RNI: DELENG/2005/15153
Publication: 15th of every month
Posting: 19th/20th of every month at NDPSO

No: DL(E)-01/5079/17-19
Licensed to post without pre-payment U(E) 28/2017-19
Rs.150

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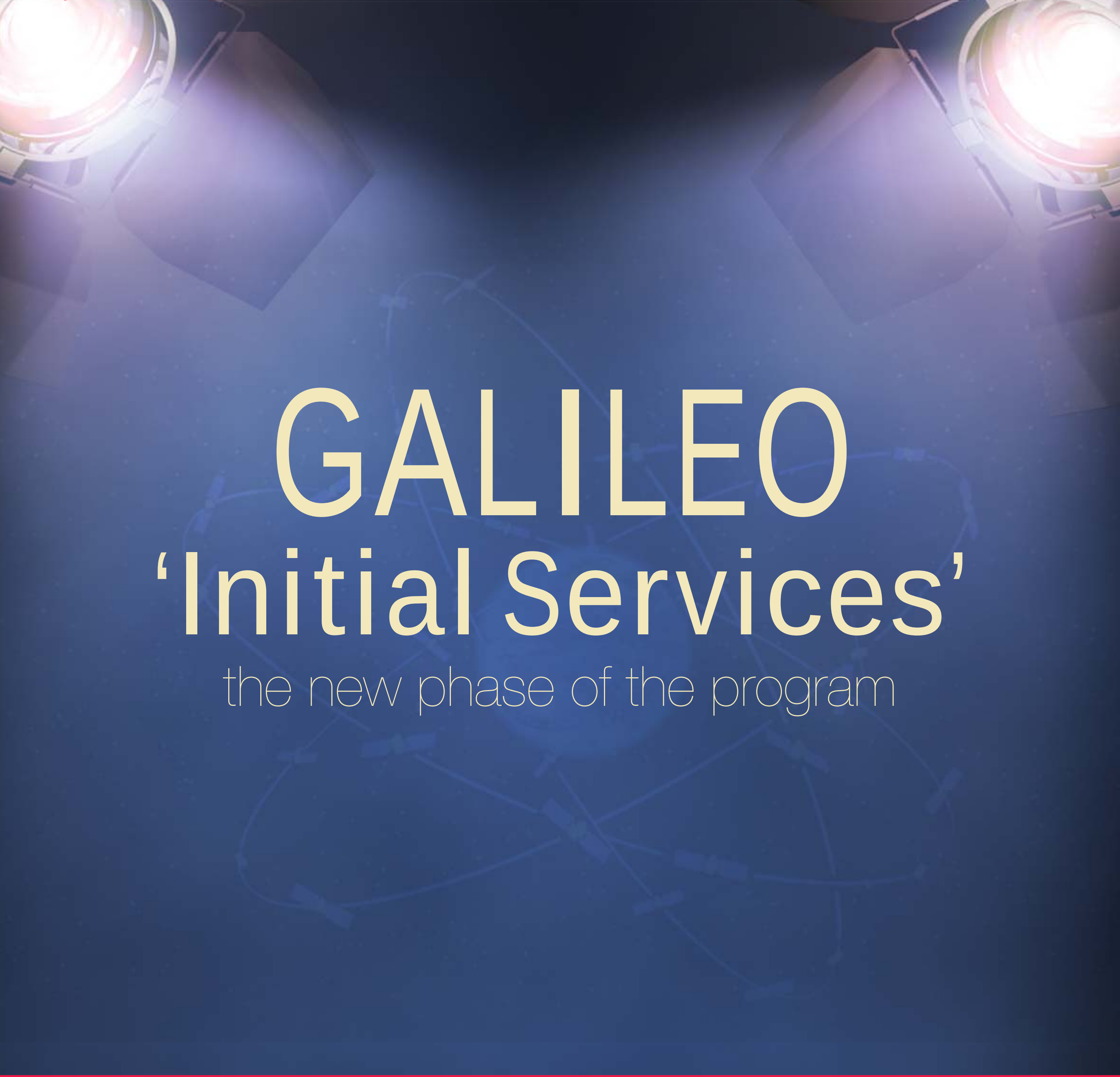
Coordinates

ISSN 0973-2136

Volume XIII, Issue 03, March 2017

THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND



GALILEO 'Initial Services'

the new phase of the program

Outcomes of SBAS-Africa project

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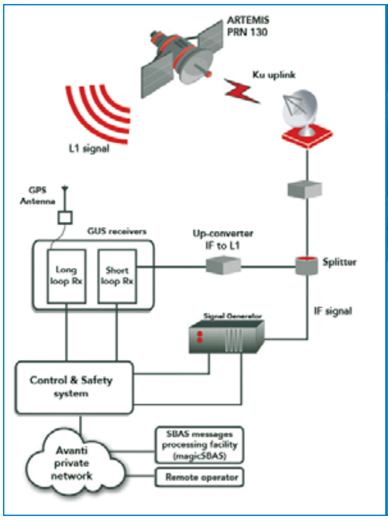

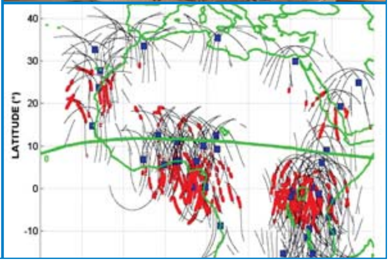

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This issue has been made possible by the support and good wishes of the following individuals and companies
Abderrahamane Touzani, Christine Amory-Mazaudier, D Hill, D Pérez, G Lamprecht, E Avenant, J Ostolaza, J J Lera, Jack McKenna, Marco Lisi, P Milway, Rolland Fleury, S Basker, S Sheppard, Sharafat Gadimova, V Boissinot, and W Roberts; Accord, Effigis, Ip solutions, Javad, Labsat, MicroSurvey, Pentax, Riegl, SBG System, Spectra and many others.

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[subscriptions] iwant@mycoordinates.org

Web www.mycoordinates.org

Annual subscription (12 issues)
[India] Rs.1,800 [Overseas] US$100

Printed and published by Sanjay Malaviya on behalf of Coordinates Media Pvt Ltd
Published at A 002 Mansara Apartments, Vasundhara Enclave, Delhi 110096, India.
Printed at Thomson Press (India) Ltd, Mathura Road, Faridabad, India

Editor Bal Krishna
Owner Coordinates Media Pvt Ltd (CMPL)
Designed at Spring Design (ajay@springdesign.in)

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


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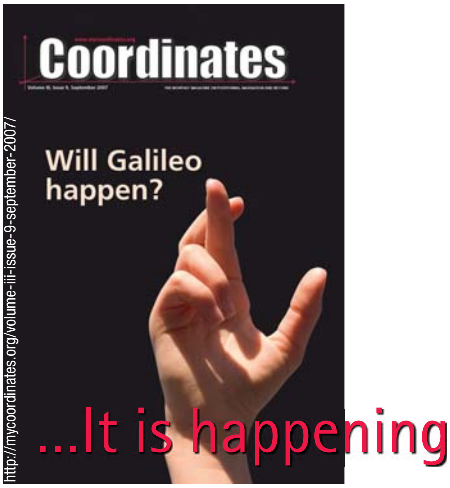


Galileo Initial Services

Officially declared operational.

This includes Open Service,

Public Regulated Service

Search and Rescue

A promising step towards

More comprehensive and better performing services

Like eCall emergency call systems

Digital tachograph, etc.

Along with some unique services (page7).

Galileo, a unique GNSS system,

Able to meanders its ways

Despite so much of economic and political uncertainties,

And at times, diverse stakes of various stakeholders.

Bal Krishna, Editor
bal@mycoordinates.org

"Initial Services", the new phase of the Galileo program

The benefits for users, in Europe and worldwide, arising from the declaration of the "Initial Services" are immediate and tangible

Dr ing Marco Lisi
European Space Agency - ESTEC, GNSS Services Engineering Manager, The Netherlands

On 15 December last year, during a ceremony which was attended by all the main actors of the Galileo program at institutional level (Commissioner Bienkovska and Commissioner Sefcovich for the European Commission, the Director General prof. Woerner and the Director of Navigation Programs Paul Verhoef for ESA, the Executive Director Carlo Des Dorides for GSA), the "Galileo Initial Services" have officially been declared operational.

This new phase of the Galileo program, associated with the provision of guaranteed services and a series of operational and organizational changes, however, has an essentially political significance: for the first time, the European Commission officially takes its responsibility in the face of European and global users for positioning, navigation and timing services provided by the albeit partially completed the constellation of Galileo satellites.

Figure 1

These services, because of the partial completion of the system, are still limited and guarantee a performance lower than that available in the future, when the constellation and the ground support system will be completed. Nevertheless, they will help improving immediately the applications available to users, even if in a multi-constellation perspective, that is, as integration of services provided by other GNSS (such as the American GPS). In particular, as regards the global distribution of a reference universal time (UTC), with the "Initial Services" Europe can actually claim full autonomy from the other GNSS (for the distribution of the UTC time is in fact sufficient only one satellite in visibility).

The current status of the Galileo system and its completion plan

A few days prior to the above declaration ceremony of the "Initial Services", on Nov. 17, 2016, four Galileo satellites were successfully placed into orbit by an Ariane 5 launcher, after a textbook launch carried out from the ESA base in Kourou, French Guyana.

This launch is an important milestone in the history of Galileo, not only for adding in a stroke four satellites to the constellation (which now has 18 satellites in orbit), but also because it is the first quadruple launch of GNSS satellites in history.

Galileo is a European initiative which aims to provide Europe and the whole world a positioning, navigation and timing infrastructure very accurate


Figure 2

and independent. Albeit completely autonomous, Galileo will however be interoperable with other existing GNSS, in particular with the American GPS.

