need to anticipate modernisation of public services, ii) need to rationalise mandates of different Agencies, iii) new data collection campaign, iv) easy adaptation of existing data and services, .. Countries that are more advanced (e.g. data already standardised and archived in digital form) and organised as in UK, Germany, etc. will go faster. Vice versa other countries should start from a different lower level where we have to start (e.g. still need to digitise the information) so implementation could be slower. It is difficult to classify countries and we need to understand the different realities (cultural heritage and economic situation). However these countries will not necessarily be late despite a slower start.

We cannot propose a geographical distinction to explain the different speeds. In fact Poland and Hungary are well advanced whereas other East European countries are still organising themselves. It should be noted also that when a government changes, there may be an acceleration or delay on SDI implementation. The Croatia, as a new country that entered the European Union in June is now obliged to implement all European legislations. So they started very late (this year) but it seems that they are going very fast because they seem well organised.

The Member States have to report annually a number of indicators for monitoring the implementation and use of their infrastructures for spatial information. Their reports including i.a. information on the coordinating structures, on the use of the infrastructure for spatial information, on data-sharing agreements and on the costs and benefits of implementing the INSPIRE Directive, are prepared and submitted every three years, starting in 2010. This information about the state of the play of INSPIRE implementation in the various Member States is available on the INSPIRE website http://inspire.jrc.ec.europa.eu/index.cfm/pageid/182

What is likely to take place if a member state does not want to join or wants to get out of it? Can it?

INSPIRE is a legislation, so the Member States are obliged to implement it. Like any other legislation not implementing its provisions will result in having to pay serious penalties.

For the time being implementation is more or less in line, with acceptable minimum delays. So there are no penalties proposed. If in future, some member states will not respect deadlines the European Commission will start the procedure of infringement and Member States will be asked to pay penalties.

How long have you been associated with this project?

Since the beginning of INSPIRE but already doing anticipatory work in 1997. In fact my organisation (JRC) in 1997 launched the project “GI harmonisation and GIS interoperability” aiming to explore the possibility to create a European SDI. In 2001, we met with colleagues of the Directorate General of Environment and they recognised the importance of our work to ensure better harmonised information for environmental policy making. It was so decided to launch the INSPIRE initiative and to involve Member States since the beginning through the INSPIRE Expert Group composed by MS representatives.

What were the challenges, since it is not easy to get all the 28 member states on to the same board.

INSPIRE is unique, and this is why it is internationally recognised as a good model to develop a Regional SDI. In fact INSPIRE respects the freedom of each Member States to develop its own national infrastructure (including adoption of national standards) and focusses on common protocols to make the various NSDI interoperable at European level.

For developing the technical specifications we used drafting teams composed by representatives of the Member States. In this way we collected all the reference material allowing us to re-use and take into consideration everything that already exists.

By defining a minimum common denominator we can minimise the cost for adaption of National systems to INSPIRE. INSPIRE has been a real collective effort (open and transparent) to develop a legislation and the related technical guidelines. We had also several publication consultations. At the end, the Member States endorsed a legislation that was drafted by them. This approach took a lot more time to develop the specifications than the normal approach of asking few experts to develop them. But the advantage is that we built the consensus during the drafting and so it there is no surprise, because at the end, it is the member states who have decided what they want and can do.

Do you have any advice to countries who are struggling to set up their own spatial data infrastructure?

From the experience that we have made INSPIRE, we know what should be avoided. It could be a mistake to ask only to data providers how to build the infrastructure. The infrastructure should be designed together by people responsible for data provision together with those responsible for their use (including citizens, decision makers and application providers). By only listening to the voice of data providers, we probably develop an infrastructure that is not fitting the purpose for the use and nobody will understand why money is invested in something that nobody will use. So it is important and this is what we tried in INSPIRE, to have every decision clearly justified by user demands. The INSPIRE infrastructure is not dealing with only cartographic and geodetic. Our users are environmental users who will use the topographic data together with environmental data (forests, soils, geology, etc.) to address specific questions. My recommendation for the India NSDI is to do something that users wants, and meanwhile something that is feasible at reasonable cost. The project team responsible for the design of the NSDI should be composed of all stakeholders, and not be restricted only data provider or academic people.

What were the stumbling blocks you came across these 12 years?

One clear problem that we faced and was not foreseen was the unforeseen problem of the financial crisis. The financial situation in Europe is particularly severe, and implies cuts in the public administration resources. Resources dedicated to geographic information could be cut easier than resources dedicated to Health. So the organisation responsible for the implementation could be in difficulty because it would have fewer budget compared to past years. Anyhow INSPIRE is saving resources by avoiding duplication and is helping in making economy. So it can be seen as an opportunity to deal with financial restrictions.

A second problem that complicated our life is the quality of geographic information standards that are really not ready for use. In INSPIRE framework, we are still facing the immaturity of existing standards that are not appropriate for an operational infrastructure (there is also an increasing competition between GI standards and the main ICT standards).Additionally these standards were designed mainly by the National Mapping Agencies and their application to the environmental sector (environmental spatial data) not necessarily fit from a data provider point of view.

The third problem is the rapid evolution of ICT technology. When you have a legal frame imposing technical rules, it is difficult to dynamically adapt to technological changes. We cannot change it every time a new technology becomes available because in that case you will get the member states in trouble. If you keep changing every year, you will never have anything implemented. So we have to agree to decide on a certain point about one technology you want to impose and stay on that technology until the infrastructure is implemented. Then in the future we can evolve and adapt.

Have the benefits of INSPIRE already started? Give examples of INSPIRE as a system being used by the member states, and being beneficial.

INSPIRE as a whole system is not yet usable because as mentioned before implementing rules on data interoperability has only been adopted this year. And as well the obligation to provide the data would be in 2015. So for the time being, you don't have access to harmonise the data only to Metadata. What you have today is just the possibility to search the data and download the data under the INSPIRE scope but according to existing national data models. The benefit for national citizens is quite obvious. Information which was not accessible before, is now accessible, and in some cases is now free of charge. If you look at UK, France, they have a very restricted policy before whereas now they have decided to adopt a more open data policy. Information is now documented and people can start to use. As a consequence the number of users increases (at country level). Viceversa expected benefits for accessing cross border harmonised information will be from 2015 onwards.

A second main benefit is that INSPIRE is helping in coordinating across Public Authorities. In one country's 100-200 national public authorities could be affected by INSPIRE and are forced to collaborate and to agree on common procedures, to clarify individual roles and mandates and collate information collected by each of them and maybe put money together to buy new data. So it is a kind of an economy and also harmonisation of practices between different organisations.

A third benefit is about raising awareness. Citizens using INSPIRE services can identify inefficiencies in public administration (asking to for data that are not made accessible). Citizen will also become more concerned about the advantage of a spatial data infrastructure.

What are the steps you are taking to educate the citizens?

This is a tricky point. Education to the citizens could not be done directly by the European Commission whereas indirect actions are foreseen. Education remains a main responsibility of each Member State. What we are trying to do is to identify INSPIRE evangelists in each country. We put together representatives of different countries and we try to do some capacity building with them in order that they can then do the same in their own country training people in their own language. So we concentrate on preparing training material, organising the annual INSPIRE conference (attended by one thousand of participants) and participate to National events organised by the member states. Special attention is given to pre-accession and neighbourhood countries.

Is Galileo as an organisation or a system part of INSPIRE?

Galileo is mentioned in the INSPIRE Directive.

The establishment of INSPIRE will represent significant added value for — and will also benefit from — other Community initiatives such as Galileo. Member States should consider using the data and services resulting from Galileo as they become available, in particular those related to the time and space references from Galileo.

When INSPIRE was adopted in 2007, Galileo's services were not yet operational.

With Galileo now becoming operational, an European GNSS Agency (GSA) agency has been established last year in Prague. The Agency's strategic objectives include the achievement of a fully operational GALILEO system. Moreover, the Agency's key stated objective is to make GALILEO not just a functioning system but also the world's leading satellite navigation system for civilian applications.

For the three-dimensional and two-dimensional coordinate reference systems and the horizontal component of compound coordinate reference systems used for making spatial data sets available, INSPIRE adopts the datum of the European Terrestrial Reference System 1989 (ETRS89) in areas within its geographical scope, or the datum of the International Terrestrial Reference System (ITRS) or other geodetic coordinate reference systems compliant with ITRS in areas that are outside the geographical scope of ETRS89.

No impact is foreseen on INSPIRE specification adopted since information provided by Galileo is fully compatible.

Multi-GNSS positioning campaign in South-East Asia

In this study, the preliminary results of multi-GNSS software receiver to highlight the availability, the quality and the potential of the multi-GNSS positioning environment are summarized

Tung Hai Ta
Director of NAVIS Centre, Hanoi University of Science and Technology, Vietnam

Duc Minh Truong
MSc Student, NAVIS Centre, Hanoi University of Science and Technology, Vietnam

Tu Thanh Thi Nguyen
MSc Student, NAVIS Centre, Hanoi University of Science and Technology, Vietnam

Hieu Trung Tran
Researcher, NAVIS Centre, Hanoi University of Science and Technology, Vietnam

Thuan Dinh Nguyen
Researcher, NAVIS Centre, Hanoi University of Science and Technology, Vietnam

Gustavo Belforte
Associate Professor, Politecnico di Torino, Italy / International Co-director of NAVIS Centre, Hanoi University of Science and Technology, Vietnam

Over the past three decades the only two available Global Navigation Satellite Systems (GNSS) have been the American GPS and the Russian GLONASS. Although these systems have been initially developed for military applications, while time has been passing, the interest in using these facilities also for deriving position, velocity and time (PVT) in civilian applications has registered a continuously growing interest. As a consequence in few decades we have reached the point in which GNSSes have a key relevance in almost any sector of modern society. Efficient solutions and innovative infrastructures are increasingly using this enabling technology to ensure safer and better services in almost any branch of modern life from transportation systems (air, road, rail sea) to disaster management, from agriculture to environment monitoring, natural resources exploitation, infrastructure management, safety, and much more.

However for long time the first two available GNSSes have been mainly regarded as alternative options so that receivers, application and services have been developed for one of them only.

When at the end of the twentieth century the design of new GNSSes started together with some Regional Navigation Satellite Systems (RNSS) [1] the scientific community and commercial users have started to consider benefits and challenges of a multi-GNSS environment analysing the possibility to use jointly two or more systems and debating problems and difficulties that could arise by such an environment [2][3][4].

Recently, the multi-GNSS environment has become reality due to the completely recovered global constellation of GLONASS, the launches of the new 4 In-Orbit-Validation (IOV) satellites of Galileo, and the start of the civil service for Asia-Pacific region of Beidou. This paper presents the work in development of multi-GNSS positioning solutions, with focuses on signal processing algorithms, able to accommodate multiple systems, in all blocks of the receiver.

The solutions are tested with real data collected from all 4 GNSSes to analyse the advantages of multi-GNSS environment for civil users worldwide.

Multi-GNSS environment

Status of all GNSSes

In this section a short overview of the status of the different analyzed GNSSes is presented for reference.

GPS: As remarked GPS is the first GNSS and it has been continuously working for decades. The system has undergone maintenance and has been modernized with the launch of new types of satellites equipped with new capabilities. As designed, the full constellation has 24 medium elevation orbits (MEO) satellites on six orbit planes, which have approximately 55° inclination relative to the equator and are separated by 60° right ascension of the ascending node [5].

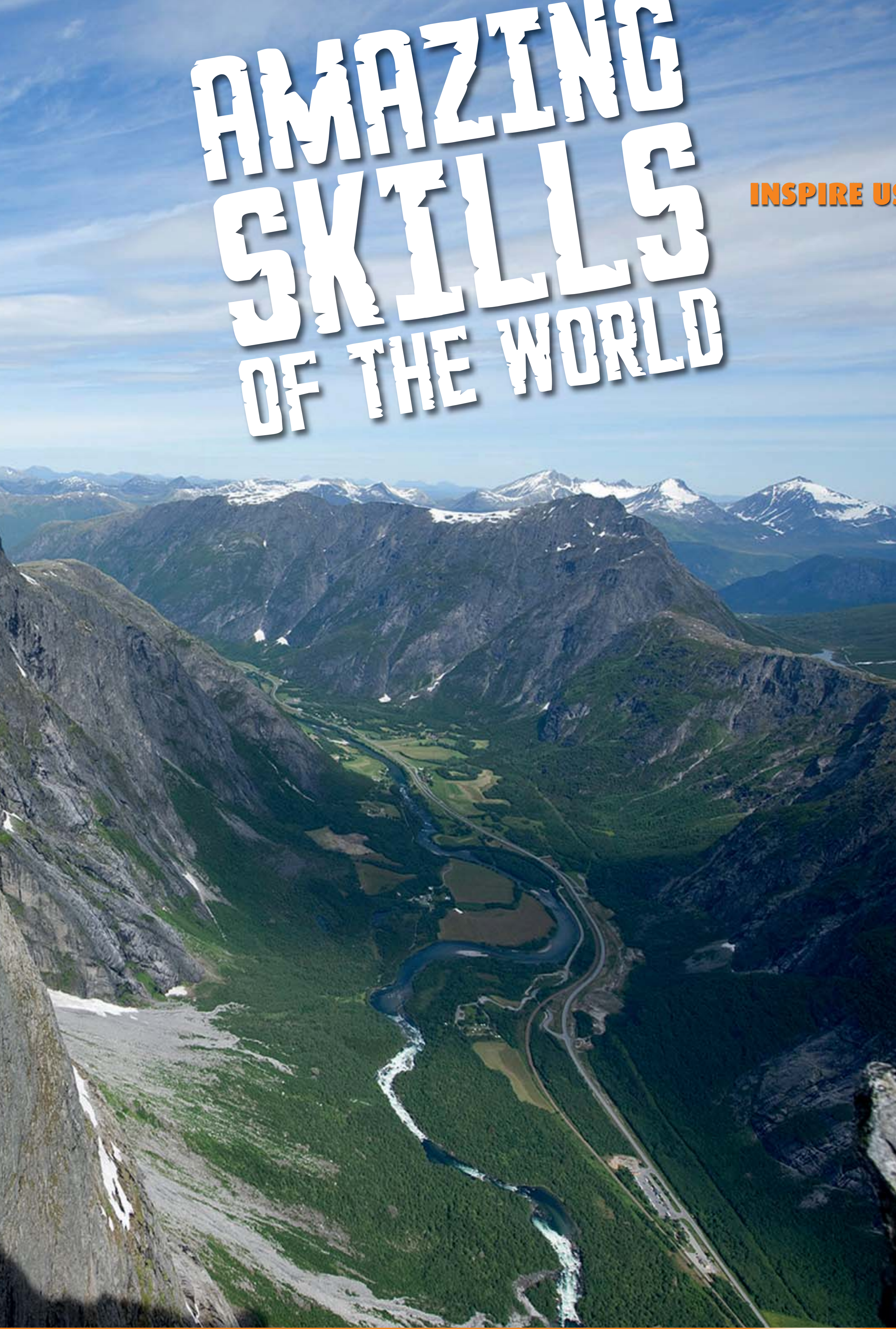
GLONASS: is the GNSS developed by the Soviet Union in the past and Russia currently. Its constellation is composed of 24 MEO satellites on three orbital

Photo: Sindre Lundvold

NORWEGIAN EXTREME ARTIST, ESKIL RONNINGSBAKKEN, ON A UNICYCLE AT TROLLVEGGEN, THE TALLEST VERTICAL ROCK FACE IN EUROPE. NORWAY, 2010.

AMAZING SKILLS OF THE WORLD

INSPIRE US ...



planes (8 satellites evenly spaced on each orbit). In 2011, the full constellation of GLONASS was restored. Unlike the other GNSSes, GLONASS broadcasts FDMA signals; however in future with new satellite generations, GLONASS will broadcast CDMA signals also [8].

Galileo: The European GNSS foresees 27 MEO working satellites on 3 orbital planes, which have 56° inclination relative to the equator and are separated by 120° right ascension of the ascending node. Currently the Galileo system is under deployment and only its first 4 satellites were launched. These satellites have been transmitting the open service signal since March 2013 thus enabling the Galileo-only position fix [6]. New satellites should be launched over the next few years to allow the system to become fully operational [7].

Beidou: This Chinese GNSS foresees the use of 3 different types of satellites: (i) geosynchronous equatorial orbit (GEO); (ii) inclined geosynchronous orbit (IGSO) with an inclination angle to the equatorial plane of 55°; and (iii) MEO. At present the Beidou system consists of 14 satellites (5 GEO, 5 IGSO and 4 MEO satellites). The existing satellites started offering services to users in the Asia-Pacific region in December 2012 [9].

The signal spectrum of each GNSS is shown on Figure 1.

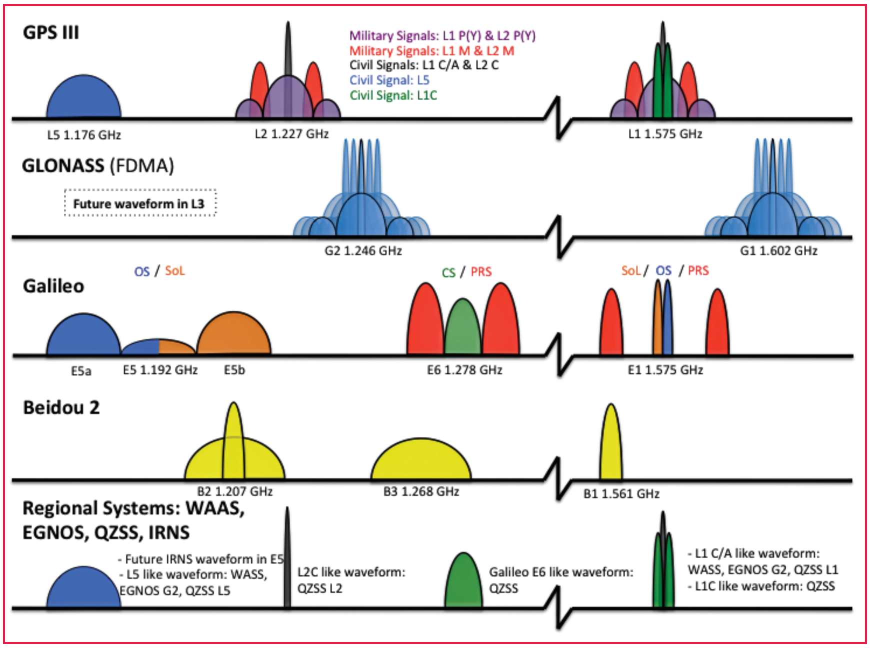


Figure 1. Signal spectrum of all GNSSes

Advantages of Multi-GNSS environment

Availability increase: Obstacles like high buildings, trees… in urban canyons prevent a receiver from receiving signals from at least 4 satellites of a GNSS system for positioning purposes. However, if the receiver can work with other GNSSes (i.e. more navigation satellites), the problem of lacking satellites is solved. This is the scenario in which the multi-GNSS environment shows its most importance.

Accuracy improvement: Multi-GNSS environment is significant for not only availability but also accuracy improvements. Research in [10] showed that GPS stand-alone gives users worldwide a mean horizontal positioning accuracy (over 95% of time) of about 30 meters, while that of the combined GPS and Galileo positioning is less than 5 meters.