The implementation of the Galileo system has been developed in two phases: an initial "In-Orbit Validation" (IOV) phase") and a subsequent "Full Operational Capability" (FOC) phase, still under completion.

At the end of FOC, in its final configuration, the Galileo system will include 30 satellites in orbit (24 plus 6 in active redundancy) and a complex ground network, with control centers and stations scattered over the whole surface of the globe.

The Galileo system is designed to provide a range of services, each associated with different radio signals being broadcasted ("Signals in Space", SiS):

- The "Open Service" (OS) and the "Public Regulated Service" (PRS), which are similar, respectively, to the "Standard Positioning Service" and the "Precise positioning Service" of the GPS system;
- The "Commercial Service", one of the innovations introduced by Galileo, which will provide very accurate and, most important, authenticated positioning and timing, specifically for commercial applications;
- The "Search & Rescue" (SAR) service", part of the wider international Cospas-Sarsat organization, which will provide emergency services to users in case of distress and extreme danger.

Some information about the Galileo FOC satellite is shown in the figure.

The Galileo satellites are not very big: their mass at launch is about 700 kilograms. Through their solar panels they are able to generate a useful electric power of approximately 2 kilowatts. The entire satellite is designed for a lifetime of at least 12 years in orbit.

The heart of the Galileo satellites consists of atomic clocks, which have recently suffered from some problems, however in the process of resolution. Each satellite Galileo embarks four atomic clocks:

- 2 "Passive Hydrogen Masers", with a stability of 0.5 nanoseconds in 12 hours, that is, of 1 second every 3 million years (!) (At the time, these are the more stable clocks ever placed in orbit);
- 2 Rubidium clocks, with a 3 second stability over 1 million years.

Just to clarify things, think that a good quality quartz wrist watch has a typical stability of one second per year.

The Galileo constellation is distributed over 3 orbital planes, inclined at 56 degrees w.r.t. the Equator. In its final configuration, it will be composed of

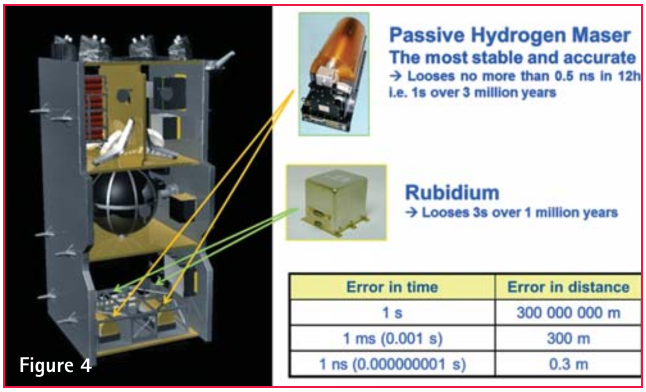


Figure 4

Figure 3

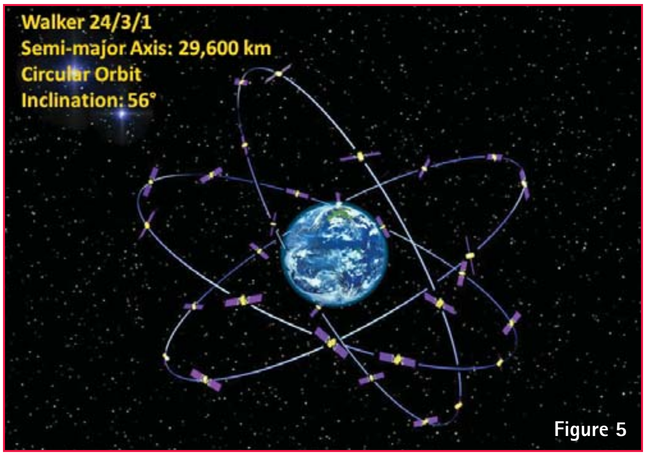


Figure 5

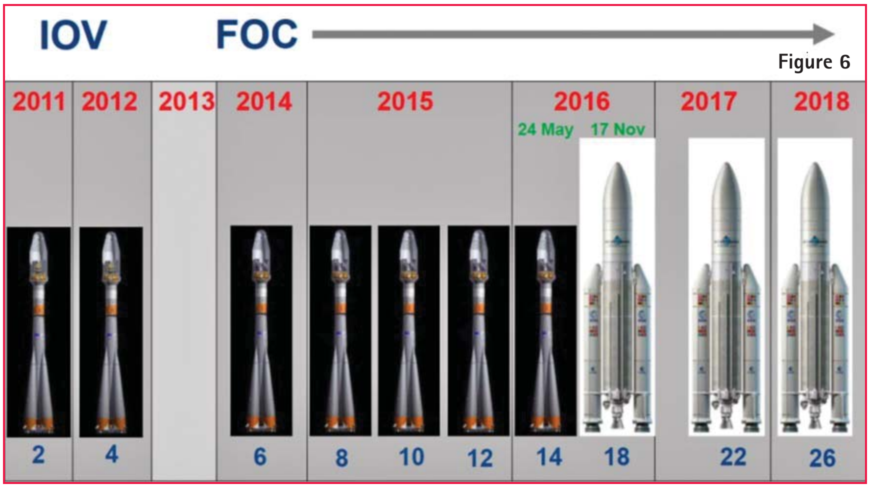


Figure 6

24 satellites, 8 for each of the three orbital planes, plus 6 satellites in active (or, as we say, "hot") redundancy (2 satellites for each orbit plane). The satellites orbit around the Earth at an altitude of about 23,000 kilometers.

The sequence of launches in the IOV and FOC phases is shown in the following figure.

Of the eighteen satellites currently in orbit, only 12 will be operational for the purposes of "Initial Services". The last four satellites, launched November 17, 2016, are currently under testing and acceptance in orbit, and they will join the others in the provision of services in April and in June. By 2017, therefore, the operational satellites for the purpose of "Initial Services' will become 16.

Constantly updated information on the status of the satellites and their specifications is available on the website of the "Galileo Service Centre (GSC)" in Madrid, the Galileo (more properly GSA) interface with the world of users and of downstream services and applications (https://www.gsc-europa.eu).

In 2017 and in 2018 two more quadruple launches with Arianne 5 are expected, which should bring the total number of satellites in service to 24.

As already mentioned, the ground segment of the Galileo system consists of many control centers, of remote stations (monitoring, Up-Link, TT&C) distributed on the whole Earth surface and of a complex network of communication lines, all together to form a complex ICT ("Information and Communication Technology") infrastructure.

The various control centers of the system are located on European territory, as shown in the figure.

The last two acquisitions, still being completed, are the "Galileo Reference Centre (GRC)", located in the Netherlands, which will monitor quality and performance of services continuously and independently from the rest of the system, and the "Galileo Integrated Logistic Centre (GILC) ", in Belgium, which will have a key role in the maintenance and logistic activities, fundamental to ensure continuity and availability of the system.

What are the "Initial Services"?

As already mentioned, the "Initial Services" are limited only to certain types of services and with limited performance, compatibly with the reduced number of satellites in orbit. For declared services, however, quality, availability and continuity are guaranteed, according to official documents that, as we shall see, were published and made available to the world of the potential users.

The "Initial Services" constitute an official commitment undertaken by European Commission, GSA and ESA, to manage the complex technical and organizational machine of the Galileo system in order to ensure maximum availability and added value for users.

The change of perspective is drastic and noticeable: from an earlier phase during which the focus was mainly directed to technological, technical and implementation aspects, to the present stage, in which, together with earlier technical and programmatic objectives, emphasis and priorities are given to services and users satisfaction. This obviously leads to an ever increasing attention to operational, logistic and organizational aspects.

In detail, the "Initial Services" will include the following services:

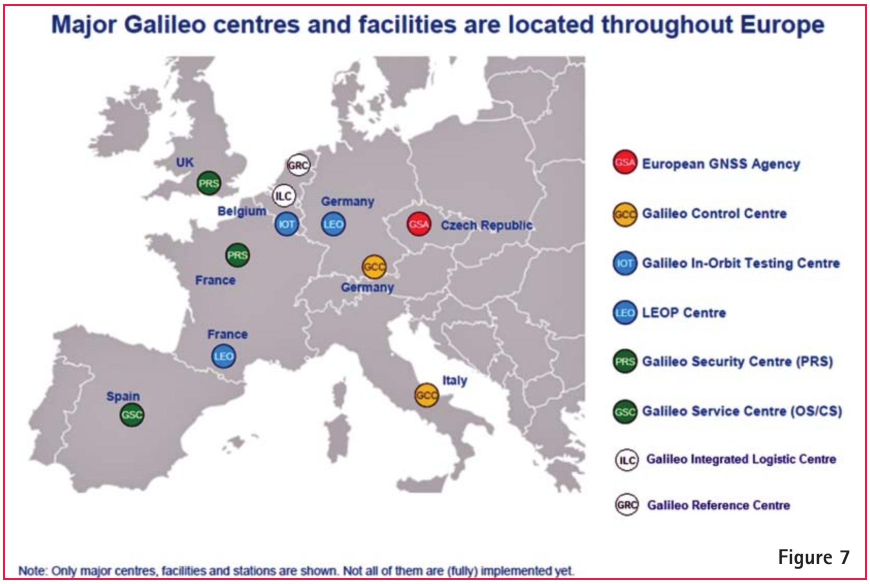


Figure 7

Figure 8

Figure 9

Figure 10

Figure 11

- **Open Service**
  - Open to all and interoperable with other GNSS;
  - Global availability.
- **Public Regulated Service**
  - Access authorized and controlled by the government authorities of the Member EU
  - Global availability.
- **Search and Rescue**
  - Open to all;
  - Global, under the control of the Cospas-Sarsat international organization;
  - Locate signals sent in case of emergency and communicate the distress call to the Search & Rescue centers.

Performance and conditions of the services offered are described in a series of official and public documents issued by the European Commission.