Reliability increase: Intentional and un-intentional interference sources, including jammers and spoofers, are major threats for GNSS services. The redundancy provided by multi-systems and multi-frequency bands are really important to increase the robustness of GNSS receivers, as well as the reliability of the positioning services.

Challenges of Multi-GNSS environments

Inter-system interference: GNSSes broadcast navigation signals in overlapped frequency bands. This fact could be convenient from the viewpoint of receiver design, but on the other hand, raises the issues of inter-system interference. However, as for GPS and Galileo, the signals were designed in the ways that reduce that interference while support interoperability [7].

Complexity increase: the new and upgraded GNSSes broadcast modern signals, which have advanced but complex structures in multiple frequency bands. These signals give much improvement in terms of accuracy, availability, and reliability to navigation services, but also challenge receivers to accommodate for such advantages. In multi-GNSS solutions, the analog parts of a receiver must operate with multiple systems, multiple frequency bands at larger signal bandwidths. These requirements surely increase the complexity and consequently the

Table 1. Characteristics of the civil signals in the campaign

Signals	Carrier (MHz)	PRN code	Code Length	Code rate	Data rate
GPS L1-C/A	1575.42	Gold	1023	1.023	50
Galileo E1	1575.42	Memory	4092	1.023	250
Beidou B1	1561.098	Gold	2046	2.046	50/ 500
Glonass L1-OF	1602+ k×0.5625	Maximal length	511	0.511	50

cost of the receiver. As for the digital parts, the signal processing requires more advanced and complex algorithms to cope with multiple systems, multiple channels as well as to fully exploit the advantages of the modern signals. These increase the computational complexity, the resource capability requirements and eventually the cost of the receiver. Recently, together with the rapid improvement in computational capability of programmable processors, such as CPU, GPU, DSP, and FGPA… the software receiver approach, which minimizes the hardware requirements, is favourable for the multi-GNSS solution because of its flexibility, easy-to-upgrade for complex requirements.

However, the important advantages of multi-GNSS environment together with the development in the electronic industry give a promising future for multi-GNSS solution.

Multi-GNSS positioning solution

Figure 2 shows the signal processing chain of a conventional GNSS receiver.

The chain consists of 5 main blocks, namely: (i) front-end; (ii) signal synchronization composed of acquisition and tracking processes; (iii) data demodulation; (iv) Position Velocity and Timing computation; and (v) display and storage. In the following sub-sections, each block is introduced together with our solutions for multi-GNSS positioning. It should be noted that in this campaign, the civil signals broadcasted by all 4 GNSSes are considered (see Table 1). These signals are referred hereafter by their abbreviation, L1-C/A (GPS), E1 (Galileo), B1 (Beidou), and L1-OF (GLONASS).

Antenna and front-end

For the purpose of multi-GNSS positioning with free civil signals, the chosen antenna must be capable of receiving the signals in Table 1. In the campaign, the antenna AeroAntenna Choke Ring AT1675-120 with a frequency band of [1525 ÷ 1615] MHz is used.

The radio frequency (RF) signal from the antenna goes through the front-end, which is responsible for conditioning and converting the analog RF signals to the digital IF samples.

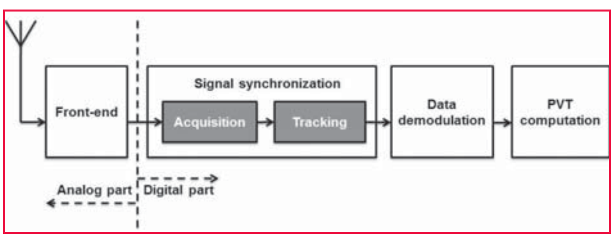


Figure 2. GNSS signal processing chain

Table 2. MAX 2769 front-end configuration

Sampling frequency	F_S = 16.368 MHz
Intermediate frequency	F_{IF1} = 4.092 MHz (for L1-C/A, E1 and B1) F_{IF2} = -16 kHz (for L1-OF)
Bandwidth	B_{w1} = 4.2 MHz (for L1-C/A, E1 and B1) B_{w2} = 8 MHz (for L1-OF)
Number of quantization bits	2 bits

In this campaign, the MAX2769 front-end [11] is chosen. The configuration of the front-end is reported in Table 2.

It should be noted that the chosen bandwidth of the L1-OF signal is larger (8 MHz) since the GLONASS uses FDMA as the multiple access method for this signal.

Signal synchronization

The general representation of a digital GNSS signal after the front-end is showed on (1).

$$r[n] = \sqrt{2C}c_i[n+\theta]\cos(2\pi(f_{IF} + 0.5625k + f_d)nT_S + \varphi) + n_W[n] \quad (1)$$

where C is the carrier power (W); $c[n]$ is the spreading code of the navigation signal; for the CDMA signals, i is the PRN number uniquely assigned for a satellite, however for the GLONASS FDMA signal, i is common for all satellite; F_{IF}, f_d denote the Intermediate Frequency (IF) and Doppler shift (Hz) respectively; k = 0 for the CDMA signals, but for the FDMA signal, k is uniquely assigned for a satellite in view; $T_S = 1/F_S$ stands for the sampling period (s) (F_S is the sampling frequency (Hz)); φ is the initial carrier phase (rad); θ is the initial code delay (samples); and n_W is the Additive White Gaussian Noise (AWGN) with zero mean (μ = 0) and variance σ_n^2 ($n_W \sim N(0, \sigma_n^2)$). It should be noted that PRN codes are used not only for the multiple access purpose, but also for the ranging purpose to measure the distance between the receiver and the satellites in view. Table 1 also summarizes the characteristics of the PRN codes of each system.

The main task of the signal synchronization block is to create a local replica of $r[n]$, referred to as $\bar{r}[n]$, for code and carrier wipe-off. This block is usually divided into signal acquisition and tracking processes.

Signal acquisition process

The main objectives of this process are: (1) to determine the satellites in view (i for the CDMA signals, and k for the FDMA signal); (2) to roughly estimate the incoming signal parameters namely: code delay ($\bar{\theta}$) and Doppler shift ($\bar{f}_d$).

In fact, the acquisition is a search process; which generates tentative local replica signals made of (i or k, $\bar{\theta}$, $\bar{f}_d$), and tries to find the one closest to the received signal. For each tentative replica, the estimation is performed via calculating the correlation also referred as the Cross Ambiguity Function (CAF) between the received signal and the local replica over a dwell time T, which is often equivalent to one full PRN code length (see Table 1). The correlation value is compared with a pre-determined threshold to decide which hypothesis between H_0 (unmatched), H_1 (matched) is true [12]. The uncertainty of the three parameters creates a 3-D search space for each signal as reported in Table 3. Note that: in Table 3, for code phase search, the uncertainty is one full code, with the conventional step size of 0.5 chip (0.25 chip for E1 due to BOC(1,1) modulation of the signal [7]); and for the Doppler search, the uncertainty is for a general moving receiver, with the conventional step size being: $\Delta\bar{f}_d = \frac{2}{3T}$ [13].

Signal tracking process

Except the satellite id, the signal parameters estimated by the acquisition process are not accurate enough to be used for positioning and navigation. Moreover, these parameters change over time due to the Doppler effects on code and carrier. Therefore, to completely remove the code and carrier from the received signal, the synchronization block needs another process, so-called tracking, in order to produce the fine estimates of the signal parameters as well as to dynamically follow their variations. A standard tracking process consists of two concatenated loops, which are code tracking and carrier tracking. The two loops are strictly interrelated, and work in a concatenated way [13].

The chosen code tracking loop is a non-coherent *"normalized early minute late power"* Delay Lock Loop (DLL). The input signal is split into two paths and correlated with two versions, an early and a late of the local PRN code. The two versions are equally spaced (0.5 chip for L1-C/A, B1, L1-OF, and 0.25 chip for E1 due to BOC(1,1) modulation [13]) about the prompt PRN code. Based on the early and late correlation values, the *"normalized early minute late power"* discrimination function is formed to tune the code phase estimate perfectly matching with the received one.

For all the signals, the Costas loop, which is insensitive to the phase transitions due to navigation data bits, is chosen for the carrier tracking. The discrimination function is the phase error: $D = \arctan\left(\frac{Q^k}{I^k}\right)$, with I^k, Q^k being the energy in the in-phase and quadrature branches at time instance k respectively. The phase error is used to tune the Numerically Controlled Oscillator (NCO)

Table 3. Acquisition parameters of each signal

Signal	iork	$\bar{\theta}$ (chip)	$\Delta\bar{\theta}$ (chip)	$\bar{f}_d$ (kHz)	$\Delta\bar{f}_d$ (kHz)
L1-C/A	[1,32]	[0,1022]	0.5	[-10,10]	0.667
E1	[1,36]	[0,4095]	0.25		0.167
B1	[1,37]	[0,2045]	0.5		0.667
L1-OF	[-7,6]	[0,510]	0.5		0.667

Table 4. Short description of navigation message format of each signal

Signal	L1-C/A	L1-OF	E1	B1
Preamble	8	30	10	11
Subframe	300	200	250	300
Error detection /correction	Parity	Hamming	CRC	BCH

to produce the local carrier perfectly matching with the received one [13].

Data demodulation module

After the signal synchronization block, the code and the carrier are completely removed from the received signal. Based on the encoding scheme and the message format of each signal, the data demodulation block recovers the navigation message. The navigation message includes (i) ephemeris and (ii) almanac data. The content of the navigation message is also validated in this module based on the error detection and correction mechanism of the signal, see Table 4.

PVT computation block

The block is responsible for computing the position, the velocity and also the time of an object attached with the receiver. To do so, the block performs:

- Satellite position calculation based on the navigation messages: whereas GPS, Galileo and Beidou use Kepler parameters to identify the position of the satellites, GLONASS provides directly the coordinates of the satellites in the Earth-Centered, Earth-Fixed (ECEF) coordinate system;
- Pseudo-range estimation: the ranges between the receiver and the satellites are measured via the signal travel time based on the information from the navigation messages and the synchronization block. However, the error sources such as: satellite clocks, ephemeris errors, noise, atmospheric delays… make the measured ranges being just the pseudo ones.
- Navigation equation system solving: in principles, GNSS uses tri-lateration technique to compute the position *(x,y,z)* of an object. By measuring the ranges from the object to three satellites at known position in the sky, the 3-equation system is obtained. Solving this equation system gives the position of the object. The obtained ranges are measured by the travel time, however, although the satellite clocks are synchronized to the standard time system, but the receiver clock is not. Therefore, an extra unknown, the bias of the receiver clock to the time system, is added. This unknown requires one more satellite to make the equation system with 4 unknowns solvable. In multi-GNSS solution, among the systems, there is no common time system. Without loss of generality, let us assume that GPS time is the standard time, adding one more system to the positioning solution means adding one more unknown, which accounts for the difference between the time of that system and the GPS time, to the navigation equation system. For example, if all 4 GNSSes are considered, the navigation equation has 7 unknowns. The equation is show on (2).

$$\begin{cases} \rho_{1,GPS} = \sqrt{(x_{1,GPS}-x_u)^2+(y_{1,GPS}-y_u)^2+(z_{1,GPS}-z_u)^2}+ct_{GPS} \\ \rho_{2,GPS} = \sqrt{(x_{2,GPS}-x_u)^2+(y_{2,GPS}-y_u)^2+(z_{2,GPS}-z_u)^2}+ct_{GPS} \\ \vdots \\ \rho_{i,GPS} = \sqrt{(x_{i,GPS}-x_u)^2+(y_{i,GPS}-y_u)^2+(z_{i,GPS}-z_u)^2}+ct_{GPS} \\ \vdots \\ \rho_{i,Gal} = \sqrt{(x_{i,Gal}-x_u)^2+(y_{i,Gal}-y_u)^2+(z_{i,Gal}-z_u)^2}+ct_{Gal} \\ \vdots \\ \rho_{i,Glo} = \sqrt{(x_{i,Glo}-x_u)^2+(y_{i,Glo}-y_u)^2+(z_{i,Glo}-z_u)^2}+ct_{Glo} \\ \vdots \\ \rho_{i,Bei} = \sqrt{(x_{i,Bei}-x_u)^2+(y_{i,Bei}-y_u)^2+(z_{i,Bei}-z_u)^2}+ct_{Bei} \\ \vdots \end{cases} \quad (2)$$

Where $\rho_{i,k}$ is the pseudorange of satellite i of system k (k is GPS, Galileo, GLONASS, or Beidou); $(x_{i,k}, y_{i,k}, z_{i,k})$ is the ECEF position of satellite i of system k; (x_u, y_u, z_u) is the receiver position; and t_k is the difference between the time system of system k and the receiver time. The equation system can be solved by least mean square (LMS) method.

However, Galileo also broadcasts in its navigation message the so-called *"GPS to Galileo System Time Conversion and Parameters"*. By using these parameters, the extra unknown is not necessary. However, to make a general solution for all the systems, these parameters are not used in this work.

Furthermore, each GNSS uses its own coordinate reference systems as reported in Table 5, these differences contribute to positioning errors at level of some centimetres [13].

Table 5. Satellite position and coordinate reference system of each GNSS

System	GPS	GLONASS	Galileo	Beidou
Satellite position	Kepler param.	ECEF	Kepler param.	Kepler param.
Coordinate reference system	WGS-84	PZ-90.02	GTRF	CGCS2000

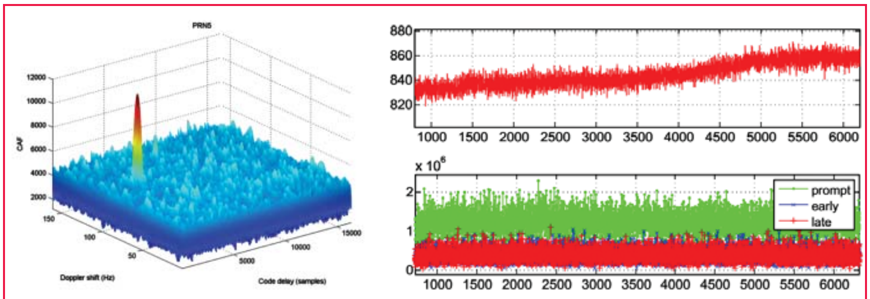
Results and analyses

The experimental results described in this part are obtained by using real datasets collected through the Aero Antenna Choke Ring AT1675-120 on the roof of the NAVIS Centre building (Figure 3)

Standalone positioning result

Since the other signals show the similar behaviours, Figure 3 shows only the results of the signal synchronization block in case of the L1-C/A signal broadcasted by the PRN 5. As seen in Figure 3(a), the correlation peak is clearly emerged from the noise floor. This peak gives the satellite id (PRN 5), and the rough estimates of the code phase

Figure 3. The antenna used in the campaign



(a) signal acquisition (b) signal tracking

Figure 4: Example of signal synchronization results in case of L1 C/A (PRN 5)

(3181 samples) and Doppler shift (1600 Hz) of the received signal. As for the tracking results, the upper plot of Figure 3(b) shows that the carrier tracking loop locks to the true carrier with a noise of 20 Hz. The result in the lower plot clearly shows that the DLL also locks to the true code phase. The prompt correlation values are the highest; meanwhile the early and late values are similar.

The signal synchronization, data demodulation and the PVT computation blocks give the identification and also the position of all 26 satellites in view from all GNSSes as seen in Figure 4.

Table 6 shows the accuracy of the positioning results of each system obtained from the datasets of the campaign. It should be noted that the results should not be generalized to make the performance comparison among GNSSes, which can only be done with exhaustive investigations in well-designed scenarios, and especially when all systems fully operate.

The three performance parameters are the location easting and northing errors (i.e. standard deviation), and the Geometric Dilution of Precision (GDOP) parameter. When visible navigation satellites are close together in the sky, the geometry is said to be weak and the GDOP value is high; when far apart, the geometry is strong and the GDOP value is low. As seen in Table 6, GPS has the highest positioning accuracy related to its GDOP being smallest. The skyplot in Figure 5. shows the strong geometry of GPS. Meanwhile, Galileo shows its poor performance since at that moment there are only 4 Galileo satellites, just enough for positioning. Considering Beidou, its northing error is highest, since in Figure 5, its satellites are close together and 4 of them are geostationary satellites at the equatorial plane. GLONASS gives a good accuracy since currently it is one of the two complete systems.

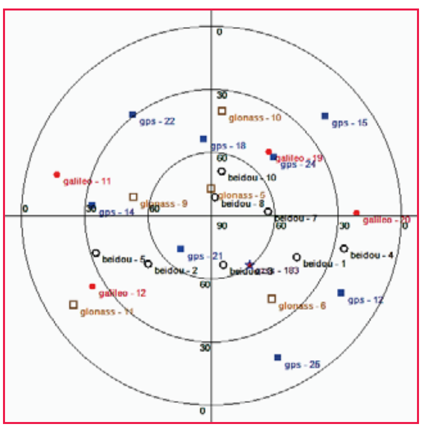


Figure 5: Skyplot of all 26 satellites in view from all GNSSes

Multi-GNSS positioning results

In this subsection, the multi-GNSS positioning solutions in different scenarios are considered. Since currently GPS is the most popular and also dominant navigation system for civil purposes, the combination between GPS and each other system is investigated. As seen in Table 7, the multi-GNSS solutions always give better results than stand-alone solutions, which were already reported in Table 6. This is due to the fact that more satellites give more information and better geometry.

The last scenario is to consider all 4 systems for a common positioning solution, as reported in Table 7 and in Figure 6(a) the accuracy of this solution is the best in comparison with the others. Figure 6(b) shows the improvement of GDOP in this solution with respect to the stand-alone ones.

Conclusion

This paper has presented the positioning results of the existing and also the recently launched Global Navigation Satellites Systems including GPS, GLONASS, Galileo and Beidou. More importantly, the paper has proved that the multi-GNSS positioning in the South East Asia region is possible and its performance is outperform the stand-alone ones in terms of positioning accuracy, availability and reliability.

Future works will focus on exhaustive investigations of multi-GNSS positioning towards an objective of proposing suitable system combinations in different scenarios.

Table 6. Performance of stand-alone positioning solutions (200 fixes with a stationary antenna)

System	δ_{North} (m)	δ_{East} (m)	GDOP
Glonass	3.2584	8.1746	3.3992
Beidou	3.7629	13.4952	3.5421
Galileo	4.0887	12.8882	3.7411
GPS	2.9859	6.3924	2.2609

Table 7. Performance of multi-GNSS positioning solutions (200 fixes with a stationary antenna)

System	δ_{North} (m)	δ_{East} (m)	GDOP
GPS + Galileo	2.4029	5.8056	1.9631
GPS + Beidou	2.5541	6.1344	2.2214
GPS + GLONASS	2.8008	5.7767	1.9230
All 4 System	1.7582	3.7840	1.8923

Acknowledgement

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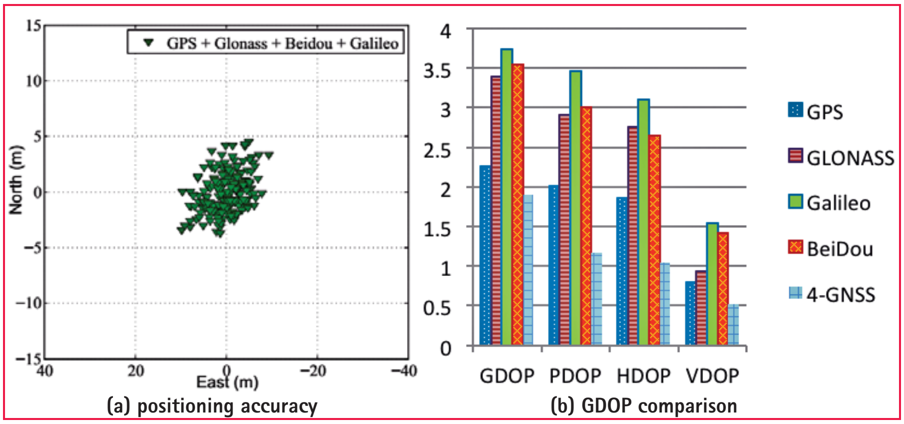

Figure 6. All 4 GNSSes positioning solution

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NSDI-2013, the premier 2-day event bringing together GIS data providers, application developers, government agencies, academia, industry and the NGOs, will be held at the Indian Institute of Technology, Bombay in Mumbai, India. NSDI-2013 will be held on Nov. 29-30, 2013. NSDI-2013 is a good opportunity to update you with recent developments in Geo-spatial Data, Technologies, Applications, and Research & Education and also on various upcoming initiatives in these areas. There is no registration fee, participation is only on invitation.

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Dec. 1, 2013 at IIT Bombay

A series of tutorials on Geo-spatial Interoperability are planned on Dec. 1, 2013, highlighting recent standards and technologies for innovative and critical applications of Geospatial Data. Register at the NSDI-2013 web site above for the tutorials as well. Participation is without any registration fee. Geo-spatial professionals and researchers are encouraged to participate.

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Dec 2013 edition of the OGC Technical Committee (TC)/ Planning Committee (PC) meetings will be held on Dec. 2-6, 2013 at IIT Bombay. The meeting holds in-depth discussions on proposed standards for their adoption by the Geo-spatial community. The core OGC standards like GML, WFS & WMS have already become part of the geo-spatial products, and are being used extensively for developing the state-of-art and inter-operable applications. There is an opening Plenary and a host of sessions discussing technologies and standards that participants may find interesting to attend (some sessions are only for OGC TC/ PC members).

A solution to map project area lying in two UTM zones

Our proposed system defines an alternate TM (ATM) projection system for which the central meridians are parallel to the central meridians of UTM but shifted by 3 degrees to East

Suddhasheel Ghosh
Department of Civil Engineering, MGM's Jawaharlal Nehru Engineering College, Aurangabad, Maharashtra, India

Bharat Lohani
Department of Civil Engineering, Indian Institute of Technology, Kanpur, Uttar Pradesh, India

Ajay Dashora
Department of Civil Engineering, Indian Institute of Technology, Kanpur, Uttar Pradesh, India

The Survey of India (SoI) is the pioneer surveying and mapping agency for India. The organisation conducts surveys at regular intervals and generates classified and non-classified topographic map sheets using a polyconic system of projection. Modern applications are now demanding maps at higher scales and precision. Thus, cartographers have been shifting to other standard systems of projection. Currently, the Universal Transverse Mercator (UTM) projection system is the most popular system for making maps or executing projects in combination with the WGS84 datum. SoI has also started generating a public series of maps in this popular combination, in order to comply with the need for standards.

Current trends in mapping

The UTM system is a specialized version of the Transverse Mercator (TM) cylindrical projection system. With the TM projection, for a particular study area, a cartographer selects a central meridian, a latitude of origin, the false easting and false northing and the scaling factor, in addition to the semi-major axis and the flatness (1/f) factor. On the other hand, UTM is a special form of Transverse Mercator projection where the Earth is divided into various zones numbered from 01 to 60. The central meridians in each of these zones are different. Although, officially the UTM zones extend up to 3.5 degrees on both the sides of the central meridian to allow for one degree of overlap [1], the standard is to restrict the extension up to 3 degrees. This implies that the difference in the meridians for two consecutive zones is 6 degrees. The other parameters, namely the scaling factor, latitude of origin, the false easting and northing, semi-major axis and flatness remain the same. Also, the project parameters vary for the northern and southern hemispheres. For India, the UTM zones vary from 42 to 47 starting from the state of Gujarat on the extreme left to Arunachal Pradesh on the extreme right.

Problems faced by map makers

Map makers, nationally and internationally, have been facing a frequent dilemma of selecting the UTM zone for a particular study area which falls in two consecutive zones e.g. some parts of Dehradun, situated in North India, fall in zone 43 and others in zone 44 [2-4]. As a result, cartographers cannot select the UTM and therefore reluctantly choose a locally suitable projection like Transverse Mercator or Lambert Conical Conformal (LCC) with appropriate parameters. In general, it is observed that in these cases, the cartographers select the central meridian at the centre of the area of interest. Though, this map serves the purpose locally well, it results in different central meridians being selected by different agencies. Further, different agencies use different names to represent their

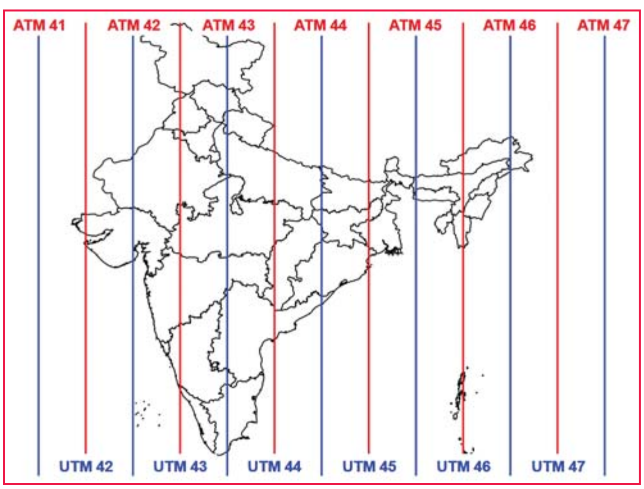

Figure 1: Proposed projection system using ATM and UTM zones

local projection. The non-conformity to one global system leads to difficulty in working with these maps produced by different agencies, as they do not conform to one meta-data system.

Proposed solution

In this article we propose an alternate system of projections which alleviates the problem of selecting the UTM zones for study areas lying in two successive UTM zones for large scale maps derived from high spatial resolution datasets.

Our proposed system defines an alternate TM (ATM) projection system for which the central meridians are parallel to the central meridians of UTM but shifted by 3 degrees to East. All other parameters of the ATM remain same as UTM. A schematic view of the ATM and UTM is shown in Figure 1. As is obvious, besides the usual UTM zones we have now additional ATM zones e.g. ATM42 through ATM47 to cover India. We define the ATM system as follows: If UTMz is a zone number with a certain central meridian X degrees and other defined parameters, then ATMz would have a central meridian as (X+3) degrees with other parameters remaining the same, which is also clear from the Figure 1. While defining this new and alternate form of TM, it is assumed that a study area will be less than 6 degree in longitudinal extent, which is very likely the case for the projects that need data on a 2D Cartesian system, as produced by TM projection.

We recommend that one should always use the UTM system. However, in cases where the project extent lies in two different UTM zones, the ATM system should be used.

Conclusion

This new form of TM projection in conjunction with UTM will provide a solution for map making for those areas which fall on the boundary of two UTM zones. Additionally, we propose that this system of ATM should be standardized, so all organisations adopt this system which will facilitate structured generation of meta-data, thus exchange of data products.

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Do more satellites lead to a better integrity performance

This paper employs the question whether simply using all satellites in view at user location mandatorily leads to the optimum integrity performance. This will be demonstrated for the EGNOS integrity concept

Michael Mink
System engineer for satellite navigation, Astrium GmbH, Ottobrunn, Germany

Julian Daubrawa
System engineer for satellite navigation, Astrium GmbH, Ottobrunn, Germany

As more GNSS satellites will be operational within the next few years, the confidence of the position and timing solution for the user is expected to increase. On the other side from the integrity point of view the user faces new problems. It has to protect itself against more potential failures that might occur and hence need to be taken into account. But also considering a single constellation it might not always lead to optimal integrity performance using all GNSS satellites in view of the user. This paper aims at analysing the impact on the size of the vertical as well as the horizontal protection levels based on all satellites in view on the one hand and an optimal subset solution on the other hand by means of a defined statistical value. This issue will be assessed based on the SBAS integrity concept at the example of EGNOS.

SBAS

This section provides an overview of Satellite-Based Augmentation system and in particular European Geostationary Navigation Overlay Service (EGNOS).

Overview

The SBAS is basically the wide-area differential GPS (WADGPS) service effective for numerous users within a continental service area. In order to achieve seamless service area independent of the baseline distance between user location and monitor (or reference station), the WADGPS service provides vector correction information, consisting of separate corrections such as satellite clock, satellite orbit and in case of a single frequency user ionospheric propagation delay as well. In the case of vector correction, the pseudorange correction is separated into components representing different error sources. User receivers can compute the effective corrections as functions of user location.

SBAS relies on a network of ground reference stations distributed over a wide area. Differential corrections that take into account spatially correlated error contributions within a specified area, are calculated and sent to the user via geostationary satellites. Beside SBAS is able to provide integrity information to the user. Finally, the geostationary satellites also transmit a ranging navigational signal similar to the GPS satellites. However, the GEO ranging option is currently only available for WAAS [3].

EGNOS

European Geostationary Navigation Overlay Service (EGNOS) is a pan European Differential GPS system emitting the correction data via Geostationary Satellites. The EGNOS system has four

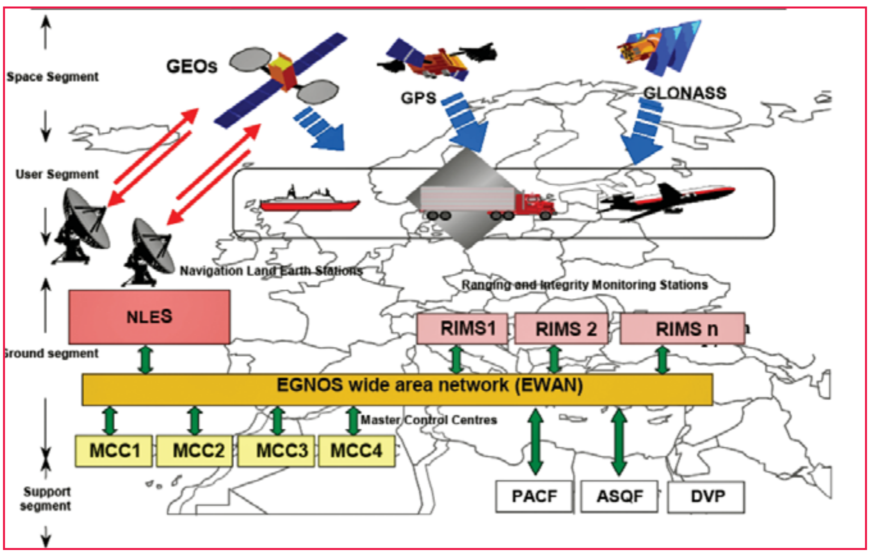

Figure 1: EGNOS system-architecture overview [1]

distinct segments: a Ground Segment, a Space Segment, a User Segment and a Support Segment (see Figure 1).

The Ground Segment is the real-time part of EGNOS. It computes precise differential corrections together with the according integrity parameters and makes all of this information available to users through a broadcast by the Space Segment.

The Space Segment, using Geo satellites, provides redundant data transmission channels to broadcast to EGNOS users messages containing differential corrections with the associated integrity information.

The User Segment is made of EGNOS receivers that enable their users to accurately compute their position.

The Support Segment contains the following off-line facilities: a Performance Assessment and Check-out Facility (PACF), which provides support for EGNOS operations in such areas as performances analysis, troubleshooting, operational procedures and support to maintenance. The next off-line facility is the so called Application-Specific Qualification Facility (ASQF) which provides civil-aviation and aeronautical-certification authorities with the tools to qualify, validate and certify the different EGNOS applications. The Development and Verification Platform (DVP) is used to validate and verify EGNOS requirements during the design phase. It contains simulation facilities, a real-time testbed and an assembly, integration and verification platform [1].

The observations from the GNSS are collected at the Ranging and Integrity Monitoring Stations (RIMS) and are sent via the EGNOS wide area network (EWAN) to the Master Control Centres (MCC). In the MCC the user correction data as well as the according integrity information is processed and sent to the Navigation and Land Earth Station (NLES) where the information is linked up to the Geosynchronous Earth Orbit Satellites (GEO) for distribution to the users throughout the service area.

Hence EGNOS provides the user with correction and integrity data for the GNSS. It protects the user from Misleading Information (MI) and Hazardous Misleading Information (HMI) such as faulty range measurements within the specified Time-To-Alert (TTA) of 6 seconds. This applies mainly for the aviation where safety critical applications demand a need for GPS integrity. Until now the EGNOS signal is certified for system integrity and in use since March 2011. For further information refer to [1].

SBAS user integrity concept

The SBAS integrity service should protect the user from failures of GPS by detecting and excluding faulty satellites through the measurements of GPS signals within the network of reference ground stations. Also the user should be protected from transmission of erroneous or inaccurate differential corrections. These erroneous corrections may in turn be induced by either undetected failures in the ground segment or processing of reference data corrupted by the noise induced by the measurement and algorithmic process. This last type of failure, which may occur when the system is in a nominal state meaning no satellite failure, no ground segment or user equipment failure is occurring, is usually known as the "fault-free case". Protection of the user against noise effects has proved quite demanding during the process of definition and validation of the ICAO SBAS integrity concept. In fact, the potential for such non-integrity events generated in fault-free conditions is inherent to data measurement and processing, to provide users with basic and precise correction messages, and is thus a permanent risk which has to be carefully managed. This has involved the definition of statistical error bounds called horizontal and vertical protection levels (HPL and VPL).

The SBAS integrity concept is published in the GNSS Standards and Recommended Practices (SARPs), published in November 2002. There it is recommended that the equipment shall use the following equations for computing the protection levels.

The following equations are applied to calculate the VPL for the user's position. They are taken from [2]. Although the computation of VPL is described in the following exclusively, the HPL are calculated in an analogous way.

The variance of model distribution that overbounds the true error distribution in the vertical axis d_U^2 is described as following:

$$d_U^2 = \sum_{i=1}^{N} s_{U,i}^2 \sigma_i^2 \qquad (1)$$

With $s_{U,i}^2$ being the partial derivative of the position error in the vertical direction with respect to the pseudorange error on the i^{th} satellite.

The total user variance σ_i^2 per satellite i and user location is defined as follows:

$$\sigma_i^2 = \sigma_{i,flt}^2 + \sigma_{i,UIRE}^2 + \sigma_{i,air}^2 + \sigma_{i,tropo}^2 \qquad (2)$$

In which

σ_i^2 :	variance of the position error distribution
$\sigma_{i,flt}^2$:	variance of fast and long term correction residuals
$\sigma_{i,UIRE}^2$:	variance of ionospheric delay
$\sigma_{i,air}^2$:	variance of airborne receiver error
$\sigma_{i,tropo}^2$:	variance of tropospheric errors

The models are further described in [2]. This information is fed to the SBAS integrity equation.

The VPL is then computed using the above variance of model distribution and a value for K_V being consistent with certain assumptions on the distribution of position error and on error correlation time satisfying the integrity requirement respectively [2].

$$VPL_{SBAS} = K_V d_U^2 \qquad (3)$$

Simulation

The simulation is performed via the "System Volume Simulator" from Astrium GmbH extended with functions that are necessary to run the analysis. First the assumptions on which the simulations are based on are listed.

Moreover an overview of the strategy is depicted how to derive a statement of whether the all-in-view or a dedicated subset solution leads to optimal integrity performance is depicted.

Assumptions

The following assumptions are applied:

- The service area is ECAC and ENP
- Single- and Dual-Frequency user
- A GPS constellation of 24 satellites plus GEO ranging (in a second scenario)
- The evaluation period here is one day with a sampling rate of 30 seconds.
- A regular grid with a distance of 1 degree in latitude and a position dependant sampling for the longitude is used to define the user locations [2].

Performance assessment

The idea is to assess the difference in the integrity performance using all satellites and all possible subsets of satellites in view at user location. Therefore the HPLs and VPLs of both using all satellites in view at each user side and all possible subset solutions is being calculated. The number of subsets is given by

$$number_{subsets} = \sum_{k=m}^{n-1} \binom{n}{k} = \sum_{k=m}^{n-1} \left(\frac{n!}{k!(n-k)!} \right) \quad (4)$$

With n the total number of satellites in view and k the number of satellites used to form the subsets respectively. Using a single constellation the number of unknown parameters m to be estimated for a general least squares position solution is 4. Hence a minimum of m satellites in view is required. Here it can be seen that the number of all combinations is a function of the number of satellites in view. For example having 10 satellites available would lead to 210 possible subset combinations.

Out of all possible subsets the subset is chosen with the smallest VPL (and HPL respectively) and declared as the optimal subset solution. The optimal subset solution is then compared to the VPL (and HPL respectively) derived from the respective all-in-view solution.

Both the availability either for the all-in-view (AIV) case and best subset solution case (BSS) is calculated. A solution is available if the HPL and the VPL is smaller than the respective Horizontal and Vertical Alert Limits (HAL, VAL).

$$Availability_{AIV} \begin{Bmatrix} HPL_{AIV} < HAL \\ VPL_{AIV} < VAL \end{Bmatrix} \quad (5)$$

For the BSS Case the smallest HPLs and VPLs either from the AIV or BSS case are compared to the respective Alert Limits.

$$Availability_{BSS} \begin{Bmatrix} \min(HPL_{AIV}, HPL_{BSS}) < HAL \\ \min(VPL_{AIV}, VPL_{BSS}) < VAL \end{Bmatrix} \quad (6)$$

Finally, the difference between both results for the availability is calculated. A positive difference means that the AIV solution leads to smaller Protection Levels whereas a negative difference means that the BSS is the optimal solution.

$$\Delta_{Availability} = Availability_{AIV} - Availability_{BSS} \quad (7)$$

The difference in availability for each user location in the service area is then used as the parameter to be evaluated in order to decide whether the AIV or BSS leads to optimal integrity performance.

Results

This section shows the results of the analyses. The figures show the difference in integrity availability of both the protection levels derived from the all-in-view (AIV) and the best-subset-solution (BSS) compared to both the LPV-200 (HAL/VAL=40/35m) and the APV-I (HAL/VAL=40/50m) requirement.

In Figure 2 the difference of integrity availability from both the AIV and the BSS using the LPV-200 requirement is shown for the service area. For this scenario the Geo ranging option is used. In the center of the service area the difference of integrity availability is zero meaning that the AIV solution leads to the optimal integrity performance. Nevertheless some areas show that the BSS leads to up to ~40% higher integrity availabilty than the AIV solution. It is obvious that these areas concentrate more at the borders of the service area.