In summary:

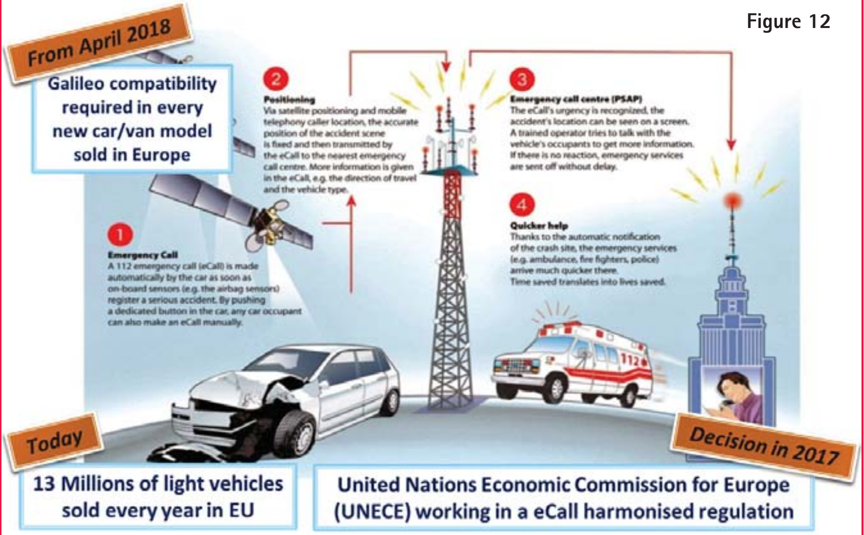
- ~ 0.8 meters average ranging accuracy", at 95% availability;
- ~ 3 / ~ 8 meters average localization accuracy, horizontal and vertical, respectively, at 95% of availability and when PDOP <6;
- ~ 9.5 nanoseconds of accuracy in the dissemination of the UTC time, at 95% availability;
- ~ 7 nanosecond error in the offset distribution of Galileo-GPS time, at 95% of availability;
- probability of localization of a SAR distress message within 10 minutes from its sending higher than 98%.

It is evident that the "Initial Services" are just the first, albeit very promising step towards the provision of more comprehensive better performing services.

The "Initial Services" from the user's point of view

The benefits for users, in Europe and worldwide, arising from the declaration of the "Initial Services" are immediate and tangible. They result largely from an increased confidence of downstream applications and services providers wrt Galileo and especially of manufacturers of integrated circuits (the so-called "chip-set manufacturers") and of devices (such as smartphones).

Figure 12



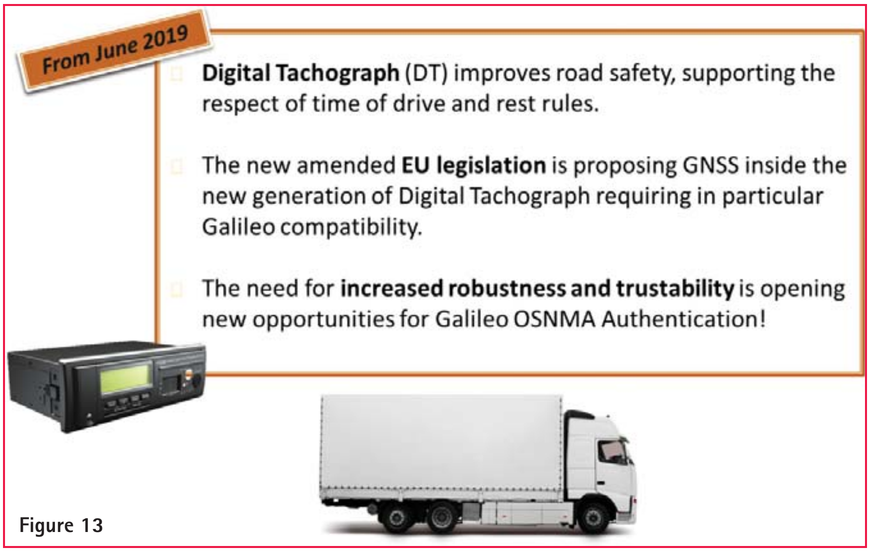


Figure 13

> The "Initial Services" constitute an official commitment undertaken by European Commission, GSA and ESA, to manage the complex technical and organizational machine of the Galileo system in order to ensure maximum availability and added value for users

Moreover, the "Initial Services" open the way to a series of important regulated services at European level.

In terms of adoption of the Galileo standard among the GNSS receiver manufacturers, we passed from 3 manufacturers adopting Galileo in 2010 to 17 in 2016, representing more than the 95% of the global market.

In July last year, the Spanish company BQ launched Europe's first "Galileo ready" smatphone, the model BQ Aquaris X5 Plus, which incorporates a Qualcomm Snapdragon 652 chip.

At the level of socially beneficial European services regulated by the EU, it is worth remembering eCall and the Digital Tachograph.

By 2018, a Galileo receiver will be available in every new vehicle model sold in Europe, allowing the use of the eCall emergency call system, completely free. In case of car accidents, through eCall, a distress message will be transmitted to the single European emergency number, 112, with the information useful for providing support and help.

Another service of great interest for trucking companies is linked to the digital tachograph. A European law provides that from 2019 the newly registered vehicles are equipped with the new digital tachographs, capable of receiving signals of the Galileo satellite navigation system. This will allow the automatic recording of the vehicle position and the monitoring of driving and rest periods; it will also allow the Police to interrogate the device remotely, to ascertain the presence of anomalies.

Conclusions and a look to the future

The official declaration of the Galileo "Initial Services" in December last year and the new phase of service delivery confirm, in spite of much controversy, the strategic, economic, technological and technical value of the Galileo program.

Through this program, Europe has become the protagonist in a highly strategic and technologically advanced field, promoting the growth of new technical knowledge and the development of countless industrial and commercial initiatives, all highly innovative.

The greatest promise for the future are derived from a feature that makes peculiar Galileo as compared to other GNSS: that of being able to provide authentication services for position and time. This potential is rendered all the more important as a result of the growing fear of possible "spoofing", that is of the falsification of GNSS signals.

Authentication is the system's ability to guarantee to users that they are using signals from Galileo satellites and not from other sources, more or less malevolent.

At the moment two different levels of authentication are being considered:

- one, easier, based on the Open Service E1b signal, which may already be available in 2018, with low implementation costs;
- the other, based on the Commercial Service E6 signal and on a sophisticated cryptographic system, starting in 2020.

Recently the European Commission adopted the "Galileo Commercial Service Implementing Decision", confirming that the first generation of Galileo will provide "High Accuracy and Authentication" services to users.

It has been noted that the "Commercial Service" is unique and peculiar, not being provided by any other GNSS; therefore it represents a great opportunity for Galileo to differentiate itself from other systems and to provide users with a precious added value as compared to already available standard services.

Outcomes of SBAS-Africa project

Feasibility analysis, infrastructure development, aviation, precision agriculture, UAV, maritime demonstration trials and preliminary business case for a South African SBAS

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Whilst Europe has benefitted for a number of years from the European Geostationary Navigation Overlay Service (EGNOS) and North America from the Wide Area Augmentation Service (WAAS), the countries of Africa have not had the same opportunity to benefit both economically and socially from improved navigation services. Many airports across Africa lack the infrastructure that enables aircraft to use precision landing approaches. This makes landings less safe, reduces their mainstream commercial use and constrains regional economic development.

One of the top priorities of the Africa-European Union cooperation is the Satellite Based Augmentation Service (SBAS) introduction in Africa aiming to support Air Transport Sector and Satellite Navigation. After several meetings remarking the third Africa-EU Summit, an action plan for the years 2011-2013 was agreed to implement the Joint Africa EU strategy. The expected result was to build a core technical capacity for SBAS within relevant African organizations in each region and to implement the preliminary backbone infrastructure.

The SBAS-Africa project (http://sbas-africa.avantiplc.com/) – led by Avanti Communications plc (Avanti) and co-funded by the UK Space Agency (UKSA) under the International Partnership Space Programme (IPSP) has been made possible by a collaboration between the South African National Space Agency (SANSA) and the UK Space Agency (UKSA). The objectives for this programme are to promote and foster the international relationship and to bring societal or economic benefits from the use of satellite or space technology for countries that currently do not have these benefits.

In partnership with GMV, NSL, Pildo Labs, TAS UK, the South African National Space Agency (SANSA), Ghana Council for Scientific and Industrial Research and the Agency for Aerial Navigation Safety in Africa and Madagascar (ASECNA), the SBAS-Africa project has delivered a live SBAS signal in space serving the southern part of the African continent. The system generates SBAS messages using GMV's magicSBAS tool suite with input data from a network of GPS ground monitoring stations developed by NSL which are deployed across South Africa and neighbouring countries. The messages are broadcast via the ARTEMIS satellite originally an ESA EGNOS test satellite which is now owned and operated by Avanti plc. The system provides an immediate improvement of GPS accuracy having far-reaching benefits across a range of user communities and applications, such as aircraft precision landings.

The impact of SBAS-Africa will be the acceleration in the adoption of Satellite Based Augmentation Services (SBAS) within Africa for the benefit of African aviation safety and the wider African economy. As a flagship project SBAS-Africa paves to way towards an operational SBAS service which brings benefits to many market sectors including maritime navigation, precision agriculture and general aviation. Apart from economic benefits, it will stimulate innovation, attract inward investment, create high-value jobs, reduce imports and open up new export markets, increase productivity and improve the environment among others.

For African partners, this project represents an opportunity to understand the safety, societal and economic benefits that SBAS services will offer, to build business cases for and to move towards a fully operational SBAS service.

The paper will summarize the SBAS-Africa project and provide an overview of the performances that have been achieved in the demonstration campaign that have taken place. These demonstrations include flight tests, precise agriculture, UAVs and maritime taking place in Cape Town, Stellenbosch, Pretoria and Johannesburg in South Africa. The paper also showcases the results of the business case for a South African SBAS. The immediate and derived benefits to different user communities will be described and quantified and the steps required to fulfil a permanently operating service will be given.