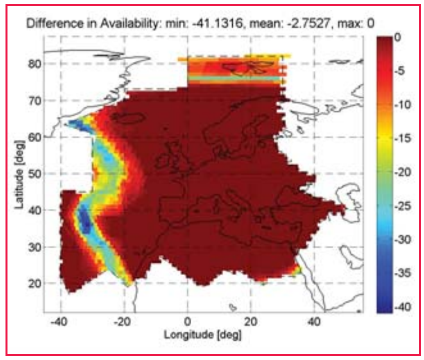

Figure 2: Difference of integrity availability from both the AIV and the BSS Solution using the LPV-200 requirement

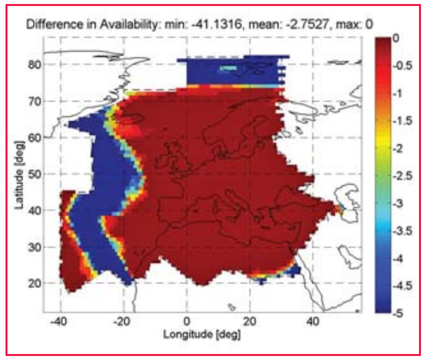

Figure 3: Difference in SBAS Integrity Availability from both the AIV and the BSS Solution using the LPV-200 requirement. Another scaling is applied

Figure 3 reveals the same results but is displayed with a different scale factor for the difference of integrity availability. In doing so highlights the smaller values for the difference of integrity availability and hence reveals an increase in integrity availability for even more areas using the BSS. The differences of integrity availability shown in Figure 4 are based on another set of requirements (APV-I). Here it also can be seen that the AIV solution does not mandatorily lead to the optimum results. In the border areas it can be observed that a subset solution reveals up to 35% higher integrity availability using the BSS than the AIV solution.

Table 1 summarizes the results of the performance analyses. It can be clearly stated that for a dual frequency user the AIV solution leads to optimal integrity performance. Whereas computing integrity performance using the BSS instead of the AIV increases availability for both scenarios up to around 3% mean for the whole service area. However, locally an

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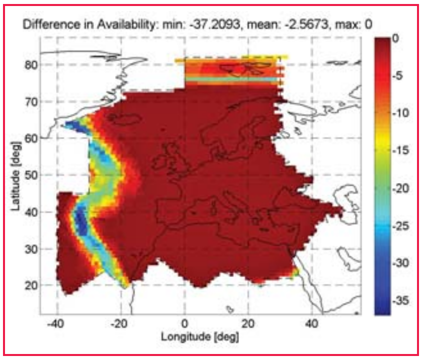

Figure 4: Difference in integrity availability from both the AIV and the BSS Solution using the APV-I requirement

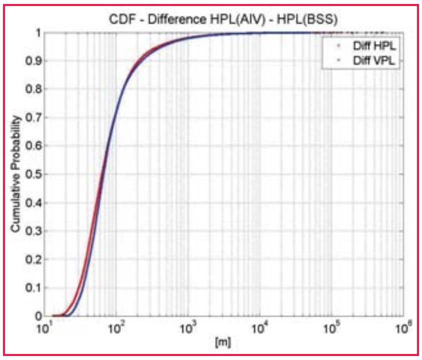

Figure 5: Cumulative Distribution of the differences in the AIV and the BSS Protection Levels

Table 1: Mean of Increase of Integrity Availability for different scenarios and assumptions (single-frequency and dual-frequency).

Scenario	Operation	Single-frequency	Dual-Frequency
GPS	LPV-200	2.75	0.00
GPS+GEO ranging	LPV-200	2.75	0.00
GPS	APV-I	2.75	0.00
GPS+GEO ranging	APV-I	2.57	0.00

increase in availability up to 40% can be observed. These results lead to the strong suspicion that the contribution of the ionosphere causes this effect. In some areas there might be conditions under which a reliable estimation of the ionospheric error contribution to the integrity equation is not possible. This might cause conservative ionospheric estimations leading to degraded integrity performance. This will need to be further investigated.

Figure 5 shows the cumulative distribution of all the Horizontal and Vertical Protection Levels from the BSS being smaller than the ones derived for AIV solution. It can be stated that around 75% of these differences remain below 100 meters. Around 0.1% is higher than 1000 meters. Obviously these errors come from insufficient estimations for the ionosphere.

Conclusion

Performance analyses have been performed in order to evaluate under which conditions the optimal integrity performance can be achieved. The focus of these analyses is the number of satellites used for deriving the Protection Levels. Therefore the integrity performance using all satellites in view and all possible subsets of satellites have been compared.

Based on the analyses it can be clearly stated that using all satellites available at the user side does not always lead to optimal integrity performance. Especially in the border areas it can be observed that the all-in-view solution is much worse than the solution coming from the optimal subset. It is observed that in some locations an increase of integrity availability up to 40% can be achieved using the best subset solution instead of all satellites. However, this effect can only be observed for single-frequency users. For a dual-frequency user the performance analyses show that there is no benefit for the users in terms of integrity performance using an optimal subset solution.

A feasible explanation is that error contributions for remote satellites cannot be estimated with high accuracy. Remote satellites are not seen by many RIMS stations which lead to a poor estimation especially of the ionospheric error contribution of that satellite. This assumption is supported by the fact that the areas in which the optimal subset solution leads to better results the number of RIMS stations is poor. In the western part of the evaluation area this is simply due to ocean. However in the northern and south-eastern part of the evaluation area there is a potential to counteract by considering an optimized arrangement of the RIMS stations.

In the northern part there arises also the problem that the number of visible satellites is strongly impacted by the ionospheric grid mask. If satellites are excluded from the position solution the remaining geometry could be improved as the weight of a satellite more to the south is increased. In addition to that the number of Ionospheric Pierce Points (IPP) is limited in the northern region which decreases the quality of the determination of the Ionospheric Grid Points (IGP).

The south-eastern effect could be due to the dimensioning of the RIMS network as there are no RIMS outside the area in this direction. This could be improved with an evolution of the RIMS network dimensioning considering this point.

The outcome of the assessment performed in this paper is to demonstrate that simply using all satellites that are available in sight of the user does not always lead to optimal integrity performance. However as hundreds of subset combinations are possible depending on the number of satellites available it is deemed that a very high computational load is needed at user side. To avoid computing all possible subset combinations an intelligent selection of the subsets that are taken into account can be chosen.

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[1] European Space Agency, ‘The European Geostationary Navigation Overlay System - A cornerstone of Galileo’, ESA Publications Division, 2006

[2] RTCA, ‘Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment’, RTCA DO-229D, 2006

[3] Pullen S. et al, ‘System Overview, Recent Developments, and Future Outlook for WAAS and LAAS’, Department of Aeronautics and Astronautics, Stanford University

Introducing

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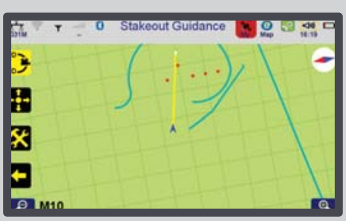
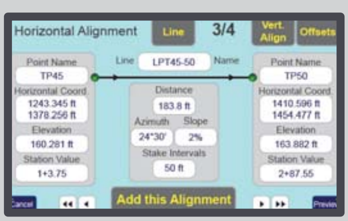
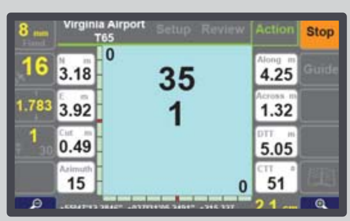




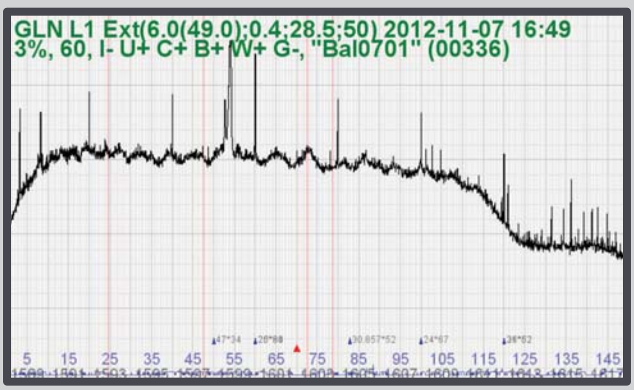


Interference Monitoring and Reporting

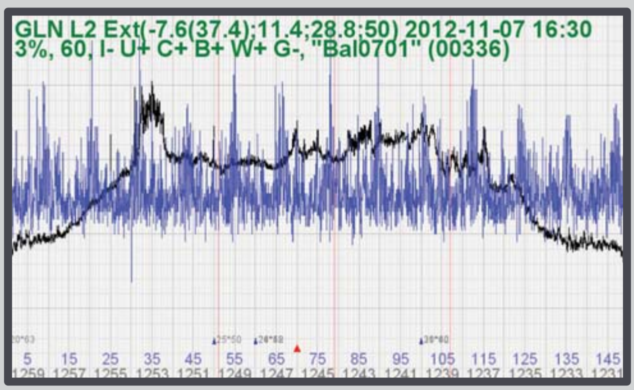
Radios
TV's
Radars
Harmonics
GSM
LTE
&
Jammers

Have you noticed in some places on some days that your receiver does not operate as it should? Intentional and unintentional interference appears almost everywhere. The Triumph-LS has the best available interference protection. It is the only receiver that monitors and reports interference graphically and numerically. Over 100 channels are dedicated to continuous interference monitoring.

Interference awareness is a must when performing GNSS work. It allows safe GNSS operation in a city, airport and military environment.



Some interference



Big interference

Productivity & Performance

864 Channels, All Satellite signals, 6-parallel RTK engines, Visual Stake out, innovative simple and accurate field line work.

channels

864

~~440~~

~~220~~

~~216~~

~~76~~

~~12~~

~~4~~

JAVAD has always been the channel count leader with 12, 76, and 216 channel receivers and now we introduce the TRIUMPH-LS with 864 channels combined with three powerful processors and program memory in a single chip which uses less power and makes the total system less expensive.

Some questioned the need for the 216 channels. They now realize the need for 440 channels. We assign multiple channels to each satellite for redundancy and reliability. We use over 100 channels to scan GNSS bands for interference (patent pending). 864 channels is the KEY to reliable performance.

Our satellite tracking technology, 6-parallel RTK engines, visual stakeout, revolutionary innovative simple and accurate field line work, visual stakeout, an unique interference monitoring and reporting feature, TRIUMPH-LS is the most advanced GNSS system ever built.

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Battery Life: 25 Hours;
System Weight: 2.5 Kg (5.5 lb)

hours

25

~~10~~

~~8~~

~~6~~

~~4~~

~~2~~

25 hour battery life in RTK rover mode with full screen brightness and UHF/GSM. Hot Swappable" and "removable batteries" are concepts of the past.

Two hours of charge = Two days of surveying

The internal batteries are field serviceable and can be easily replaced by the user when needed.

The TRIUMPH-LS, including batteries and pole is the lightest complete GNSS RTK receiver in its class. The total weight of the TRIUMPH-LS RTK system, including radio, controller, pole and 25 hours of internal battery is 2.5 Kg.

For comparison, the Trimble R10, TSC3 data collector and pole, with about 5 hours of battery life is 3.57 Kg (7.86 lb).

~~50 (110)~~

~~30 (66)~~

~~20 (44)~~

~~10 (22)~~

~~5 (11)~~

2.5 (5.5)

Kg (lb)

TRIUMPH-LS
Rugged, Tough, Versatile

Built on a tough magnesium alloy chassis, all connectors, SIM cards, Micro-SD cards are protected against the harshest environment.

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9 keys provide direct access to all functions. Six keys are user programmable.

The built in GNSS full tracking antenna has a large ground plane and the best centering and rotational performance on the market.

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complete RTK receiver system

Receiver+Antenna+Radio Modem+Controller+Pole

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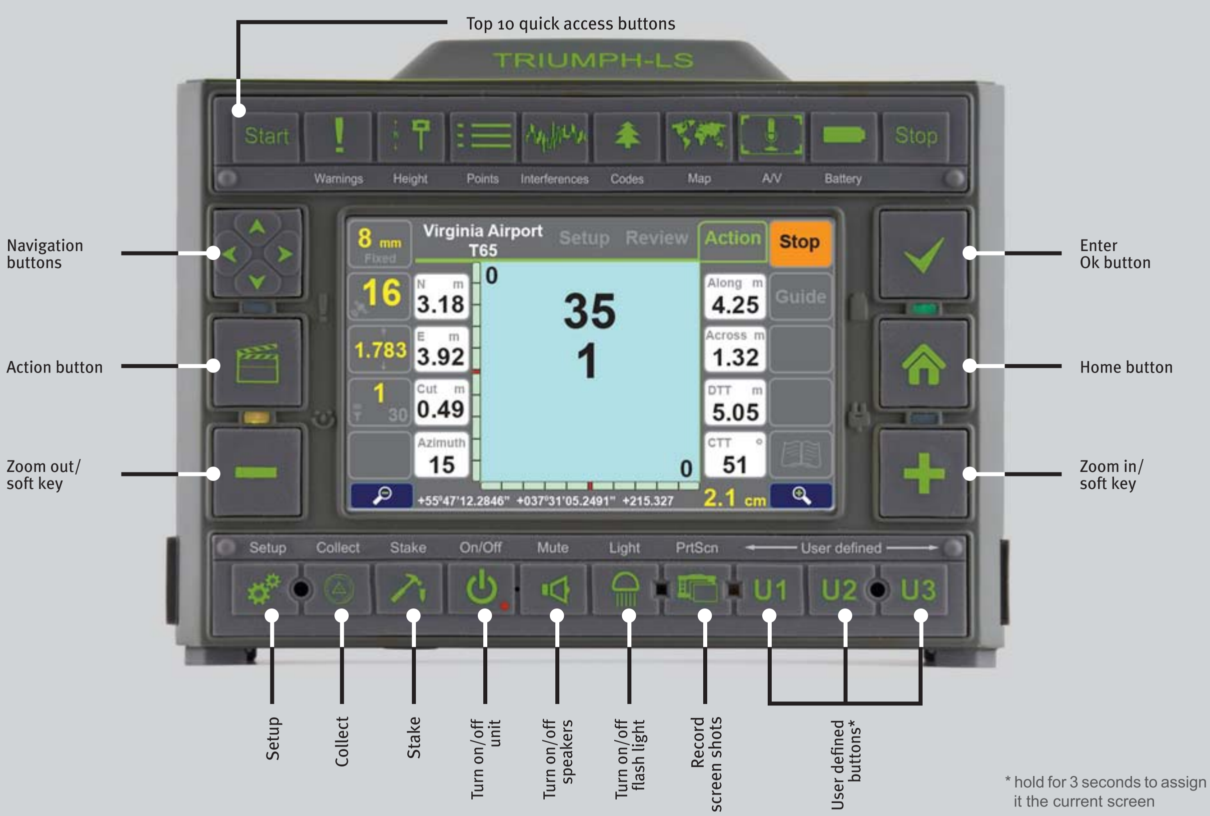
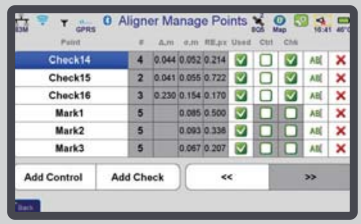
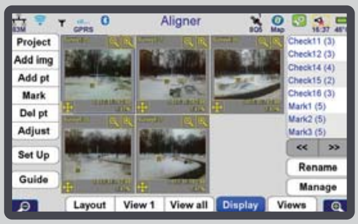
U.S. Professional Land Surveyors (registered PLS) can test drive the TRIUMPH-LS for two weeks at no charge (includes 2 Day FedEx delivery and return).
See **www.javad.com** to reserve one (for U.S. Licensed PLS only).

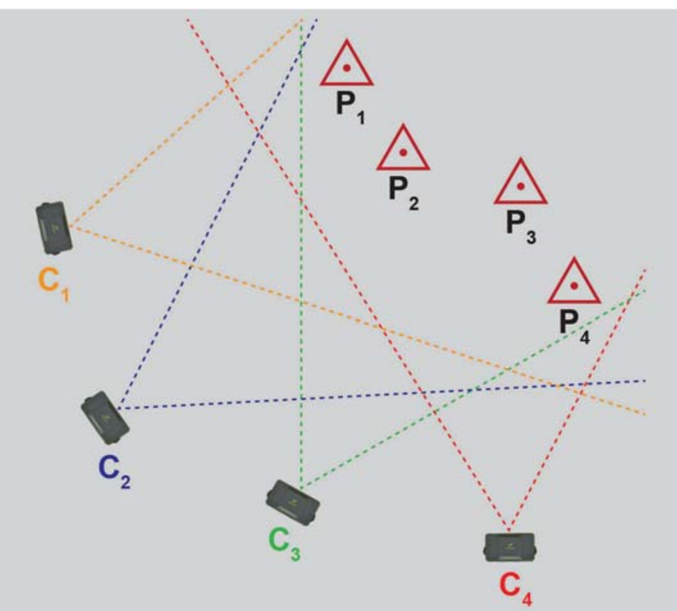


Offset Survey with Photogrammetry

Offsets can be calculated using the internal camera of the TRIUMPH-LS or with an external camera!







GNSS Vulnerabilities at sea

The paper examines how jamming impacts GNSS receiver function and performance, and quantifies that impact particularly for operational use by SOLAS (Safety of Life at Sea) marine users

Applications and services based upon GNSS are becoming increasingly embedded in modern society, to the extent that we Europeans, along with much of the rest of the World, have now become critically dependent upon their correct operation. In the event of GNSS problems, telecommunications networks could fail, aeroplanes and ships could stray off course, power grids could become unstable, financial transactions could become unreliable, the whole world of logistics could crumble, and train doors could fail to open in stations to let passengers on or off. These and many more applications and services presently take advantage of a unique conjunction of beneficial elements, in some cases without even realising that GNSS lies at their heart:

- GNSS services are for the most part free of charge at the point of use;
- GNSS equipment is astonishingly cheap;
- GNSS performance is outstandingly accurate, and reliable, and it is available ubiquitously to all of humanity irrespective of race, colour or creed.

This combination makes GNSS dependency inevitable, and in many respects highly desirable in advanced modern society. And yet threats and vulnerabilities exist that are neither addressed, nor even understood by the overwhelming majority of those who depend on GNSS for the successful accomplishment of their daily lives.

This paper is based on a presentation [ix] given to the ENC Conference in Vienna in April 2013. It reports from the STAVOG study that examined two major threats and vulnerabilities of GNSS, namely jamming and severe ionospheric disturbance. In this paper due to space constraints we report only on the jamming analyses. We examine how jamming impacts GNSS receiver function and performance, and quantifies that impact particularly for operational use by SOLAS (Safety of Life at Sea) marine users.

User domains impacted by GNSS T&V

A wide set of GNSS User Domains were analysed and categorized by the level of impact on their operations of threats and vulnerabilities of GNSS. The needs were assessed based on the impact potentially caused by loss of GNSS services, or by erroneous navigation data. Such impacts included safety, financial, and environmental. A total of 21 distinct application domains were identified as heavily impacted. These included:

- Maritime, particularly SOLAS-related;
- Aviation, particularly Integrity-dependent;
- High-value services including navigation and timing dependencies.

Standards were identified as very important to a number of the user domains. Current standards pertaining to GNSS vulnerabilities and needs for robustness were assessed as at best

Chaz Dixon
MD, Navigation Unlimited
Head, Position Navigation and Timing, Satellite Applications Catapult
Chair, Satellite Navigation Special Interest Group, Royal Institute of Navigation, United Kingdom

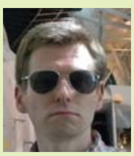
Stuart Smith
Spirent Communications plc, United Kingdom

Andrew Hart
Spirent Communications plc, United Kingdom

Rob Keast
Spirent Communications plc, United Kingdom

Simon Lithgow
Spirent Communications plc, United Kingdom

Alan Grant
General Lighthouse Authorities of United Kingdom and Ireland



Jan Šafář
General Lighthouse Authorities of United Kingdom and Ireland

George Shaw
General Lighthouse Authorities of United Kingdom and Ireland

Chris Hill
University of Nottingham, United Kingdom

Steve Hill
Technical Director, CBIL, United Kingdom

Colin Beatty
Managing Director, CBIL, United Kingdom

weak, and at worst absent. Although certain initiatives were identified (for example GLAs efforts to address GNSS vulnerabilities for the maritime domain), these appear to be the minority, with most application domains apparently ignorant about such vulnerabilities.

Many user domains appear to place a higher level of reliance on RAIM-type algorithms in GNSS receivers than the authors consider is safe. RAIM algorithms have evolved over many years to be good at detecting the types of faults they were designed to cope with, typically step changes or ramps in pseudorange errors from one or several satellites. The errors caused by interference do not generally fit the error characteristics that RAIM algorithms were designed for, and consequently it is unsurprising that the performance of receivers with RAIM was found to be unacceptable in the presence of interference, as is reported in this paper. This important finding is highlighted since it appears to have escaped the attention of many.

Maritime User Requirements

Marine SOLAS was selected as a specific user domain to study in detail. The marine SOLAS GNSS receivers, whether (D) GPS and/or (D)GLONASS are subject to existing IMO performance standards (listed below). Each performance standard is itself the subject of a corresponding IEC test specification (the IEC61108 range) which defines what tests are required to prove the IMO performance standard. In addition there are several other generic standards that list performance requirements (also listed below). Therefore all existing receivers are subject to meeting the following standards.

- GPS receivers should perform in accordance with IMO Resolution MSC.112 (73) (2000)
- DGPS receivers should perform in accordance with IMO Resolution MSC.114(73) (2000)
- The IEC 61108-X test series refer to GNSS and DGNSS receivers.
- Such equipment should perform in accordance to the general requirements contained in IMO resolution A.694(17)
- Such equipment should perform in accordance to IEC 60945

In order to implement specific measureable performance, a single specific maritime application was selected, albeit one of wide utility. This is that of “Harbour Entrances, Harbour Approaches and Coastal Waters”. Many aspects of the specification may be applicable to other applications but any such use is advised to take careful note of the particular focus and to take responsibility for any difference between their use and the particular application in this specification. Work undertaken by the International Maritime Organisation (IMO [i], updated as noted by a later IMO document [ii]), provides a number of general requirements as well as specific performance demands. Among these, requirements related to “Harbour Entrances, Harbour Approaches and Coastal Waters” can be extracted, and are provided below:

§ 2.1.1.3: …”GPS has been recognized as a component of the World Wide Radionavigation System (WWRNS) for navigational use in waters ….”

§ 2.1.1.4: … “GPS does not provide instantaneous warning of system malfunction. However, differential corrections can enhance accuracy (in limited geographic areas) to 10 m or less (95%) and also offer external integrity monitoring. Internal integrity provision is possible by autonomous integrity monitoring using redundant observations from either GNSS or other (radio) navigation systems, or both”.

IMO also discuss GLONASS in a subsequent section; this is treated essentially the same as GPS as a component of WWRNS.

Appendices 2 and 3 of the IMO document provide tables of minimum maritime user requirements for navigation and positioning. Appendix 2 applies to “general navigation”. Appendix 3 applies to “positioning” and includes several Tables: Table 1 “Manoeuvring and traffic management applications”; Table 2 “Search and rescue, hydrography, oceanography, marine engineering, construction, maintenance and management and aids to navigation management”; Table 3 “Port operations, casualty analysis, and offshore exploration and exploitation”; Table 4 “Fisheries, recreation and leisure applications”. Relevant sections from the IMO Requirements pertinent to “Harbour Entrances, Harbour Approaches and Coastal Waters” are provided here for information. Although great care has been taken with this, in the event of discrepancy between the present work and IMO, the IMO originals should be used, taking careful note that the IMO specification A915(22) was qualified in parts by a later document IMO in A1046(27).

Table 1: Maritime User Requirements (1)

	Absolute[1] Accuracy	Integrity[2]		
	Horizontal (metres)	Alert limit (metres)	Time to alarm[3] (seconds)	Integrity risk over 15 minutes[5]
Harbour Entrances, Harbour Approaches and Coastal Waters	10	25	10	10^{-5}
Port	1	2.5	10	10^{-5}

1 Absolute accuracy is the accuracy of a position estimate with respect to the geodetic co-ordinates of the Earth; Predictable accuracy is the accuracy of estimated position solution with respect to charted solution. GNSS position solutions are derived in absolute coordinate frames (WGS-84 for GPS) and would have to be transformed to chart datums. Only GNSS accuracy is pertinent to Absolute accuracy.

2 IMO A1046(22)notes that “An integrity warning of system malfunction, non-availability or discontinuity should be provided to users within 10 s.”

3 IMO notes that “More stringent requirements may be necessary for ships operating above 30 knots”.

Potential future requirements for robust navigation in maritime domain

A number of desirable Marine Community potential future requirements were defined by the project team. These are not presently standardised, but are presented here as an outline set for consideration and comment by the wider community. These were used as part of the analysis of performance reported below.

The GNSS receiver should:

1. Mitigate the problem if at all possible - provide continuous, resilient PNT.
2. Identify that there is a problem as soon as possible after it occurs.
3. Continue to operate with 'graceful degradation' of performance with a limited amount of jamming for a particular roll over time – the time is dependent on application and the amount of jamming present.
4. Raise an alert when the reported position changes beyond the realistic dynamics of the vessel.
5. No false or misleading information presented to the mariner.
6. Stop providing a position and alert that there is a problem when jamming gets too much.
7. When jamming ceases, receivers should recover within 1 minute, in line with a warm start requirement.

Based on the fact the current standards do not include any of these items, there remains a strong suspicion that current operational equipment in some, and potentially many, domains may not be adequately capable of coping with interference or ionospheric scintillation problems.

Specification of interference / jamming

Two distinct categories of jammers were considered in Project STAVOG. The first type, PPDs (or Personal Protection Devices), are small jammers which all use a comparatively low transmission power. As a product (albeit an illegal one) they are aimed to disrupt / block GNSS signal reception in the immediate vicinity of the jammer, typically within 5 metres or so, although some have sufficient power to block signal reception at substantially longer ranges, and degrade signal reception over a wider area still.

The second type of jammers considered were higher-power jammers, designed to disrupt / block GNSS signal reception at a distance of up to tens of kilometres. Other sources of GNSS interference may be accidental but often behave like either PPDs or higher-power jammers depending on the power and characteristics of transmissions into the GNSS bands.

A number of researchers have published characteristics of small PPD-type jammers that, although illegal to operate, are available for sale on the internet and are known to be used for a variety of purposes including:

- Disabling vehicle tracking devices;
- Avoiding GNSS-based tolls;
- Blocking tracking devices.

Although STAVOG project did not focus on protecting any of those applications, other GNSS-based applications including the maritime community, other safety of life users, and critical infrastructure users can be "accidentally" impacted by nearby PPDs.

The analysed publications are in some cases quite thorough in defining detailed jammer characteristics (as illustrated by Figure 1 and Figure 2) such as centre frequency, bandwidth, temporal, power and other characteristics of jammers found. Such information is invaluable to the community in assessing the threats with which it must cope, and this information was used as the basis for the STAVOG definitions of PPD jammers.

In the public domain, information published about larger, higher powered jammers was found to be quite sparse. The specifications for such units used in project STAVOG were therefore based on a combination of well-known jamming models and higher-powered versions of PPD characteristics.

Several research groups have analysed PPD jammer characteristics, providing

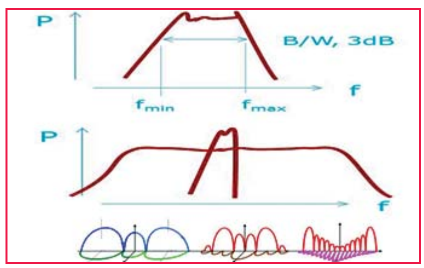


Figure 1: Example Jammer Frequency Characteristics

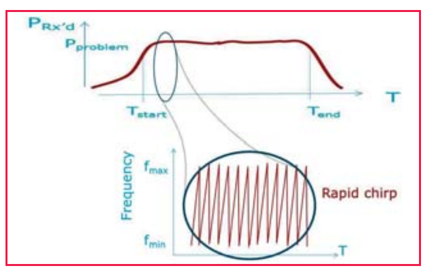


Figure 2: Example Jammer Temporal Characteristics

Table 2: Maritime User Requirements (2)

	Availability %[4]	Continuity % over 15 minutes[5]	Coverage	Fix interval[6] (seconds)
Harbour Entrances, Harbour Approaches and Coastal Waters	99.8	99.97	Regional	2
Port	99.8	99.97	Local	1

4 IMO A915(22) superseded by A1046(22): The former defined availability per 30 days; the latter defined signal availability as an absolute parameter.

5 IMO A915(22) superseded by A1046(22): the former defined continuity over 3 hours.

6 IMO A915(22) superseded by A1046(22): "The radionavigation system should permit an update rate of the computed position data not less than once every 2 s. ...This applies to the computed and displayed position data, but not to the update rate of any correction data, which may remain valid for 30 s or more."

an invaluable input to threat assessments and performance analyses such as those undertaken in project STAVOG. Kraus et al [iii] analysed seven PPD units and provided their technical characteristics in substantial detail. He reported peak powers up to 0.11mW, although most jammers were an order of magnitude weaker. Mitch et al [iv] characterised signal properties of 18 commercially available GPS jammers (PPDs). Mitch found that all jammers used a swept tone, and reported powers up to 23mW and even 640mW, substantially higher powers than had been found by Kraus. Both Mitch and Kraus found that the majority used chirp-like signals. Tong [v] reported analyses of PPDs, but provided a presentation rather than a full technical report, consequently and regrettably providing less detail than some other researchers. Guinand et al [vi] undertook various works including laboratory characterisation of jammers; he found chirp jammers but also noted other characteristics in some units. Like Mitch, Guinard reported jamming powers of PPDs up to hundreds of mW. Most jammers attack the GPS L1 frequency (1575.42 MHz), but some implement multiple frequencies. Sweep rates of microseconds to tens of microseconds appear most common. Borio et al [x] also recently characterised jammers. Although their work was not available in time to consider for implementation in the project STAVOG, it is noted that the jammers they found and analysed were nevertheless consistent with those modelled for STAVOG.

The twin fears for User Communities with all forms of jamming and interference are:

a) That a GNSS receiver is unable to maintain tracking lock on the satellite measurements, potentially leading to a navigation outage.
b) That a GNSS receiver's measurement ability is degraded to the extent that it is still able to maintain lock on the satellite measurements, and thereby produce a navigation fix, but that the measurement accuracy may be degraded to the extent that the measurements lead to the derivation of erroneous position fixes (i.e. position fixes outside of acceptable tolerance). Associated with this type of degradation is the additional risk that the receiver may not autonomously determine that its position solution is degraded, thereby potentially leading to the delivery of Hazardously Misleading Information (HMI).

User Scenarios

Characterising the jamming threat alone is insufficient to understand the impact on User Communities of jamming. Operationally, the impact of a jammer close to a user will generally be much more severe than the impact of a distant jammer. If Users in a particular domain never approach a jamming source closely, then even widespread use of jammers may have negligible operational impact on operations in that domain. Within Project STAVOG, operational proximity to sources of jamming / interference were characterised through User Scenarios. These Scenarios simultaneously served two major aims:

a) explain to users in terminology, and in physical terms with which they were familiar, the exposure that their operations risk with respect to jamming and to ionospheric scintillations; and
b) to quantify the user operational exposure to threats in terms that could subsequently be simulated using the available state-of-the art-simulation tools.

Two categories of User Jamming Scenario were created for the selected maritime SOLAS users. The first was of a shore-based jammer / interferer; the second of a jammer onboard a vessel. Abbreviated details from the first scenario details are provided in Table 3.

A wide variety of interferers / jammers were modelled during the project. The frequency and temporal characteristics are relatively complex and will not be covered in this short paper but were based on the characteristics from a number of researchers as cited in section V above. Table 4 presents an abbreviated description of the main different categories of interferer modelled. These are based on those observed "in the wild" and published in open literature. A variety of different power levels and temporal characteristics were modelled to cover the range of reported jammers. A subset are covered in the test results presented later in this paper.

Configuration for Tests

Test Facilities fundamentally comprised a state-of-the-art GNSS Constellation Simulator, a source of disturbance (interference / jamming / ionospheric scintillation), an interconnect to the receiver under test, and a control unit, as shown in Figure 3. In the figure the source of disturbance is marked "jammer" for illustrative purposes.

The state-of-the-art GNSS Constellation Simulator models satellites of the desired type (GPS, Galileo, GLONASS, etc.) and derives their motion relative to the defined user track parameters. The Simulator produces radio signals representative of those that would enter the GNSS receiver under test through its antenna port.

The source of disturbance generates interference / jamming, or ionospheric scintillation. Ionospheric scintillation is dealt with internally to the Spirent Simulator and the external unit is not required. Interference / jamming is generally dealt with as an external (RF) source, controlled by the same controller as the Simulator. The signal power from

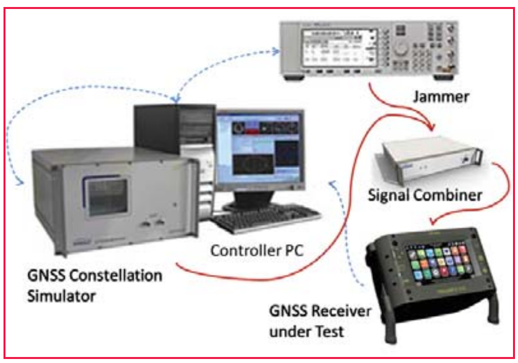


Figure 3: STAVOG Test Configuration

Table 3: Abbreviated Details of User Scenario 1

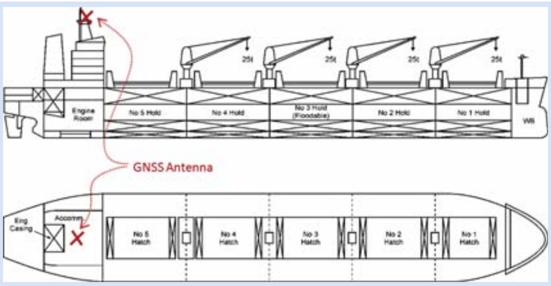
Title	Vessel Transit close to shore with jammer on mainland				
Reference	STVG_US_01				
Description	Route northwest to southeast close to Flamborough Head; jammer mounted ashore by Flamborough Head.				
Gross location	Flamborough Head; 54.1160° N, 0.0830° W				
Reason for Scenario	To assess impact on passing vessel of relatively powerful jammer ashore				
Author	CS Dixon				
Creation Date	23rd August 2012				
Vessel GNSS Equipment & Mount					
Rx	Rx 1 & Rx 2 (anonymised for reporting purposes)				
DGNSS	Marine Radiobeacon - corrections type RTCM V2.3				
Antenna Pattern	Hemispherical, 0dB gain				
Antenna height	30 m (above sea level)				
Illustration (Optional)					
Vessel trajectory	**T (mins)**	**Lat**	**Lon**	**Ht.**	
Startpoint	0	54.215417° N	0.13105° W	0	
Endpoint	80	54.0808° N	0.11845° E	0	
Uniform straight track (approx. 13.7 nautical miles) at constant speed (approx. 10 knots)					
Interferer Characteristics	**Included?**		Y		
Location	**Lat**	**Lon**	**Ht.**	**Mnt Ht.**	
	54.117° N	0.08° W	20m	2m	
Characteristics	Wide variety of jammers investigated – see below				

Table 4: Abbreviated Interferer Characteristics

STAVOG Interferer Model	Description
STAVOG Model 1	Continuous wave (CW) signal
STAVOG Model 2	Chirp signal with one saw-tooth function
STAVOG Model 3	Chirp signal with frequency bursts
STAVOG Model 4	Broadband Jammer
STAVOG Model 5	Pulsed Jamming

the interferer is controlled depending upon (a) the power of the jammer we wished to model, and (b) the user / jammer separation including modelling of power variations from modelled user motion. This was particularly important for Scenario 1, with the vessel moving past a jammer ashore.

The signal combiner unit takes simulated GNSS signals and disturbance (interference / jamming) signals and combines them at appropriate power levels for the receiver under test. The receiver under test generally interfaces to the signal combiner via its antenna port. Different configurations may also be used, particularly for receivers with built-in antennas.

The Controller PC is the control unit for the whole system and instructs the controlled equipment on simulation parameters. It may typically be fed with a data input from the receiver under test for real-time or post-processed analysis of the receiver performance.

Test Results to Scenario 1: Jammer Ashore

The scenario 1 testing required the use of a modelled Yagi antenna, the power levels were modelled to have a main high powered zone, (corresponding to the main lobe on the Yagi array), and a lower powered zone either side, (corresponding to the side lobes of the Yagi array). This type of antenna typically has a null point between the side lobes and the main high power lobe. Previous live jamming trials undertaken by the GLAs had showed the effects of this profile where there was a slight recovery in navigation as the vessel passed from the low powered to high powered zones through the null. Three jammer powers were implemented for Scenario 1: 23mW, 640mW, and 25W. A variety of jammer characteristics were implemented as previously explained (Table 4).

The scenario was created with the vessels route planned to pass by Flamborough Head on a straight course. The transmitting antenna was profiled to represent a typical Yagi antenna. The vessel would pass through a zone of no interference for approximately 13 minutes so that the receiver could receive a full navigation broadcast, then a zone of low level, a zone of higher power then a lower power zone and finally a period of no interference.

During the testing both receivers were reset each time before the scenario was run and started from a cold start state. There were complexities to this operation with certain receivers but this is not considered material for this paper.