SBAS-Africa context

As explained above, the SBAS-Africa project [1] – led by Avanti Communications PLC (Avanti) and co-funded by the UK Space Agency (UKSA) under the International Partnership Space Programme (IPSP) has been made possible by a collaboration between the South African National Space Agency (SANSA) and the UK Space Agency (UKSA). The objectives for this programme are to promote and foster international relationships and to bring societal or economic benefits from the use of satellite or space technology for countries that currently do not have these benefits.

In partnership with GMV, NSL, Pildo Labs, TAS UK, the South African National Space Agency (SANSA), Ghana Council for Scientific and Industrial Research and the Agency for Aerial Navigation Safety in Africa and Madagascar (ASECNA), the SBAS-Africa project generated a live SBAS signal in space serving the southern part of the African continent and delivered:

- 1-metre horizontal accuracy SBAS test services for Southern and Eastern Africa
- Service demonstration and user trials for aviation, maritime and agriculture sectors
- A draft capital project appraisal and transition plan for SBAS in South Africa
- A basis for extension to southern African neighbouring states and build-up of capacity in region

This paper provides an overview of the system infrastructure and of the performances achieved during the demonstration campaign. It also showcases the results of the business case for a South African SBAS.

SBAS-Africa infrastructure

The end to end infrastructure can be divided in 7 parts (see Figure 1): a network of GNSS Ground Monitoring Stations (GMS) deployed in Southern Africa, the HYLAS 2 Avanti satellite to transmit the GPS data collected by the GMS monitoring stations, the NTRIP caster, GMV's magicSBAS [2] Processing Facility that computes the SBAS messages and the Ground Uplink Station (GUS) that sends the messages to ARTEMIS satellite which then broadcasts them throughout its area of coverage on the L1 GPS frequency to the users.

The Ground Monitoring Stations (GMSs) are generally deployed throughout the area where the SBAS corrections will be valid. In the case of SBAS-Africa, they are spread throughout the whole country of South Africa. The GMSs collect the navigation information from the GPS satellites they have in view and send it to the NTRIP caster. The monitoring stations consist of the three following element:

- A dual frequency GPS antenna
- A GPS receiver to receive dual frequency GPS raw messages
- A VSAT to transmit the raw GPS message in a timely manner to the magicSBAS SBAS processing facility. The messages need to be received by the processing facility in less than 1 second.

The high throughput Avanti satellite HYLAS 2 is used to send the GPS raw messages to the magicSBAS SBAS Processing Facility in a timely and highly-reliable manner. If the navigation messages were not received on time by the magicSBAS Processing Facility, they would be discarded and the SBAS messages would not contain such information. If that situation persists for a long time and for the whole network of stations, the SBAS messages generated would lack of valid SBAS corrections data. Also, since the GMSs are mostly located in remote locations with little or no means of reliable access to internet, relaying data through satellite often represents the only way to ensures reliable and timely delivery of GPS messages to compute the SBAS corrections.

The Networked Transport of RTCM via Internet Protocol (NTRIP) caster is a software hosted on a server in the Avanti Goonhilly (GHY) data centre in the UK. This programme receives the raw GPS messages from all the GMSs deployed and acts as a server to access the data from a centralised, time-synchronised source. The data is also recorded on the server for research purposes.

The SBAS messages are generated by magicSBAS, a state-of-the-art, multi-constellation, operational SBAS testbed developed by GMV to offer regional differential corrections and non-safety critical integrity augmentation to any interested region.

The Ground uplink station (see Figure 2) comprises a first part which included

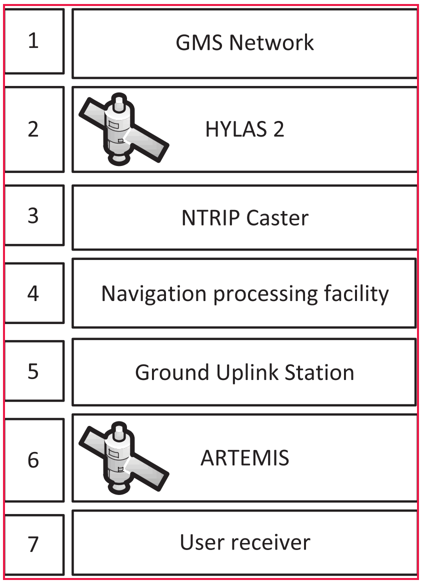

Figure 1: SBAS-Africa architecture building blocks

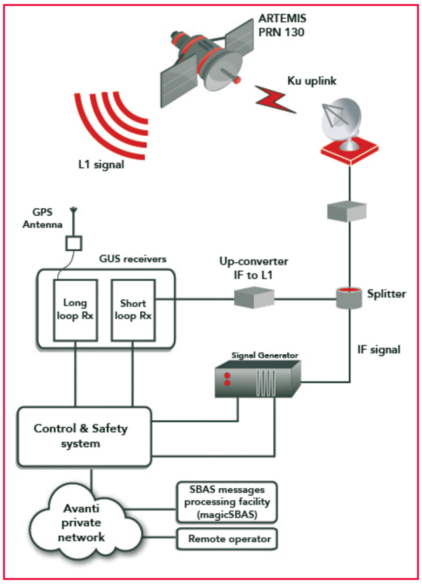

Figure 2: Ground Uplink architecture

Table 1: Safety requirements (see [3])

The signal must be transmitted using PRN 130 (different from other SBAS providers).
An SBAS MT0 shall be sent at least once every 6 seconds. This tells the users that the system is not for SoL use.
The SBAS MT1 mask contains only the GEO of the system (PRN 130).
The GEO PRN and service provider ID in SBAS MT17 are the ones selected for the system (130 and 7 respectively).
The IGP mask in SBAS MT18 is limited to a fixed area over South Africa.
The Service Area information in SBAS MT27 is set for the use of the system over South Africa (the system is degraded outside that area).

the signal generator and the control and safety system and a second part that enables the transmission to ARTEMIS (up-converter, High Power Amplifier and Antenna). The Avanti ground uplink station is located in the Makarios Satellite Earth Station in Cyprus. The SBAS messages are uplinked to ARTEMIS in Ku-band using a 4.9m dish antenna.

The ARTEMIS GEO satellite previously owned by ESA and now property of Avanti Communications was originally used operationally as part the EGNOS constellation to provide Safety of Life services from 2011 through 2013.

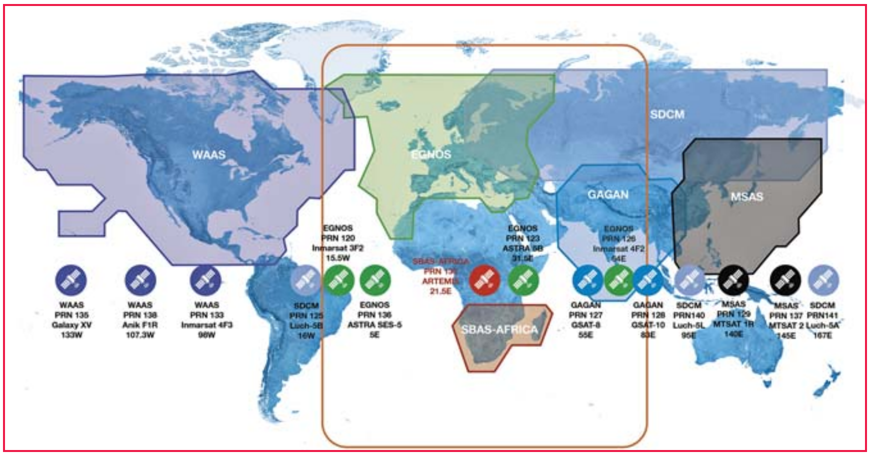

Figure 3: SBAS-Africa and EGNOS coverage [1]

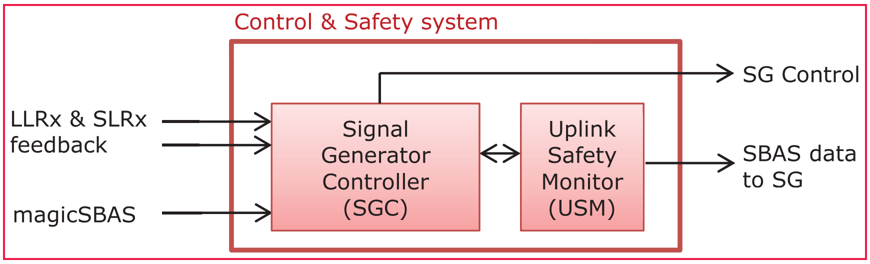

Figure 4: Control & Safety system

For SBAS-Africa ARTEMIS GEO was used to broadcast the signal on GPS PRN130 and allowed multiple user trials to be performed.

Safety and interoperability

SBAS-Africa intends to implement a testbed, precursor of an operational SBAS system for non-safety-of-life users. However, SBAS-Africa copes with a challenge that neither WAAS nor EGNOS had: SBAS-Africa shares GEO coverage with already mature Safety-of-Life (SoL) SBAS providers. These providers are mainly EGNOS, to a lesser extent WAAS and the recently certified one, GAGAN in India (see Figure 3).

The shared GEO coverage with other SBAS providers implies the necessity of introducing strict safety protections in the SBAS-Africa architecture, with a level of assurance comparable to that of WAAS or EGNOS itself.

To implement such a level of safety, a rigorous safety analysis was carried out, detecting the possible ways in which SBAS-Africa could affect other SBAS service performance or impact their users. Another critical aspect is that SBAS-Africa must inform its users that the signal may only be used for non-SoL operations. A user, for instance an aircraft, could be coming from a SBAS SoL enabled area, like Europe and start using the SBAS-Africa signal as if it were SoL. Taking these two factors into account, the minimum safety requirements in Table 1 were obtained.

The SBAS-Africa project was constrained to develop the SBAS prototype system with a limited cost (much lower than WAAS or EGNOS prototypes) and also in a short period of time (less than a year). In order to overcome this challenge, a novel approach was envisaged. This approach consisted on dividing the uplink system in two hardware/software processing elements: the Signal Generator Controller (SGC) developed with a non-critical assurance standard and the Uplink Safety Monitor (USM), developed with high assurance standards. All safety-critical checks are to be performed by the USM ensuring that the requirements in Table 1 are met, even if the rest of the system failed. Figure 4 shows the SGC and USM within the Control and Safety system.

As it can be seen in Figure 4 the SGC acts as a communications hub: it receives the SBAS messages to be broadcast from the magicSBAS [2] server and also serves as an interface with the operator. The SGC is also in charge of collecting the feedback data from the Long and Short Loop Receivers (the first one receiving signal-in-space and the second one connected to the Signal Generator output directly) as well as commanding the Signal Generator and sending the SBAS messages and feedback from the receivers to the USM.

The USM has been designed to work autonomously i.e. it is not commanded, it is not connected to the internet and its configuration is hardcoded. This element checks the PRN using the feedback from the receivers and analyses the SBAS messages before sending them to the Signal Generator and being broadcast. It checks also the consistency between the messages sent and the ones received through the receivers, detecting any possible anomaly after the message is sent to the Signal Generator. Note that the SBAS messages have to go through the USM to get to the Signal Generator; therefore it is a physical barrier. The USM will enable the signal generation only if all the safety checks pass.

System performance

SBAS performance is typically measured by the following concepts:

- **Accuracy:** measurement of how small position error is. At user level it is a statistical distribution of error, while at system level it uses estimated range errors and geometry.
- **Integrity:** measure of trust on the correctness of the service. 'Protection levels' can be defined as statistical bounds on the position error for a target integrity risk of 10^{-7} following aviation standards. See [4].
- **Availability:** this is the fraction of time that the computed protection levels are below a threshold known as 'Alert Limit'.

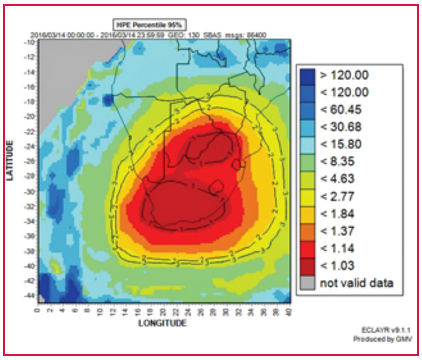

Figure 5: Horizontal Position Error (95%)

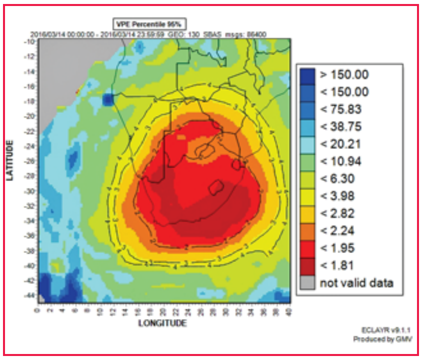

Figure 6: Vertical Position Error (95%)

- **Continuity:** measurement of the probability that the system becomes unavailable during a certain procedure (for example, a precision approach).

System level

The performance at system level can be measured by GMV's ECLAYR [5] tool. From the two-week series of trials the performances from 14^{th} March have been selected as example (performance is similar throughout the trials period). The figures show the results for that day.

Figure 5 and Figure 6 show that the system accuracy, defined by the 95^{th} percentile of position error, is typically about one meter horizontally and below two meters vertically over South Africa.

As a measurement of integrity, the Safety Index can be defined as the quotient between position error and protection level (horizontally and vertically). When the SI is below one, then the system preserves integrity. Figure 7 and Figure 8 show that for a typical day, the maximum safety index is below 0.25 for any location within the service area,

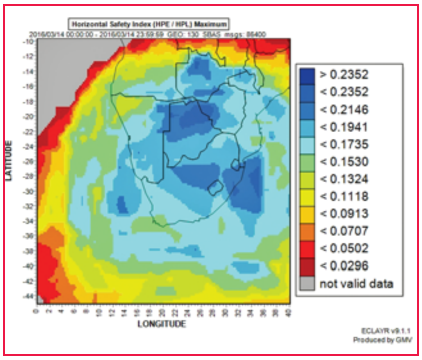

Figure 7: Horizontal Safety Index (HPE/HPL)

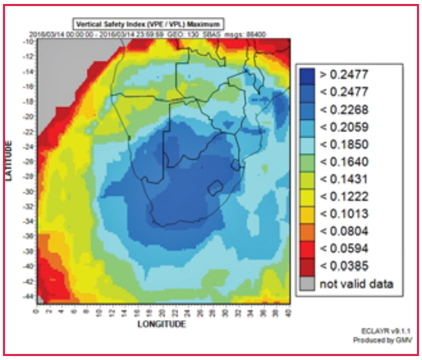

Figure 8: Vertical Safety Index (VPE/VPL)

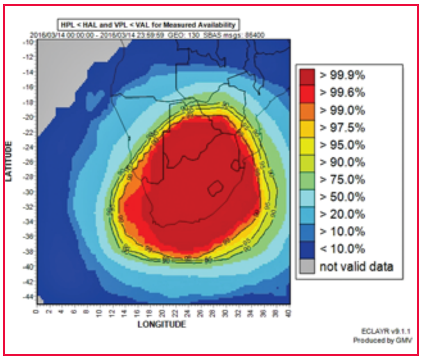

Figure 9: Availability (HAL=40m, VAL=50m)

which means that the position error is four times smaller than the protection level.

The availability at APV-I service, defined by a horizontal alert limit of 40m and vertical alert limit of 50m is plotted in Figure 9. As it may be observed, the availability is above 99.9% over South Africa. Continuity risk at this level is below $5 \cdot 10^{-4}$.

User level

In addition to the results at system level presented in the previous subsection, performance can also be measured at user level.

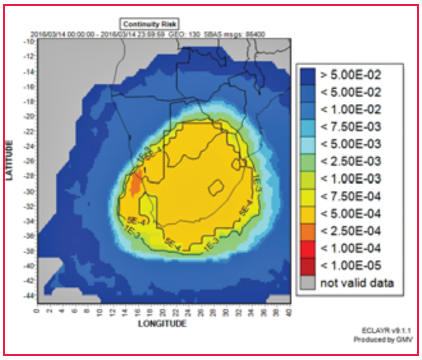

Figure 10: Continuity Risk

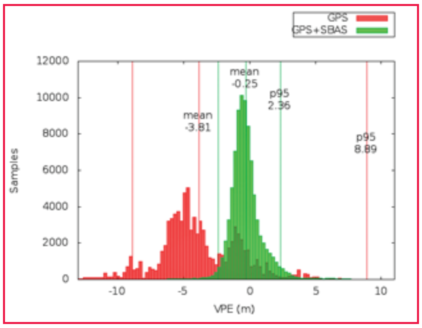

Figure 12: CTWN VPE distribution (GPS vs GPS+SBAS)

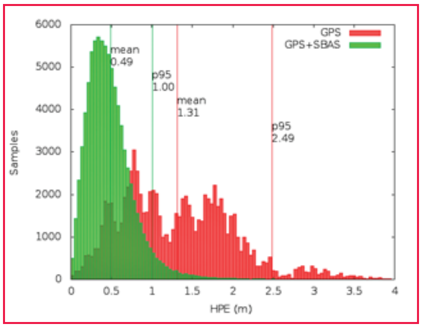

Figure 11: CTWN HPE distribution (GPS vs GPS+SBAS)

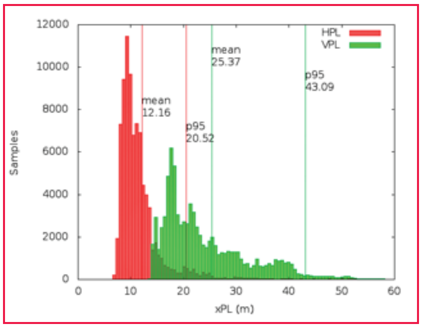

Figure 13: CTWN Protection Levels (HPL and VPL)

GMV's magicGEMINI [6] tool can be used to compute performance using GNSS data – either real-time or stored GNSS data, with the possibility to compute several solutions simultaneously.

As an example, data obtained from the Cape Town Trignet station CTWN can be analysed (for 24 hours on the 13th March). The SBAS-aided solution can therefore be compared to the standalone-GPS solution. Figure 11 and Figure 12 show the statistical distributions of horizontal and vertical position error, respectively. The GPS-only distribution is plotted in red, and the SBAS-aided solution in green. Percentile 95 is computed from absolute value of error.

Although Cape Town is not a central location in the service area (as it can be observed in Figure 5 and Figure 6), the performance obtained by SBAS-Africa in this station has an accuracy of 1.00m (95%) horizontally and 2.35m (95%) vertically, which is comparable to WAAS or EGNOS.

Computed statistics show that mean protection levels during the same period are 12.2m and 25.4m for the horizontal (red) and vertical (green) components, respectively.

Trials

Flight trials

In the case of aviation, the International Civil Aviation Organisation (ICAO) has developed the Approach with Vertical guidance (APV) concept. An SBAS APV is an approach similar to an ILS (Instrument Landing System) approach, i.e. it comprises, essentially, a localisation segment to orient the aircraft on final approach with a continuous descent profile to the landing area. It is implemented as a specific Localiser Performance with Vertical (LPV) guidance approach. Operationally, it is flown in precisely the same way as an ILS approach and has similar performance. SBAS technology can also be used to fly Point-in-Space (PinS) approaches for rotorcraft, where similar concepts are employed to enable localization onto a point in space followed by a visual approach to the helicopter landing area.