Rachapudi Kamakshi Memorial Gold Medal for

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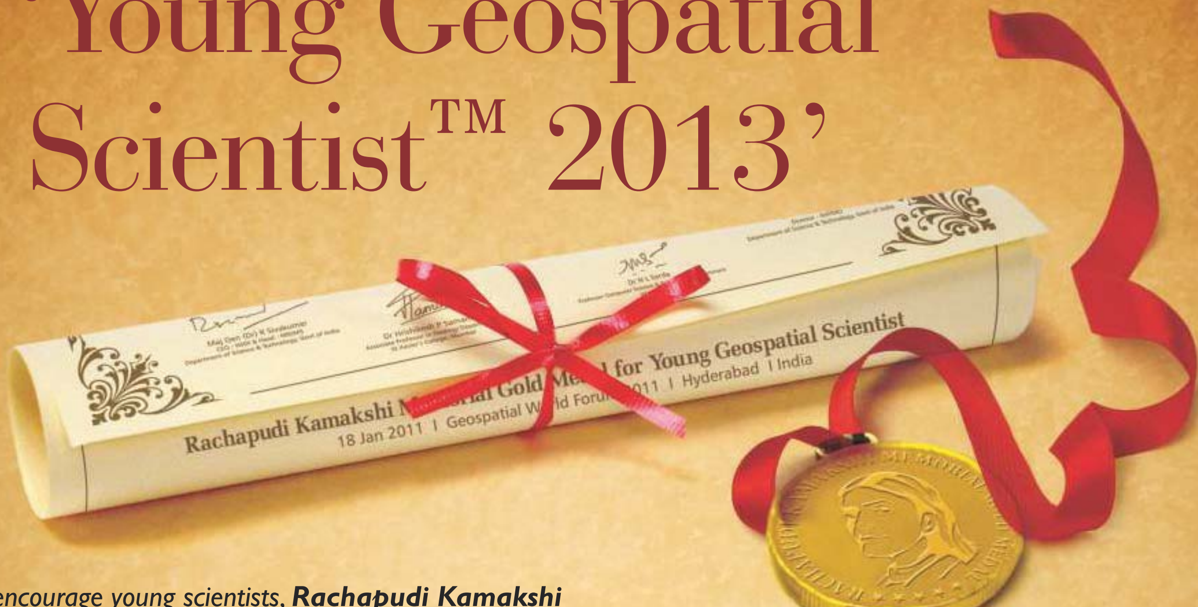

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Criteria for selection

Basic criteria for the award will be the research work carried out in the field of geosaptial science and technologies with innovativeness and appropriate use of scientific methodology, backed with quality write-up, social relevance and commercial acceptability of the idea and the adequate usage of geospatial technology.

Selection process

An eminent panel of jury will evaluate the nominations and interact with the nominees, if required, before selecting the awardee.

Nominations

Nominations are invited from scientists, engaged in research work in any of the areas related to Geospatial Information Science and Technology, who is not more than 35 years of age, as reckoned on 31 December 2013.

Nominations for the award should clearly state the scientific contribution supported by relevant documents. Self nominations are permitted.

The nominations are required to be submitted to Dr Hrishikesh P Samant, Associate Professor & Head, Department of Geology, St. Xavier's College, (Autonomous) Mumbai - 400 001 and also by email at hrishikesh.samant@xaviers.edu or rkmt2011@gmail.com

Past awardees

2012

Ms Farjana Sikander Birajdar, receiving the 2012 award from Dr Shailesh Nayak, Secretary, Department of Earth Sciences, Government of India.

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2010

Ms. Thiyam Tamphasana Devi, Indian Institute of Technology Guwahati, receiving the 2010 award from Shri Narendra Modi, Chief Minister of Gujarat

The last date for receipt of the nominations is December 31, 2013

For more information visit: http://www.rachapudikamakshi.org/

At the end of each scenario the NMEA from the receiver and the truth NMEA from the Simulator were saved along with the post process file which captured the interference levels and received interference levels along with positional information of the vessel.

The files were used to produce a plan error plot for each scenario run and a Google Earth plot of the route output by the receiver.

Power levels and free-space path loss had been pre-calculated and pre-tested and gave a good understanding of whether and where the interference would have an effect on the receiver in the scenario. It was expected that the lower level tests at 23mW would have a limited effect, the 640mW tests would have a larger and/or earlier effect, and the high power tests would have a definite and more prolonged effect. What was not known was the extent of the period of potential HMI before the receiver would stop navigating, nor was the period known for the receiver to recover when moving out of the high power jamming zone.

A period of high error with no alert was particularly evident with Rx 1 (anonymised as noted previously) during the CW test at 23mW and 640mW. The results showed there was a period of time where the positioning error was high prior to the point where the receiver stopped navigating, but that this did not consistently result in an alert being raised. More detail is given below.

Generally the reacquisition was seen to be a clean response with little positional error at the point navigation resumes. The exception to this was the CW test with a high power (25W) jammer where there was an initial recovery followed by some larger errors.

A visual comparison is presented in Figure 4 of the STAVOG Simulation results against previous live jamming trials conducted by the GLAs. Although precise details (jammer beamwidth and other characteristics, precise Marine Receiver used) differed, the gross characteristics of the results gave good confidence that the simulation approach was consistent with operational experience.

Figure 4: Comparison – GLAs Live Jamming Trials Vs STAVOG Simulation Results – shore-based jammer

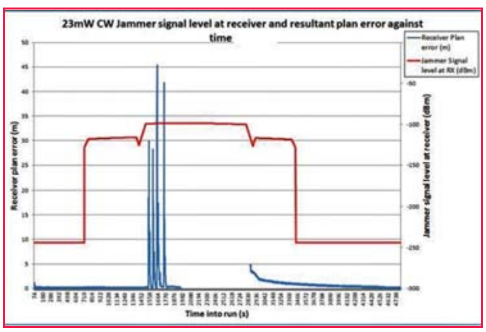

Figure 5: Impact on Receiver 1 of 23W Jammer Ashore (User Scenario 1)

In Figure 5 results are presented from tests with Receiver 1 encountering a modest power (23mW) jammer ahore. The horizontal axis is time from start of the test. The vertical scale is (a) received signal power, dBm with the red line showing received power level against the RHS axis, and (b) horizontal error of the receiver in metres with the blue line showing error against the LHS axis.

It can be seen that as the receiver enters the first main sidelobe of the jammer, around 700 seconds into the track, there is no effect on positioning error. Once it enters the main lobe, however, at around 1550 seconds into the track, the position becomes unreliable, displaying peak errors of 45 m. Figure 6 shows further detail of this period. No alert was raised during this period. As shown in Table 1, the positioning error required is better than 10 metres (or 1 m for port operations), with an alert limit of 25 metres (or 2.5 metres for ports). This is a clear failure of a mainstream marine receiver approved under IMO and other relevant regulation for marine use. It is assumed that the receiver's implementation of RAIM was never designed to cope with jamming or interference; its inability to reliably alert on such errors is therefore not altogether surprising. It is clear that IMO and other standards need to rapidly evolve to address this known threat.

A duplicate test was conducted but with a higher jammer power (640mW).

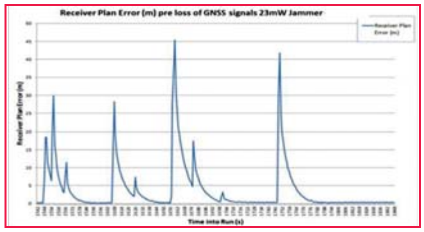

Figure 6: Receiver Plan error detail from Figure 5

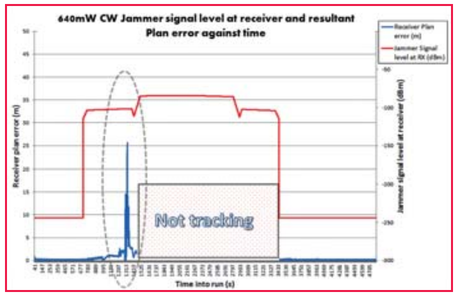

Figure 7: Impact of 640mW Jammer Ashore

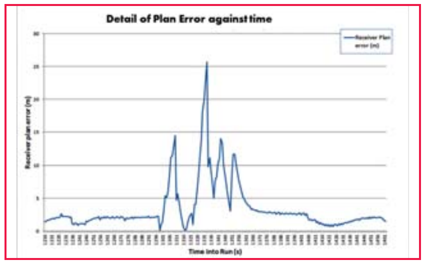

Figure 8: Receiver Plan error detail from Figure 7

Figure 9: Receiver 1 Plan Error during reacquisition after exiting 25W Jammer area

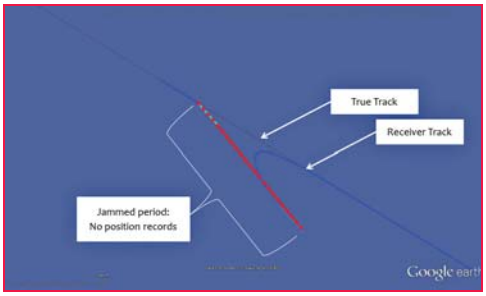

Figure 10: Receiver Track, 25W Jamming

Clearly the impact of the jamming in this test was expected to be much more severe. Results are summarised in Figure 7. In this case, with the higher jamming power, the receiver is disturbed whilst within the jammer sidelobe, and positioning becomes unreliable for about 60 seconds between 1300 and 1360 seconds (simulation time). During this period position errors of up to 25 metres were recorded (illustrated in Figure 8) with no alert sounded. As it entered the main jamming lobe, the receiver was unable to maintain track on the satellites and ceased to produce a position solution as shown. An alert was raised within approximately 14 seconds of the position solution becoming unavailable. This fails (but is not far outside) the IMO specification of 10 seconds time to alert.

A further set of tests were repeated with the jammer power increased to 25W. In this case, the receiver behaviour was "more acceptable", in that the jamming power swamped all signal reception as soon as the receiver entered the jammer sidelobes. Position solutions could not be produced at all during the jamming period. Once the receiver had passed right through the jammer beam and had exited the jamming sidelobe, at the point of reacquisition, a short period of very high error, peak of 460 metres, was observed and persisted above 50 m for 30 seconds as shown in the horizontal error plot (Figure 9) and the track plot of Figure 10. Although it could be argued that this post-jamming behaviour might be "expected", for example by receiver designers, there remains a question about whether such behaviour is "acceptable", for example to the marine community. The occurrence of large position errors without an associated alert is certainly a cause for concern, and further evidence of the inadequacy of existing approved SOLAS Marine Receiver techniques to cope with the impact of interference.

When these tests were repeated with Receiver 2 (again anonymised) the results were less "exciting". Under 23mW and under 640mW jamming, the receiver continued to track and was apparently unaffected, although in one case with the higher powered jammer the position error did exceed 4m. When jamming power was increased to 25W, the receiver lost lock and was unable to navigate as illustrated in Figure 11. No spurious errors were observed in this instance, highlighting the difference in performance between two receivers, both fully compliant with current marine standards.

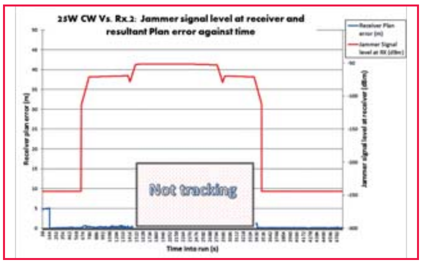

Figure 11: Impact of 25W Jammer Ashore Vs Rx.2

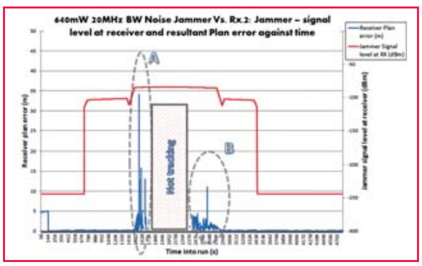

Figure 12: Impact of 640mW Broadband Noise Jammer Ashore Vs Rx.2

Other interference types produced broadly similar results – see for example Figure 12. Higher powers led to positioning outages; very low powers caused no effect; but medium power levels led to receivers generating potentially hazardously misleading information (HMI). The exception found from these tests was that pulsed interference caused no discernible effect. A explanation was considered, and future examination may prove whether it is correct, or whether there was some other reason for the observation: The jamming pulse implemented was very short, of only 10.7µsec "on" duration, over a pulse duty cycle of 1.5 seconds. If the receivers AGC or other pulse-blanking mechanism were able to adapt rapidly enough to the changing power level, then the receiver would have had sufficient signal in the unjammed time to navigate with minimal impact on signal (and consequently positioning) quality. It is noted that pulsed PPDs have not been reported by any of the cited researchers. This may reflect their lack of effectiveness, the ease with which they can be countered, or may be coincidental.

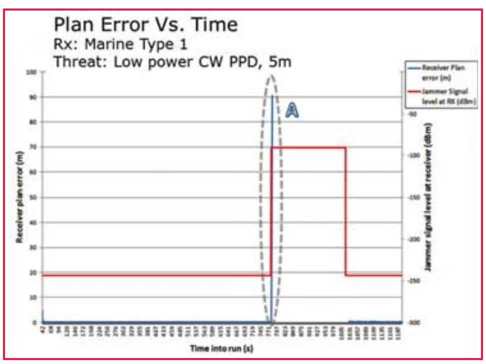

Figure 13: Impact on Receiver 1 of PPD Aboard Ship

Test Results to Scenario 2: Jammer Aboard

A second main jamming scenario was also investigated, this time simulating a jammer aboard ship. In this instance, PPD jammers were simulated, with much lower powers than implemented for Scenario 1. In this instance however, the simulation placed the

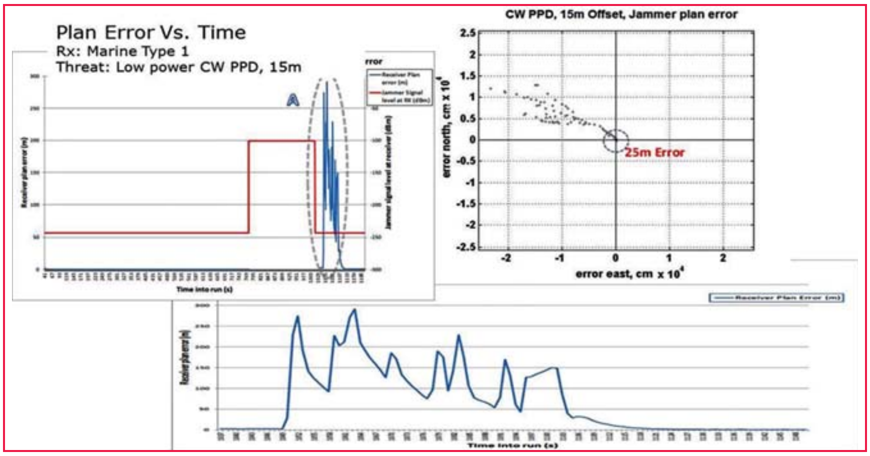

Figure 14: Impact on Receiver 1 of PPD aboard

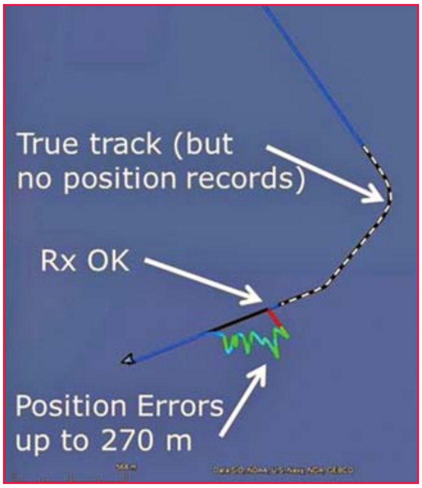

Figure 15: Errors Shown Against True Track, PPD Vs. Receiver 1

jammer very close to the receiver antenna. Combinations of different separations (5, 15, and 30 metres), different power levels (from 0.001mW to 0.1mW), and different jammer characteristics led to implementation of 34 scenarios for each receiver tested.

An example output is provided in Figure 13, in this case for Marine Receiver Type 1, for a CW PPD of 0.001mW power, and with 5m separation between jammer and receive antenna. The jammer was initially switched off to ensure that the receiver acquired data and position and was navigating correctly. When the jamming was switched on the receiver output position grew rapidly (spiked) to approximately 90 metres, in only 4 seconds, before the receivers positioning capability was lost.

Although this short duration HMI is undesirable, position spikes are arguably fairly easy to detect by eye or by electronic means. In addition, the short duration of the position spike was less than the Alert Time mandated by IMO.

A more surprising and more extreme example is shown in Figure 14. This actually implemented the same low power PPD against the same marine receiver. In this case, however, the separation between jammer and receiver was 15m. The three figures illustrate the plan error against time (also showing jamming power), the horizontal error plot, and a zoomed in version of the plan error against time.

Prior to the commencement of jamming, the receiver was able to navigate successfully. When the jamming was switched on, navigation capability was lost immediately, and no position output was generated during the jammed period. These two observations are very positive since no HMI was generated. Unfortunately, once the jamming was switched off, the receiver appeared to rapidly regain tracking lock and produced position fixes of acceptable quality for 12 seconds, after which positioning went “haywire” for approximately 60 seconds. Position error excursions up to approximately 270 metres were observed, and no alert was raised. The particularly confusing thing about this finding was that the jamming source had been switched off before the erratic behaviour began. This type of behaviour is considered a serious concern for the marine community. As shown in Figure 15, where the errored position reports are shown superimposed on True Track, had such errors been used to navigate a vessel in narrow or restricted waterways, the consequence could have been very serious.

In some other experiments, particularly when jamming power was low and separation between jammer and receiver was high (30m), the receiver was able to continue navigating despite the interference. In other cases, where incident jamming power was higher, the receiver was unable to produce a position output; sometimes an alert was raised. HMI was observed in only a few of our experiments with PPDs, and no other jammer / receiver combination yielded such dramatic effects as reported above.

These results highlight, however, that marine receivers in operation today, that are fully compliant with all mandatory function and performance specifications, are unable to operate in the presence of low-cost jammers that are available and regularly observed “in the wild” today, and in some cases the results may be dangerous.

Conclusions

A number of conclusions can be drawn from the work undertaken within project STAVOG and reported here.

I. The STAVOG simulation tests were conducted against operational marine receivers that are fully compliant with IMO and other standards. A state-of-the-art Spirent Simulator was used to replicate jamming (and ionospheric scintillation) conditions.

II. The simulation approach provided a number of benefits including: it provided the benefits of repeatability, controllability, precise knowledge of the satellite and jamming signals, leading to verifiability and traceability of results; it saved expense and time compared with field trials; it caused no impact on other GNSS users; and the security of the tests (e.g. from eaves-droppers) was assured since signals were not transmitted externally.

III. The interference / jamming results showed periods of (i) blockage (jamming too severe to permit navigation), (ii) safe navigation with acceptable performance (jamming ineffective), and (iii) HMI where position errors exceeded acceptable levels but with no alarm raised.

IV. In some cases, the temporal characteristics of the HMI errors would have been easy for "gross reasonableness checks" within the receiver or associated shipborne equipment to detect. The fact that the errored solutions were in some cases delivered without warning messages implies that the tested marine-grade receivers did not utilise such "gross reasonableness checks".

V. It was found possible for a marine-grade GNSS receiver to produce prolonged HMI (Hazardously Misleading Information) without generating an Alert message. That these units are (a) operational and in widespread use today, (b) fully compliant with maritime standards, but (c) woefully unable to cope with a variety of credible interference / jamming threats, is a serious concern.

VI. Scenario 1 (Approach to port with Interferer on mainland) identified that a High powered interferer on the shore could prevent navigation by a receiver as a vessel passed by. Interference type and received power level significantly changed the magnitude of the effect. The simulated performance was consistent with live jamming trials previously conducted by GLAs, although the precise configurations and equipment differed. This gives further confidence in the simulation approach that was used for project STAVOG.

VII. Scenario 2 (Approach to port with Interferer onboard) identified that a PPD could cause effective interference when received power level was high enough, either through high transmit power or close proximity to receiver. Again, the interference type changed the magnitude of the effect. A common observation in these trials was that the PPD's stopped all navigation of the receiver. It was also observed that certain other jammer characteristics (e.g. low incident power, and/or short duty-cycle pulses) caused no discernible adverse effects on the receiver output.