The benefits of SBAS in aviation are very well-known and include, amongst others, decision height minima reduction, safety enhancement via vertical guidance which reduces the risk of controlled flight into terrain (CFIT), and more flexibility in procedure implementation. The objectives of the trials were to demonstrate the benefits that an SBAS service can provide to Southern African aviation stakeholders.

A series of aviation trials were performed by ***PildoLabs Wessex*** using their portable flight validation and inspection platform known as PLATERO. PildoLabs designed and developed a set of test approach/departure procedures to enable the demonstration of the SBAS-supported test flights. As noted above (see section III) since the SBAS-Africa signal was broadcast in test mode with message type MT0 transmitted every six seconds, certified aviation equipment could not use the signal as is. Therefore, in order to be able to fly SBAS procedures using the SBAS messages generated by magicSBAS and provided by the ARTEMIS GEO satellite, PLATERO was adapted to decode and process the SBAS test signal. PLATERO provides the pilots with flight guidance via standard flight instrumentation for navigation and guidance.

The flight trials campaign, based on Lanseria International Airport (ICAO: FALA) in South Africa and utilizing the live, real-time SBAS-Africa signal in space during March and April 2016, comprised the following:

- SBAS LPV approach to Lanseria International Airport (instrument flight rules – IFR – airport)
- SBAS LPV approach to Grand Central Airport (visual flight rules – VFR – airport)
- SBAS PinS approach to Charlotte Maxeke Johannesburg Academic Hospital
- SBAS low-level helicopter route connecting Lanseria International Airport with Johannesburg Academic Hospital

Two South African air operators, namely ***MCC Aviation*** (fixed-wing) and ***HALO Aviation*** (rotorcraft) have been involved in these demonstrations, providing

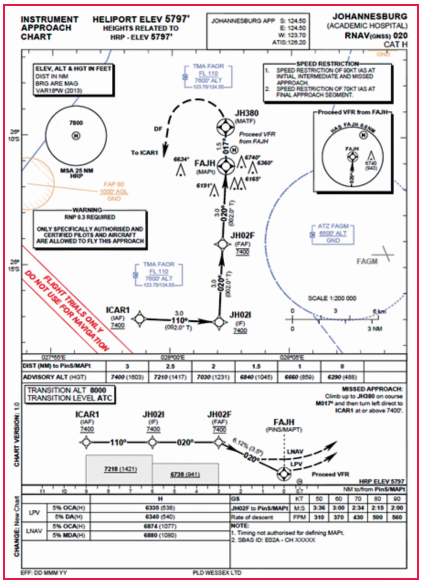

Figure 14: PinS procedure to the Johannesburg Academic Hospital (ICAO: FAJH).

Figure 15: FAJH approach – final approach segment detail

aircraft, flight crews and facilitation in the air traffic environment. Below, we provide an extract of the information pertaining to the rotorcraft trials.

Additionally, a set of flight trials (fixed-wing) were conducted by Pildo Labs (in conjunction with Thales Alenia Space and ASECNA) at Amborovy Airport (ICAO: FMNM), Madagascar, where LPV-like approach procedures were flown using GPS only and by applying the SBAS solution computed in a post-processed data mode. The intention of these trials was to demonstrate the expandability of the SBAS-Africa service coverage over Madagascar. ***Sky Services Mahajanga*** provided the aircraft and aircrew to enable the flight trials to take place.

Overall, the trials demonstrated the utility of SBAS technology in the aviation sector:

- The test LPV minimum obtained on Lanseria runway RWY07 due to SBAS is 300ft which is similar to ILS CAT-I and 400 feet lower than the LNAV (GPS-only) minimum. As such, the usual SBAS benefits of increased capacity, operability and utility for the airport would apply.
- In the case of a non-IFR airports such as Grand Central, the demonstrated SBAS capability provides an opportunity to improve capacity whilst keeping the costs at manageable levels. Even if, under current regulations, it is not possible to implement IFR procedures at Grand Central, SBAS-Africa has demonstrated that SBAS could provide the airport with an LPV-like approach procedure with a minimum of 410 feet onto RWY17.
- For rotorcraft, SBAS enables safer approach procedures due to the horizontal and vertical guidance provided, and due to better accuracy and integrity. In the case of Johannesburg Academic Hospital, the PinS procedure designed to the final approach and take-off (FATO) area would allow an instrument approach down to a minimum of 540 feet with SBAS (whereas with GPS-only it would be 1080 feet).

The feedback from all pilots was positive and supportive of the system. As an example, a pilot from Sky Service operating in Madagascar commented: "*I think SBAS presents a great advantage for airports where weather conditions can be variable and violent, since it allows secured precision approaches without any specific ground installations*".

Drone trials

The drone trials were carried out by NSL and supported by Haevic. NSL provided and operated the GNSS equipment, processing the data and analysing results. Haevic provided and operated the vehicles, arranged the test flights, prepared the drones for the additional equipment and provided market expertise. Trials were performed between the dates of 9-16 March 2016 using three different drones at different locations; Potschefstroom and Klerksdorp in North West Province and Koekenaap in the Western Cape province of South Africa.

Different types of GNSS receiver were used during the trials, each offering a different accuracy and therefore being used for a different objective.

SBAS Receiver

Many different GNSS receivers are capable of receiving, decoding the SBAS messages and implementing the ionospheric, orbit and clock corrections within their navigation solution. The purpose of this receiver was to be able to provide a navigation solution for drones, offer survey grade positioning and to store raw measurement data for post-processing. SBAS is only on the GPS L1 signal and therefore the basic functionality of the receiver had to be single frequency L1.

The SBAS-Africa SBAS signal in test mode is that in which Message type 0 is transmitted for SBAS testing. After the reception of message type 0, all ranging and correction information obtained from the SBAS must be discarded for safety critical applications. The existence of a message type 0 indicates that the system integrity performances are not assured. Another requirement was that the receiver could operate with Message Type 0.

The EOS Arrow series of receiver was selected as the SBAS receiver and the "100 Subfoot GNSS" model was purchased.

Real Time Kinematic GNSS Receiver

It was necessary to provide the possibility to determine high accuracy positioning of the drone flights in order to determine the accuracy of the SBAS system. It was decided that the single frequency RTK processing would suffice for this purpose and it was preferred that the processing was on-board.

To perform RTK positioning a GNSS receiver at a fixed base/reference station is necessary and this needs to be within a few (< 5km) of the roving receiver. The two receivers need to be connected via a radio data link. Due to problems that can occur with the data link, the receivers also need to log data allowing the possibility of post-event post-processing.

Figure 16: Test 1 – Drone and reference station

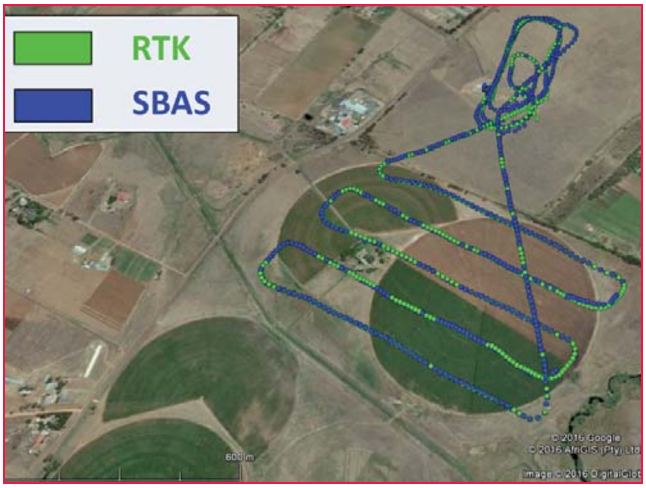

Figure 17: Test 1 Results (Google Earth)

The additional requirement for the receiver was to be small weight and power in order to be installed on a drone.

The Emlid Reach GNSS receiver was selected and an evaluation kit purchased. The Reach is a uBlox-based GNSS receiver and is designed for the drone market.

Professional Grade GNSS Receiver

In order to provide positioning within a geodetic reference frame, a professional grade GNSS receiver was also required. This is used at the fixed base/reference stations and the data that is collected is processed with data from local Continuously Operating Reference Stations (CORS) within South Africa as part of the Trignet network of CORS.

This receiver needed to be multi-frequency (minimum triple) and constellation, be able to record and store local to the device and to have an internal battery as power would not be available in the field.

The Comnav 300 Pro was chosen as the reference station.

Test 1

Three different drone flight trials were carried out, two with fixed wing vehicles and the other with a rotor style drone. In additional, a static test was performed during the drone test period.

Test 1 utilized the Haevic 1 drone flown along an agricultural flight path from Potchefstroom model aircraft club. Haevic 1 is a foam aero frame fixed wing drone with a 2.06m wingspan with the capability of flying for around 45 minutes. Its main use of operation is for aerial surveying, safety and security and reconnaissance.

The Arrow 100 and the Reach were installed within the fuselage with a single antenna feeding both receivers via a two way splitter. A reference station was established adjacent to the runway with the antennas mounted on a tripod. The Comnav and Reach were used for reference stations. The two Reach receivers communicated via 868MHz radio.

The drone was flown for two separate flights with the Arrow and Reach recording the SBAS and RTK positioning respectively. The Reach was tied into the local realization of WGS84 through processing the Comnav (common reference site) with Trignet data.

The results for Test 1 are shown in Figure 17. The standalone GPS is equivalent to a normal user's GPS position. Only resolved ambiguity RTK has been used.

Test 2

Test 2 used a larger drone known as a Panga 3M. This is a larger vehicle than the Haevic 1 with a 3m wingspan and a flight duration of up to 3 hours. The drone has a large volume fuselage being capable of carrying payloads up to 15kg. Again, the drone is used for aerial survey, safety and security applications and reconnaissance.

Being a large size drone, this requires an airport take-off and landing and the test was flown from Klerksdorp airport. The Arrow 100 and the Reach were installed within the fuselage with a single antenna feeding both receivers via a two way splitter. A reference station was established adjacent to the runway with the antennas mounted on a tripod. The Comnav and Reach were used for reference stations. The two Reach receivers communicated via 868MHz radio. Results were similar to test 1.

Test 3

Test 3 used the Haevic Superdrone rotor style drone. This is a carbon fibre airframe with a small payload capability and is usually flown for survey, inspection, safety and security. A windfarm inspection flight path was flown with the Arrow 100 and the Reach installed on the

Figure 18: Test 3 Superdrone

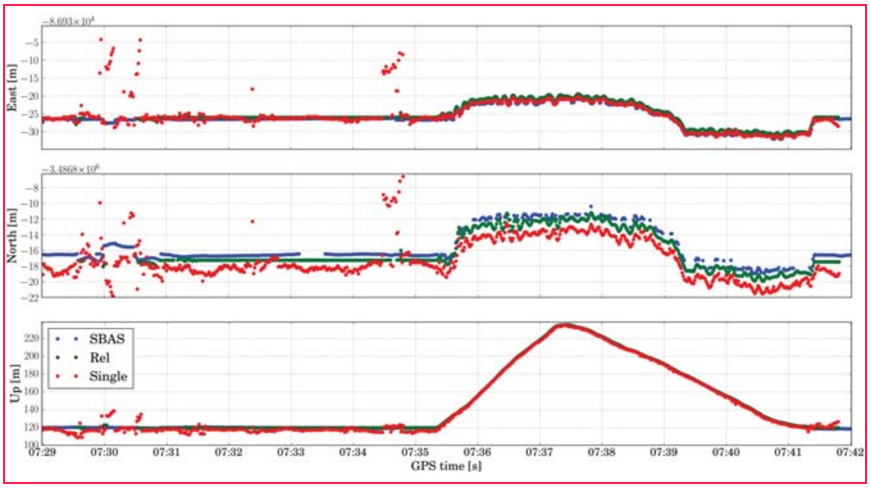

Figure 19: Test 3 Result

Table 2: Test 3 Results

RMSE [m]	2D	3D
SBAS-RTK	1	1.2
GPS-RTK	3	5

baseplate with a single antenna feeding both receivers via a two way splitter. A reference station was established near to the surveyed structure with the antennas mounted on a concrete base.

The results are shown in Figure 19 (red standalone GPS, blue SBAS, green RTK) and Table 2 showing SBAS producing a 2D accuracy of ~1m against standalone GPS of ~3m. The stability of the SBAS position against both the RTK and GPS positions is also clearly apparent.

Static Test

As well as testing the SBAS performance on the drones, the opportunity was taken to use the equipment for static tests. Here the Arrow, Reach and Comnav were set up to record data for a two and a half hour period on a static field location. A single antenna was used with a three way antenna splitter.

The Comnav was used to determine the precise location of the antenna and was processed as a network solution against two Trignet stations. The Reach was used for standalone GPS positions and the Arrow for the SBAS positions. In total, approximately 9000 epochs, or data points were collected by each receiver.

The results are shown in Figure 20 which clearly demonstrates the improvement of the SBAS-Africa solution over standalone GPS. Within this data sample, the SBAS results are producing a 95% horizontal accuracy of less than half of a metre. Standalone GPS is at the two metre level. When looking at 3D results, SBAS-Africa gives a 95% accuracy of 1.3m against standalone GPS of 4.5m.

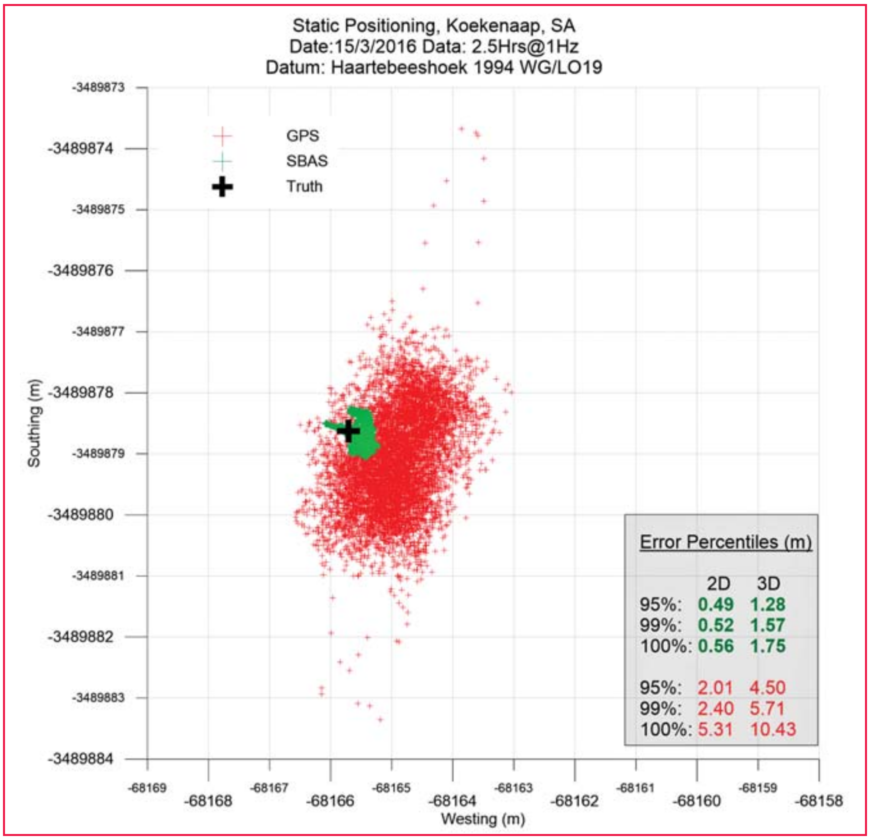

Figure 20– Static Test Results

Agriculture trials

In Europe, EGNOS is extensively used by the agriculture sector providing high precision at low cost and therefore enabling the use of precision agriculture techniques.

The use of tractor guidance was demonstrated using the SBAS signal generated by the team. The trials were executed in a test field owned by the University of Stellenbosch in South Africa.

The GNSS equipment chosen was standard commercially available units that farmers would commonly use in precision farming situations.

The results of the trials show that increased accuracy provided by the SBAS signal could be used to use auto guidance on tractors in South Africa.

A reduction in distance of 5.25% was observed with an increase in overall productivity of 26.6% using SBAS.

Figure 21: Tractor guidance equipment

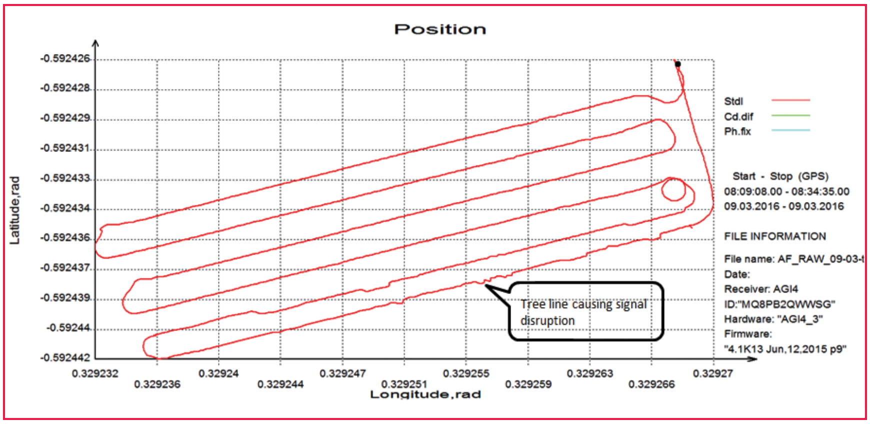

Figure 22: Tractor tracks in test field

Table 3: Benefits of tractor auto-guidance

	GPS	SBAS	SBAS benefit
Area covered	1.48ha	1.47ha	0.67%
Total hours	30min	22min	26.6%
Productive hours	21min	16min	23.8%
Distance travelled	1.9km	1.8km	5.26%

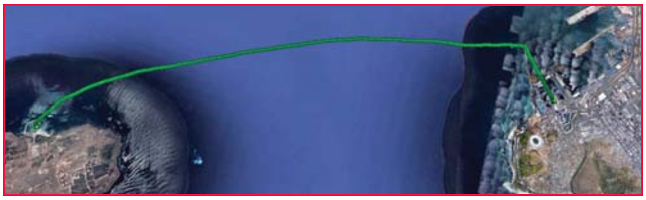

Figure 23: Robben Island – Cape Town route (Google Earth [7])

GPS positional accuracy is not good enough for accurate precision applications but the increased accuracy with SBAS enables precision agriculture system such as tractor guidance technology which brings numerous benefits. For example, it reduces overlap in the application of agricultural chemicals, reduces field traffic and compaction; it also reduces operator fatigue. It enables Variable Rate Technology (VRT) to deliver precise application of plant protection products across any type of field, all of this resulting in an improvement of crop yields.

Maritime trials

For the SBAS trials in maritime applications, several tests were performed on board the Cape Town to Robben Island regular ferries (Figure 23), in addition to a custom route near Cape Town in which several manoeuvres were tested (Figure 24, Figure 25).

These trials tested the ability to compute an SBAS-aided solution at sea, which implies several restrictions with respect to a static receiver such as the one considered in section IV.B:

- Interference and multipath from other equipment on board.
- Reduced satellite visibility due to antenna placement and wave motion.
- Degraded SBAS performance as distance to the coast increases.

The first of these points was particularly concerning since it required careful placement and a relatively high-quality GNSS antenna. The third point was not tested since it was not possible to be far enough from the coast to notice the degradation.