VIII. In some cases, the PPD jamming produced HMI in the receiver. Typically when this was observed, it was observed either (a) for a very short period, or more worryingly (b) for a longer period immediately after a period of blocked navigation. In one case, HMI position error variations of more than 100 metres were observed for a period of more than a minute after the jamming signal had been switched off. Such errors were unexpected since at this point noise levels had reverted to normal background noise.

IX. Creation of User Scenarios represents an excellent way of both engaging end users and developing meaningful scenarios and combinations of operationally relevant threats.

X. Threat definitions for jamming / interference yielded a very high number of threat combinations. Only a subset of these were implemented within the time and funding constraints of project STAVOG. A much smaller subset were presented in this paper.

Recommendations

1) Limitations of current international maritime standards were exposed during execution of Project STAVOG. Future standards refinement is considered essential and urgent in order to address the known threat of interference / jamming.
2) Education of the marine and other important communities on the vulnerabilities of GNSS, and of the gaps with present standards should be pursued with vigour.
3) Other sectors and their applications that have concerns about the detrimental effects of threats and vulnerabilities of their GPS-based equipment should consider evaluating their systems under simulation conditions that emulate their operational scenarios, following a method based on the STAVOG approach.
4) Efforts should be made to grow the wider communities' awareness of the vulnerability of services based on GNSS to interference and ionospheric scintillation. "Scare tactics" are not helpful and may be counterproductive, but education based on researched facts should be supported.
5) Researchers who analyse and publish PPD and other jammer characteristics should be commended for their efforts and encouraged to continue this valuable work; a number are identified in the references below. Knowledge about characteristics of these threats is essential to assess the risks posed by them as well as in the creation of appropriate mitigation technologies.
6) Testing Interference with multiple constellations and/or frequencies may yield interesting results on how interference affects the receiver and how the receiver deals with interference signals (for example interference on L1 with a receiver tracking L1 and L2). Such work would represent a useful extension to the present work.

Acknowledgments

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Disclaimer

The views expressed in this paper are those of the authors and do not necessarily represent opinions or policy of their organisations.

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[i] International Maritime Organisation (IMO) Resolution A.915(22), Adopted on 29 November 2001, Agenda item 9, REVISED MARITIME POLICY AND REQUIREMENTS FOR A FUTURE GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS). A22/Res.915.


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Galileo update

Israel becomes major partner in EU satellite program

In Jerusalem, Science and Technology Minister Yaakov Peri and the head of the Israel Space Agency, Menachem Kidron, signed an agreement with European Union officials to give Israeli researchers and companies access to projects associated with the EU's Galileo satellite program.

Officially called the Cooperation Agreement on a Civil Global Navigation Satellite System (GNSS) between the European Community and its Member States and the State of Israel, the deal was inked on the EU side by Antonio Tajani, Vice President of the European Commission, responsible for Industry and Entrepreneurship, and the incoming EU Ambassador to Israel, Lars Faaborg-Andersen.

Israeli companies will now be able to participate in tenders to supply software and hardware to companies involved in the project, and Israeli scientists and academics will be able to initiate and participate in studies and experiments that will be part of the Galileo program.

Israel had negotiated a similar but more-limited agreement with the EU about 15 years ago, but it was shelved when the European GNSS program faced difficulties getting off the ground. *www.timesofisrael.com*

European ground stations allow galileo to participate in search and rescue testing

ESA's completion of a pair of dedicated ground stations at opposite ends of Europe has enabled Galileo satellites in orbit to participate in global testing of the Cospas–Sarsat search and rescue system.

The Maspalomas station, at the southern end of the largest island of the Canary Islands, at the southern fringe of European waters, was activated in June. And this last month has seen the Svalbard site on Spitsbergen in the Norwegian Arctic come on line – the two sites can already communicate and will soon be performing joint tests.

This speedy progress has enabled the participation of the latest two Galileo satellites in an international demonstration and evaluation program – a worldwide test campaign for a new expansion of the world's oldest and largest satellite-based rescue system, Cospas–Sarsat.

Founded by Canada, France, Russia and the US, Cospas–Sarsat has assisted in the rescue of tens of thousands of souls in its three decades of service. Distress signals from across the globe are detected by satellites, then swiftly relayed to the nearest search and rescue (SAR) authorities.

Now the program is introducing a new medium-orbit SAR system to improve coverage and response times, with the Galileo satellites in the vanguard of this major expansion. *ESA* www.redorbit.com

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[iii] Kraus, T., R. Bauernfeind, and B. Eissfeller; Survey of In-Car Jammers – Analysis and Modelling of the RF signals and IF samples. ION GNSS 2011, 24th International Technical Meeting of the Satellite Division of the Institute of Navigation, Portland OR, September 19-23, 2011

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[v] Tong, JR; Characterisation of GNSS Interference Sources. Presented at GNSS Vulnerability: Present Dangers, Future Threats 2012. National Physical Laboratory, Teddington, UK. 22 February 2012

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[ix] Dixon, C.S., S Smith, A Hart, R Keast, S Lithgow, A Grant, J Šafář, G Shaw, Chris Hill, S Hill, C Beatty; Specification and Testing of GNSS Vulnerabilities. ENG GNSS 2013. Vienna, Austria, 23-25 April 2013.

[x] Borio, D., J Fortuny-Guasch and C O'Driscoll; Characterisation of GNSS Jammers. Coordinates Magazine, May 2013.

Orbcomm acquires the SENS asset tracking operation

ORBCOMM Inc has completed the acquisition of Comtech Mobile Datacom Corporation's (Comtech) Sensor Enabled Notification System (SENS) operation, which includes satellite hardware, network technology and web platforms. SENS is a market leader in providing one-way satellite products and services to more than 20,000 subscribers worldwide. *www.orbcomm.com*

TCS adds 14 U.S. Patents advancing LBS

TeleCommunication Systems, Inc. has announced that the U.S. Patent and Trademark Office (USPTO) has issued TCS 14 U.S. patents during the third quarter of 2013. TCS also received one foreign patent grant during the third quarter. The 14 recently issued U.S. patents describe innovations in LBS, GIS/mapping, public safety, messaging, secure communications and solid-state drives, and further strengthen these areas of TCS' intellectual property. *www.broadwayworld.com*

NTT Docomo picks NSN's Advanced Location System

Nokia Solutions and Networks provides Japanese mobile operator NTT Docomo with its Advanced Location System which supports Assisted Global Navigation Satellite System (A-Glonass) positioning technology. In urban areas with high-rise buildings, however, it is challenging to acquire enough visible GPS satellites needed for positioning. By adopting A-Glonass positioning technology, the number of visible GPS satellites can be supplemented with Glonass satellites, thus improving the positioning success rate. *www.hispanicbusiness.com*

LBS Market in China 2012 – 2016

LBS market in China to grow at a CAGR of 25.93 percent over the period 2012-2016. One of the key factors contributing to this market growth is the increasing adoption of mobile broadband. The LBS market in China has also witnessed the growing use of mobile LBS. However, the increasing concern over the privacy of the users could pose a challenge to the growth of this market. *www.marketresearchreports.biz*

Indoor location market to reach $4 billion in 2018,

The indoor location market is forecast by ABI Research to reach $4 billion in 2018, fueled by wireless technology as well as vendors offering venues such as shopping malls, warehouse retailers, airports and stadium products to provide content and services to mobile device users based on their location. The overall number of indoor location technology is expected to top 25,000 next year, while mobile devices capable of supporting indoor location services will reach hundreds of millions within two years.

MapmyIndia launches social navigation app

MapmyIndia has launched Explore, a social navigation app that enables its users to find millions of useful places of interest like ATMs, restaurants, petrol pumps, and hospitals, etc. around them.

To add a social aspect to the app, users can also login with social networking site Facebook and pin their favourite hangouts, add photos, as well as add reviews and ratings for them. *http://techcircle.vccircle.com*

LightSquared sues GPS Makers, Industry over spectrum issues

LightSquared filed a lawsuit against GPS makers and industry groups, saying their failure to disclose that LightSquared's network could cause GPS problems drove the company into bankruptcy. LightSquared said Deere & Co., Garmin International Inc. and Trimble Navigation Ltd., as well as two GPS industry groups, caused "untold damage" to the company after it spent billions of dollars to build up its network. *http://online.wsj.com*

India, Russia to boost defence ties

India and Russia have agreed to enhance cooperation in space technologies. India is the only country to which Russia has agreed to give access to Glonass military-grade signals, which will enable the Indian military to greatly improve the accuracy of its land-, sea-, air and space-launched weapon systems. *www.thehindu.com*

Russia Retires Faulty Glonass-M Satellite

A satellite in the fleet of Glonass has been decommissioned because of a terminal malfunction, space officials said. The Federal Space Agency said it stopped receiving signals from Glonass 728 on July 1 and has kept the satellite in maintenance mode ever since.

With the Glonass 728 now retired from service, Russia still maintains a group of 28 Glonass satellites in orbit. *http://en.ria.ru/russia/*

European Parliament ratifies Ukraine-EU agreement on GNSS

The European Parliament has ratified an agreement on cooperation in a civil global navigation satellite system (GNSS) between Ukraine and the European Union.

The agreement envisages the creation of ground-based infrastructure - three ranging and integrity monitoring stations (RIMS) in Ukraine under the European Geostationary Navigation Overlay Service (EGNOS) project, which is the ground component of the Galileo European Global Navigation Satellite Systems.

It is expected that the coverage of Ukraine with the EGNOS system will increase the accuracy of positioning and air navigation systems, which will help increase the safety of flights and airport operations.

At present, the European Commission is considering the funding of the project. The work on the details of the project will last for about a year. Contracts for the implementation of this project are to be signed for a period of up to three years, and the implementation of the project should be completed by 2019. *http://en.interfax.com.ua*

Russia, US to protect satellite navigation systems at UN level

Russia and the United States, concerned about competition from navigation systems being developed by the European Union and China, intend to secure frequency spectrum and other positions for their GLONASS and GPS satellite navigation systems at the level of the United Nation's International Committee on GNSS (ICG).

"The GLONASS and GPS systems were developed in the 1970s and, naturally, they include solutions that have been obsolete for a quarter century. The modernization of the systems has been fairly difficult, and radical changes to the systems are virtually impossible. China with its Compass system and the EU with Galileo, using Russian and American experience, are developing their systems at the most advanced level. Consequently, when these systems are rolled out they will be of better quality than GPS and GLONASS," a source in the aerospace industry told Interfax.*http://voiceofrussia.com*

GPS III prototype, ground station communicate in ground test

A prototype of a next-generation GPS satellite built by Lockheed Martin connected for the first time to a ground station supplied by Raytheon during a recently completed series of pre-flight tests.

The test version is jam-resistant GPS III satellite established remote connectivity and communications with Raytheon's GPS Next Generation Operational Control System during compatibility and integration testing. The prototype satellite serves as a test bed for confirming satellite functionality. The ground tests showed that the prototype could connect and receive commands from the Raytheon-built ground station. *http://defensesystems.com*

NEW

LT400HS GNSS Handheld – Accurate, Productive, and Versatile Surveying & Mapping Solution

- ***RELIABLE AND EFFECTIVE***
  The LT400HS Handheld GNSS is a rugged GPS+GLONASS data collector designed to achieve sub-meter to centimeter accuracy in adverse mapping conditions with or without the external antenna.

- ***COMPETITIVE SURVEY SOLUTION***
  Bundled with Carlson's SurvCE software, the LT400HS is the perfect cost-effective GNSS RTK Survey Solution for survey and construction professionals.

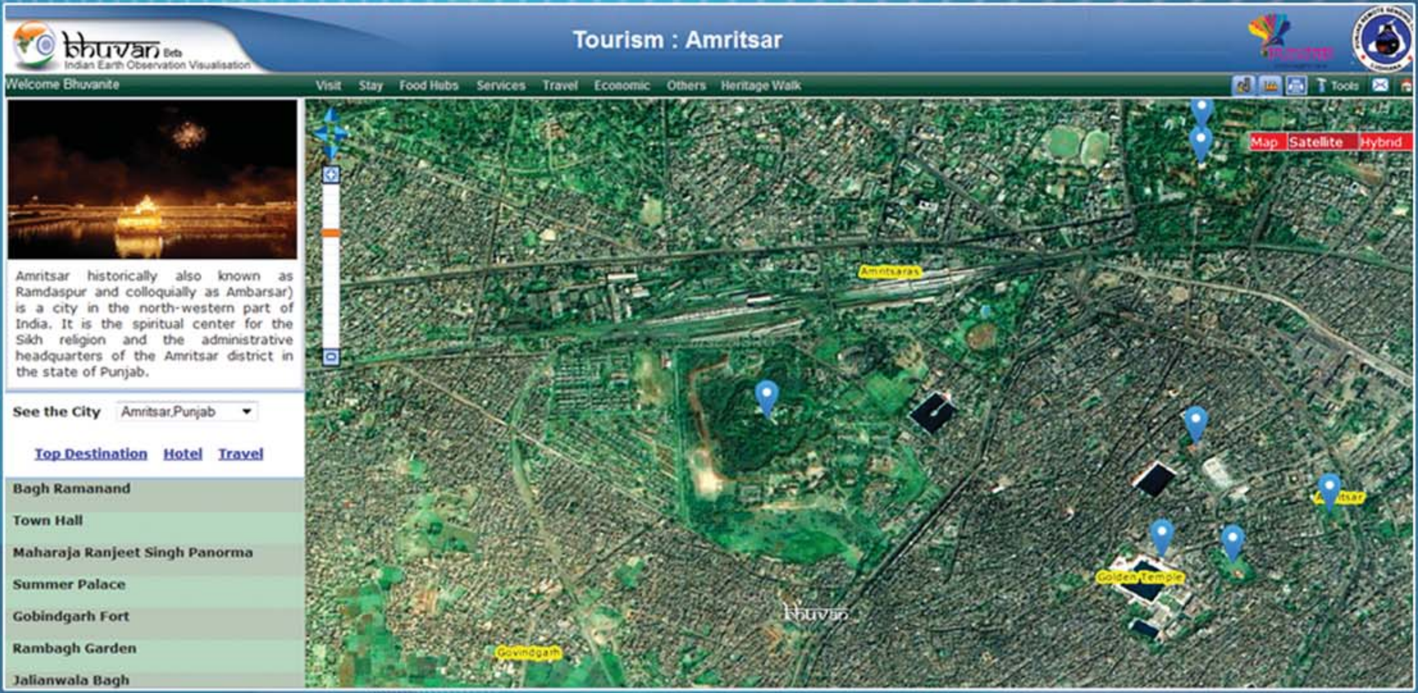
- ***POWERFUL GIS SOLUTIONS***
  Combined with DigiTerra Explorer7 Mobile GIS software, the LT400HS GNSS handheld offers feature-rich solution for accurate GIS field data collection and maintenance.

World Space Week Celebrations 2013

World Space Week (WSW) is the largest public space event on Earth celebrated by more than 65 nations during 04-10 October every year since 1999 under the declaration on United Nations. The launch of first human made Earth satellite Sputnik on October 4, 1957 and signing of the International Outer space treaty by United Nations on October 10, 1967 marks the celebrations. The theme for current year program is "Exploring Mars and Discovering Earth."

National Remote Sensing Centre (NRSC) in Hyderabad in association with Hyderabad Chapters of the Indian Society of Remote Sensing (ISRS) and the Indian National Cartographic Association (INCA) conducted one day program on 10.10.2013 for the benefit of school children from twin cities of Hyderabad and Secunderabad. This event also coincides with the 25 years of Indian Remote Sensing (IRS) program which was celebrated by the different Chapters of ISRS all over the country. The event was attended by nearly 350 children and teachers from 14 different schools in the twin cities. In his welcome address Dr V Raghavswamy Chairman ISRS-HC talked about the importance and need of such awareness programs which was formally inaugurated by Sri D S Jain, Dy. Director, Satellite Data Acquisition, and Processing & Service Area who briefly touched upon ISRO and NRSC activities. Dr Samudraiah, Vice President ISRS who graced occasion inspired children to utilize such occasion for their benefit and wished them to become future space scientists and technologists. Dr C B S Dutt, Dr V V Rao from NRSC, Dr G Venkata Narayana from VSSC and Dr N Srinivas from INCOIS delivered lectures.

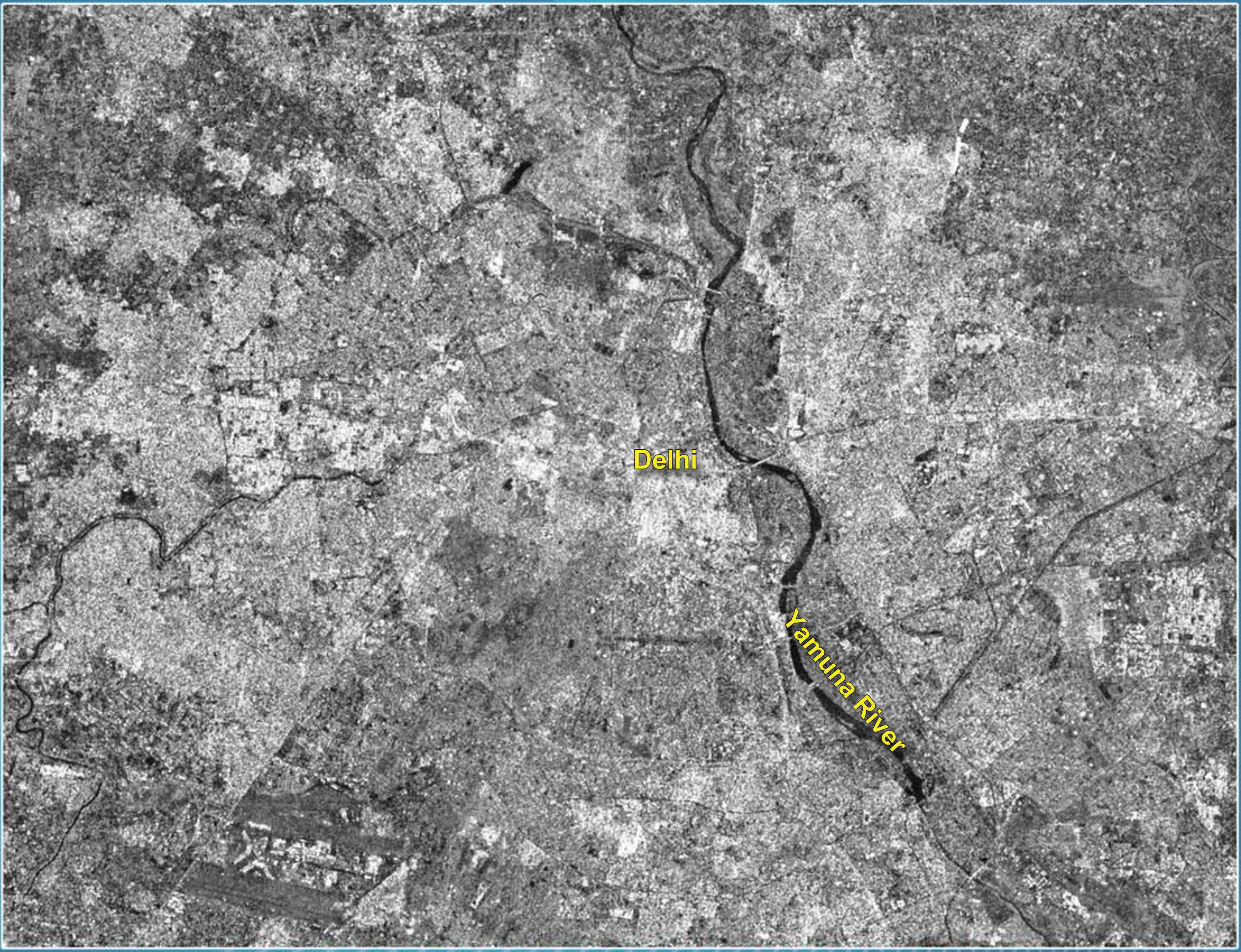
There was also a session exclusively earmarked for the question answers session. This session was made interesting and informative with a panel chaired by Dr C B S Dutt along with all speakers and Dr R Nagaraja, Chairman INCA–HC. Nearly 30 questions were screened from 240 responses from the children which were answered by panelist. The program ended with a formal vote of thanks by Dr Reghunatha Menon K P, Secretary ISRS-HC.



Tourism services on Bhuvan

bhuvan

RISAT-1 Medium Resolution with VV polarisation



Bentley announces two commercial innovations for software as a service

SELECT Open Access enables greater project agility through unrestricted access to Bentley's portfolio of information modeling applications – unencumbered by conventional software procurement cycles. Bentley's new MANAGE services offering facilitates the provisioning, rapid deployment, and operation of Bentley's ProjectWise collaboration services and AssetWise asset information management services in a hybrid cloud services environment.

OS OpenSpace SDK for Android

The new free mapping software development kit (SDK) enables developers to quickly and easily add detailed Ordnance Survey maps to mobile applications, with its launch further cementing the prominence of location-based mobile applications in the smartphone market. The SDK automatically enables access to the range of high quality datasets available within the OS OpenSpace, OS OpenSpace Pro and OS OnDemand WMTS API.

France offers Arab nations geospatial systems

France has recently made efforts to sell geospatial satellite systems to countries throughout the Persian Gulf region, as an integral component to its defense strategy. After having already reached an agreement with the United Arab Emirates, United Press International reports that French government officials are now looking to strike up a deal with Saudi Arabia. *www.ordnancesurvey.co.uk/media*

GeoCalc SDK by Blue Marble

Blue Marble Geographics has released of a fully managed .NET version of the GeoCalc 6.6 software development kit. Its geospatial data manipulation, visualization and conversion solutions are used worldwide by thousands of GIS analysts, oil and gas, mining, civil engineering, surveying, and technology companies, governmental and university organizations. *www.bluemarblegeo.com*

ALTUS introduces the GIS-1

Altus Positioning Systems is expanding its line of GNSS surveying products with the introduction of the GIS-1, a versatile PDA for data collection and geolocation. It integrates modern wireless technologies on a rugged Windows® Mobile platform for effective portable computing for mobile survey applications. *www.altus-ps.com*

OS International agreement with Kingdom of Bahrain

Ordnance Survey International has announced the signing of a five-year Specialist Advisory Framework Agreement with the Survey and Land Registration Bureau (SLRB) of the Kingdom of Bahrain. The agreement provides an opportunity for both organisations to work together collaboratively on a number of projects, the first of which will be the development of a new long-term strategy, which will support SLRB in continuing to develop its role as the authoritative cadastral and mapping authority for Kingdom of Bahrain. *www.ordnancesurvey.co.uk*

3D mapping for subways, indoor facilities

The V-World 3D mapping project was first launched nearly three years ago by Korea's transport ministry with the goal of providing high-resolution maps to the public through an open platform.

The 3D mapping service is now going underground to tackle Seoul's vast network of subway stations. A side-by-side comparison view of the 3-D spatial map of Seoul City Hall Station shows that every detail and step has been taken into account. The indoor mapping service also hopes to enable audio directions for individuals with visual impairments so they can better navigate through one of the world's largest subway systems. The 3D maps continue to be updated using highly precise laser measurements and video footage. *www.arirang.co.kr*

Delhi State Map prepared by Survey of India unveiled

Dr. T. Ramasami, Secretary, Department of Science and Technology, Govt of India recently unveiled the English and Hindi versions of Delhi State Map prepared by Survey of India in the presence of Dr. Swarna Subba Rao, Surveyor General of India. The map has attracted lot of interest and enthusiasm from the visitors.

According to the Surveyor General of India, SOI has taken initiative for generation of maps on 1:10k scale for the entire country. Topographical mapping proposed to be carried out by SOI is next level of GIS-Asset for National GIS project and the basis for National GIS version-2.0.

SOI and Tele Atlas Kalyani India agreement

Government of India has formally approved the strategic agreement between Survey of India (SOI) and Tele Atlas Kalyani India Ltd. The agreement allows Tele Atlas Kalyani India to release the first Survey of India-approved digital maps and custom map content within the public domain for commercial use in a range of navigation and location-based solutions in the mobile, internet, automotive, personal navigation system and enterprise markets. *http://www.nasscom.in*

Philippines for literacy mapping

Agencies pledged their support to the Department of Education (DepEd) as they signed a Memorandum of Understanding (MOU) for their support for the conduct of the Regional Literacy Mapping (RLM) in the Cordillera Administrative Region(CAR). The RLM is a data-gathering tool by way of conducting a survey of all Indigenous Peoples (IP) and non-IP learners, out-of-school youth and adults, purposely to determine the situation of education and literacy in the region with a special focus on IP Education. *http://news.pia.gov.ph*

Accurate position info for mobile CAD and GIS

Septentrio jointly announced with Pythagoras BVBA that they have integrated key components to propose a complete solution, ready for geospatial applications. The solution combines the Pythagoras software with GNSS device called AsteRx-m™ GeoPod that enables accurate position measurements up to 1 cm level. The AsteRx-m™ GeoPod integrates seamlessly with Pythagoras thanks to the suite of GUI utilities RxTools and the configuration module RxAssistant, also included in the solution. *www.septentrio.com/geopod*

The New FARO® Laser Scanner Focus^{3D} X 330

FARO Technologies, Inc has released new FARO Laser Scanner Focus^{3D} X 330. It surpasses previous models in functionality and performance. With a range almost three times greater than previous models, the it can scan objects up to 330 meters away and in direct sunlight. With its integrated GPS receiver, the laser scanner is able to correlate individual scans in post-processing making it ideal for surveying based applications. *www.faroasia.com*

High Performance POS Systems by Applanix

Applanix has introduced new versions of its positioning and orientation systems for airborne and land-based mapping—the POS AV™ 610 and POS LV™ 610. The new systems use next-generation commercial inertial technologies that are offered globally. Both products integrate precision GNSS with advanced inertial technology (accelerometers and gyroscopes) to provide uninterrupted measurements of the position, roll, pitch and true heading of moving vehicles. *www.applanix.com*

Sub-meter GNSS Receiver for iPad and iPhone by Geneq

iSXBlue II GNSS by Geneq Inc is a sub-meter GNSS receiver that is Bluetooth-compatible with Apple iPads and iPhones. Fully authorized and approved by Apple, it implements an Apple proprietary Bluetooth authentication feature allowing the NMEA GNSS data to replace the internal GPS location of the iPad or iPhone. Furthermore, a free SDK (software development kit) is available from Geneq to further utilize all the features of the iSXBlue II GNSS. It uses both GPS and GLONASS with SBAS (WAAS/EGNOS/MSAS/GAGAN) to attain 30cm/1 ft (RMS) accuracy in real-time using free SBAS corrections. *www.sxbluegps.com*

GNS uses CSR chip for GPS+ GLONASS module

GNS has based its latest GPS+ GLONASS combination module on the CSR SiRFstarV chip. The module has a power supply range of 1.8 up to 4.3V. A lithium battery can be directly connected to the module. It has UART, SPI or I²C communications, it supports 52 signal channels and has dimensions of 10 x 9.3 x 2.1mm. *www.electronicsweekly.com*

Improved GNSS Productivity tools by SmartNet

SmartNet North America has released new tools to improve GNSS productivity and support, including additional support tools, online Rover Error Logs and a RINEX Project Tool. It added a completely new support ticketing system along with an online Knowledge Base. To ensure users get support and help, SmartNet has now launched a new Live Support Chat feature directly on the SmartNet User Portal.

Honeywell to upgrade embedded navigation systems

Navigation and guidance experts at the Honeywell Inc. Aerospace will repair and upgrade the multiservice Embedded GPS Inertial Navigation System (EGI) that combines GPS and inertial technologies under terms of a $485.5 million contract.

The EGI, manufactured by Honeywell and the Northrop Grumman Corp. is a navigation system that combines a GPS receiver card with an inertial navigation system (INS) in one 20-pound unit that measures 7 by 11 by 12 inches. The navigation systems are for helicopters and fixed-wing aircraft as upgrades to existing systems or as replacements for older and less capable systems. *http://aerospace.honeywell.com*

Hexagon News

Acquires Airborne Hydrography AB

Leica Geosystems strengthens its market position in airborne surveying through Hexagon's acquisition of Airborne Hydrography AB (AHAB), a provider of airborne laser survey systems for hydrographic and topographic surveys. AHABproduct portfolio includes airborne bathymetric LiDAR technology. *www.leica-geosystems.com*

New ISO certification for Leica

The Quality and Environmental Management System of Leica Geosystems AG has been recertified to ISO 9001:2008 and ISO 14001:2004 compliance for the development, manufacture, distribution, support and service of products, precision tools and systems for geomatics, industrial, machine control and construction applications with zero non-conformities. *www.leica-geosystems.com*

Enhanced2 GPS-Monitoring Unit (E2GMU) from CSSI

Enhanced² GPS-Monitoring Unit (E²GMU) by CSSI is now available for commercial sale for the first time. The first unit was sold to Trimec Aviation, an FAA-certified repair facility located in Ft. Worth, Texas. The E²GMU was developed using the latest GPS receiver technology, utilizing a 20-channel GPS receiver for enhanced satellite lock, accuracy, and faster GPS acquisition time from aircraft static-position start. *www.cssiinc.com*

Spirent A-GNSS Record and Playback Solution

Spirent Communications carrier-approved Assisted Global Navigation Satellite

Hemisphere GNSS news

New OEM Positioning Modules

Hemisphere GNSS introduces the Eclipse P306 and P307, the latest models in the Eclipse series. Both track multi-frequency GPS, GLONASS, and BeiDou satellite signals and are Galileo and QZSS ready.

The Eclipse P306 and P307 are the first products to utilize the company's new SX4 ASIC. Capable of simultaneously tracking code and phase signals on 89 satellites, SX4 boasts 372 channels and can be configured to address several diverse applications through software. Both products offer scalable performance.

Mobile Handhelds and GIS/ Survey Collection Software

Hemisphere GNSS announced an all-new series of rugged mobile handheld devices, GeoMapper, with application software options to support Survey, GIS, and Mapping professionals.

The GeoMapper family of products offers a variety of features suitable for forestry, public safety, asset management, utilities, meeting a variety of field data collection requirements. GeoMapper 100, GeoMapper 200, and GeoMapper 300 feature a Windows Mobile operating system. The GeoMapper 500 tablet offers added flexibility and functionality on the Android OS platform. *www.HemisphereGNSS.com*

System (A-GNSS) Record and Playback capabilities on its Hybrid Location Technology Solution (HLTS) provides unprecedented realism and repeatability by recording GNSS signals in the field and delivering synchronized assistance data over a radio access interface to test the A-GNSS positioning performance of mobile devices in the lab.

Combining GNSS signals from multiple satellite positioning systems with assistance data delivered by the network to the device, A-GNSS is regarded as the most universal and precise positioning technology. As such, it is used in mobile devices to support the location information required by commercial services, social media and emergency services such as E911. *www.spirent.com/Products/HLTS*

New GNSS Post-Processing Program by Carlson

This simple, yet powerful data post-processing solution is tightly integrated into the Carlson field and office workflow. SurveyGNSS is designed to accept GNSS data from any receiver in RINEX format. Furthermore, it will also accept proprietary GNSS data in an increasing number of manufacturer formats including NovAtel, Hemisphere GNSS, Altus/Septentrio, and Javad. Additional manufacturer formats will be added in concert with manufacturer cooperation and customer demand. *www.carlsonsw.com*

Javad GNSS Triumph LS

Javad GNSS released its latest GNSS receiver, the Triumph LS. Incorporating all of the standard-setting capability of the Triumph VS, the new receiver has several new features, including 864 channels. Always a leader in the channel count, the new channels can be used to track existing and future satellites as well as monitoring for interference. More than 100 channels are assigned to monitor interferences in the background and give instant notification to users. Also, many channels can be assigned to a single satellite signal for reliability, redundancy and averaging for better results. *www.javad.com*

Ladybug 5 camera for Lynx Mobile Mapper™ by Optech

Optechs' Lynx MG1 and Lynx SG1 Mobile Mapper™ product lines now support the use of the Point Grey Ladybug® 5 spherical imaging system. The Ladybug 5, which boasts six high-sensitivity 5-Megapixel imagers that cover 90% of a full sphere, offers Optech users more options in assembling a mobile surveying solution optimized to meet their specific application requirements.

Trimble News

Galileo, BeiDou Preview to Post-Processing Service

Trimble has announced a "preview" version of its CenterPoint RTX post-processing service, enabling GNSS observations using available Galileo and BeiDou Middle Earth Orbit (MEO) satellites. The existing CenterPoint RTX post-processing site uses data from the GPS, GLONASS, and QZSS satellite systems to provide better than centimeter-level positions.

Real-time Deformation Monitoring

Trimble® 4D Control(TM) version 4.2 is the new version of the monitoring software that delivers enhanced communications with the Trimble NetR9(TM) and new NetR9 Ti-M GNSS receiver, REF TEK seismic sensors and the Trimble S8 total station.

R8 Model 2 GNSS Receiver

Trimble R8 integrated system delivers unmatched power, accuracy and performance in a rugged, compact unit. Supporting a wide range of satellite signals, including GPS L2C and L5 and GLONASS L1/L2 signals, the Trimble R8 contains Trimble R-track with Signal Prediction™ technology which compensates for intermittent RTK signals, enabling extended operation after interruption. *www.trimble.com*

GICHD signs MoU WITH Esri

Esri and the Geneva International Centre for Humanitarian Demining (GICHD) have recently signed a Memorandum of Understanding (MoU). Since it was first released in Kosovo in1999, Esri has been supporting the Information Management System for Mine Action (IMSMA), the GICHD's application for demining programmes. IMSMA combines a customisable database and ArcGIS software that together allow for more accurate localization of hazardous areas, accidents and other information relevant to mine action. By providing free licenses to the GICHD, Esri has proved a significant partner of GICHD

GNSS Receiver Module Tracks Multiple Satellite Constellations

Linx, the GM Series of autonomous, high-performance GNSS receiver modules is designed for navigation, asset tracking and positioning applications of all kinds. Based on the MediaTek chipset, the modules can simultaneously acquire and track several satellite constellations, including the GPS, GALILEO, GLONASS and QZSS. *www.linxtechnologies.com*

senseFly releases swarm technology for mapping

The most advanced version of senseFly's ground control software puts years of research into user's hands. The technology behind senseFly's multiple drone operation system first emerged in 2010 at the Laboratory of Intelligent Systems, EPFL (*http://lis.epfl.ch/smavs*) when a team of robotic researchers showcased the first outdoor aerial collective system involving up to 10 robots flying together. This technology was then adapted by senseFly's R&D team. It is now fully integrated in senseFly's ground control software eMotion 2. Operators can use a single interface to control multiple drones.

SATEL – Module for long-range wireless data transmission

SATEL a leading manufacturer of radio modems, recently released a new data transceiver module SATELLINE-M3-TR3. The Module is specifically designed to be integrated into host devices. It is compact, slim and easy to add to various systems. This makes it a versatile and exceptionally compatible solution for data transfer. With a 70 MHz tuning range, selectable channel width and 128-bit encryption available for secure transmission, it makes this one of the most versatile SATEL products available. With a weight of 18 grams an compatibility.

MARK YOUR CALENDAR

November 2013

NSDI India
29 – 30 November 2013
IIT Bombay, India

December 2013

5th Asia Oceania Regional Workshop on GNSS
1 – 3 December 2013
Hanoi, Vietnam
www.multignss.asia/workshop.html

ION Precise Time and Time Interval Meeting (PTTI)
2 – 5 December
Bellevue, WA, United States
www.ion.org

87th OGC Technical Committee Meeting
2 – 6 December 2013
IIT Bombay, India
www.opengeospatial.org/contact

4th International Colloquium Scientific and Fundamental Aspects of the Galileo Programme
4 – 6 December 2013
Prague, Czech Republic
http://congrexprojects.com/2013-events/13c15/introduction

6th European Workshop on GNSS Signals and Signals Processing
5 – 6 December
Munich, Germany
http://ifen.bauv.unibw.de/gnss-signals-workshop/

Esri India UC
11 – 12 Dec 2013
Delhi
http://www.esriindia.com/Events/UC2013_files/index.html

January 2014

DGI 2014
21 – 23 January, 2014
QEII Conference Centre, London, UK
http://www.wbresearch.com/dgieurope/home.aspx

ION International Technical Meeting
27 – 29 January
San Diego, California, USA
www.ion.org

February 2014

International LiDAR Mapping Forum
17 – 19 February 2014
Denver, Colorado, USA
www.lidarmap.org/international

March 2014

Munich Satellite Navigation Summit 2014
25 – 27 March
Munich, Germany
www.munich-satellite-navigation-summit.org

April 2014

ASPRS 2014 Annual Conference
23 – 28 March 2014
Louisville, Kentucky USA

ENC-GNSS 2014
14 – 17 April
Rotterdam, The Netherlands
www.enc-gnss2014.com

2014 International Satellite Navigation Forum
23 – 24 April
Moscow, Russia
http://eng.glonass-forum.ru

May 2014

China Satellite Navigation Conference
May 2014
Nanjing, China
http://www.beidou.org/english/index.asp

IEEE/ION Position Location and Navigation Symposium
5 – 8 May 2014
Monterey, CA
www.ion.org

Annual Baska GNSS Conference
7 – 9 May 2014
Baska, Krk Island, Croatia
renato.filjar@rin.org.uk

MundoGEO Connect 2014
7 – 9 May
Sao Paulo, Brazil
http://mundogeoconnect.com/2014/en/

GEO Business
28 – 29 May 2014
London, UK
www.geobusinessshow.com

June 2014

Hexagon Conference 2014
2 – 5 June
Las Vegas USA
http://hxgnlive.com/

ION Joint Navigation Conference 2014
16 – 19 June
Orlando, United States
www.ion.org/jnc

XXV FIG Congress
16 – 21 June
Kuala Lumpur, Malaysia
www.fig.net

July 2014

GI Forum 2014
1 – 4 July 2014
Salzburg, Austria
www.gi-forum.org

Esri International User Conference
14 – 18 July 2014
San Diego, USA
www.esri.com