In order to compute accuracy statistics, GMV's magicPPP [8] was used to post-process the receiver dual-frequency observations and obtain a PPP trajectory, which can in turn be used as a reference position in order to compare standalone GPS and SBAS-aided solutions with magicGEMINI [6]. This can be done thanks to PPP's centimetre-level accuracy. Applying this method to a Robben Island to Cape Town journey on the 8th April, the obtained horizontal accuracy results are shown in Figure 26. As it may be observed, mean horizontal position error in the SBAS-aided position is 0.69m, which is an improvement over the GPS-only case (1.36m). When comparing to the results in section IV.B, it must be noted that in this case the reference trajectory cannot be known to such a high degree as in the case of a static location and that the position is affected by the specific maritime circumstances, as explained

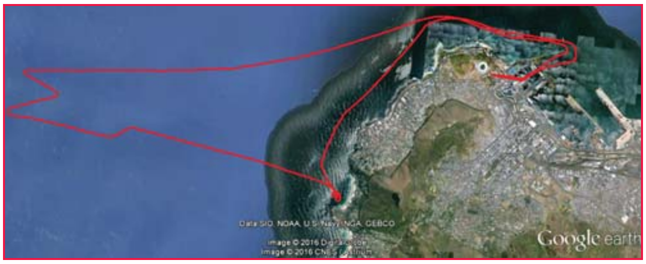

Figure 24: Cape Town coastal route (Google Earth [7])

Figure 25: Maritime manoeuvres near Cape Town (Google Earth [7])

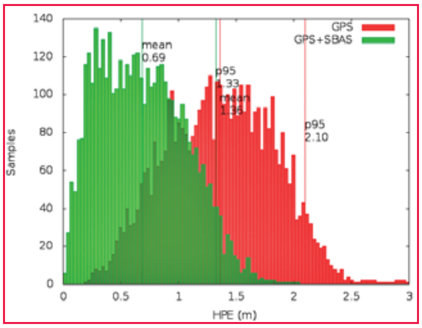

Figure 26: Maritime trial
Horizontal Position Error

Table 4: Options comparison

	2. SBAS SoL	3. SBAS OS	4. Delay OS
System complexity			
Early benefits realization (year)			
Total Costs (over 25 years)			
Total Economic Benefits (over 25 years)			
NPV (benefits - costs)			
RoI (benefits/costs)			
Policy contribution			
Affordability			

above. The results are nevertheless in line with the expected behaviour, showing a horizontal accuracy improvement of about 40% over the 73 minutes analysed

Business case

The RSA SBAS vision is for an affordable, government-funded SBAS service for public good that is free of direct user charges and delivers a high return on investment from downstream user and policy delivery benefits.

A preliminary SBAS business case has been produced in accordance with RSA National Treasury's capital planning guidelines [9]. It comprises a qualitative policy delivery assessment based on policy objectives as well as a quantified cost-benefit analysis (CBA) based on system costs and downstream user benefits.

The qualitative policy delivery assessment has considered a set of initial policy drivers arising from the RSA National Planning Commission's National Development Plan [10] and the President's Nine-Point Plan [11] as well as seven departments' strategic plans [12] [13] [14] [15] [16] [17] [18].

The assessment shows that SBAS can support RSA policy delivery across a range of areas including: compliance monitoring and enforcement; education; the environment; productivity; industrial capacity; jobs; reducing inequality; improving safety; and stimulating innovation.

The quantified CBA has considered four options:

1. **Do Nothing** – No further SBAS activity but greater reliance on existing public and commercial augmented GPS services.
2. **SBAS Safety-of-Life** (SoL) for the South African Development Community (SADC) based on EGNOS or WAAS technology.
3. **SBAS Open Service** (OS) based on SBAS-Africa technology enhanced to deliver general aviation benefits and extended across the SADC.
4. **Delayed SBAS OS** (by seven years) for SADC based on SBAS-Africa technology.

The preferred Option 3 (SBAS OS) delivers over ZAR 15.6 billion (discounted) to the RSA economy over 25 years with a return on investment greater than 10:1. The RSA SBAS can also be extended to deliver major economic benefits to SADC countries.

A high-level risk assessment has been carried out together with a sensitivity analysis to establish an action plan and clarify the strength of the quantitative analysis.

Table 4 summarises the different options. It concludes that Option 3 (SBAS OS) is the best option for the foreseeable future in terms of total economic benefits, timing, cost, net present value, return on investment, risk and feasibility.

Conclusion

The SBAS-Africa consortium implemented a full end-to-end SBAS test bed with the generation of a live, real-time SBAS signal over South Africa via a space-borne navigation transponder aboard ARTEMIS within a year.

During the course of the project, a series of trials and demonstrations were executed in key market sectors including aviation, maritime and precision agriculture in order to validate the infrastructure deployed. SBAS was also tested for the use of drones. Every user came to the conclusion that an SBAS would bring benefits to their fields. In parallel to the technical implementation of the system, an investment appraisal and business case according to RSA Treasury guidelines was developed showing and ROI of 10-to-1 and an economic impact of ZAR 1.5 billion per annum.

The work accomplished establishes a basis for SBAS services development in Southern Africa, including South Africa, Madagascar and other SADC member states and giving all the elements to move towards a fully operational cost effective SBAS service.

Acknowledgments

The SBAS-Africa consortium would like to acknowledge MCC, Halo, LANSERIA International Airport, Grand Central Airport, Haevic, Precision Decision, University of Stellenbosch, SAMSA, TRANSNET, Robben Island Museum, Tigger2Charters, Marine Data Solutions, NGI, SANSA and IGS for their support to organize the trials and workshops throughout South Africa.

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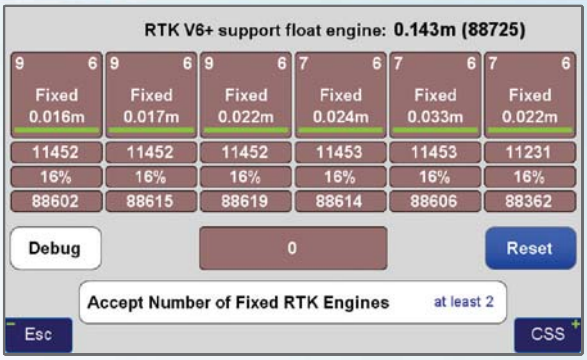
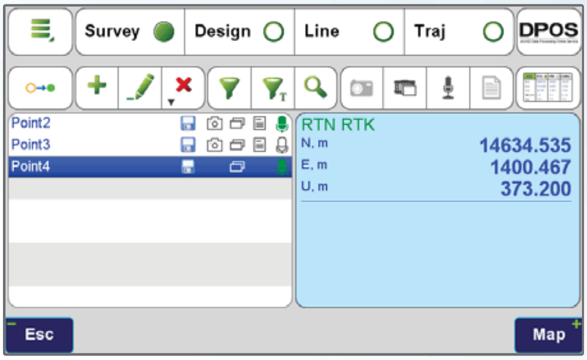
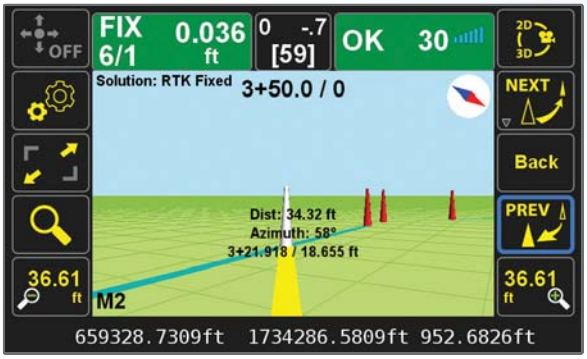
TRIUMPH-LS and J-Field

Hands free operation







J-Field is the embedded application program of TRIUMPH-LS. It has the following unique features for each point surveyed:

- Six parallel RTK engines to maximize solution availability.
- Automatic Engines Resets, verification and validation strategy.
- Several graphical and numerical confidence reports and documentation.
- Voice-to-text conversion for hands free operation and documentation.
- Lift & Tilt and automatic shots for hands free operation
- Visual Stakeout (Virtual Reality)
- “DPOS it” or “Reverse Shift it” features. The most advanced RTK verification.
- Photogrammetry and angle measurements with embedded cameras.
- Automatic or manual photo documentation.
- Automatic screen shots documentation.
- Audio files for documentation.
- Automatic tilt correction.
- Comprehensive HTML and PDF reports
- Comprehensive codes, tags and drawing tools.
- Over 3,000 Coordinate Systems.
- Automatic and free software update via Internet.

J-Tip

J-Pod

J-Pack

J-Shield

Looking back on 2016, was there a project that you could not have completed or your efficiency would have been significantly reduced without the LS?

Occasionally I will review work that I completed several years ago and it's obvious that the quality of my design work has increased significantly with the addition of the LS and T2.

Javad you have made it possible for me to expand my scope and increase efficiency. Your efforts are greatly appreciated.

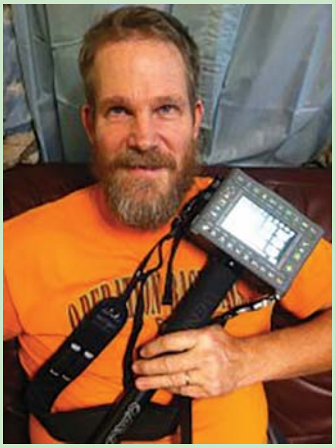
Jim Campi

Northern California
Civil PE

I have to second Jim's comment. I have dreamed of being able to GET all the data I really want, and need. I am bringing home approximately 2x as much data, as with my old system. But, that is not the BEST part of it. The BEST part is the CONFIDENCE, in the shots. THAT is the crown jewel of the Javad LS T-2 combination.
Thank you so very much.

Well, we are the SURVEYORS, and we really NEEDED the equipment you hare providing.
And, we REALLY appreciate it.

It is the most awesome piece of surveying equipment, and a pleasure to run!



Nate The Surveyor

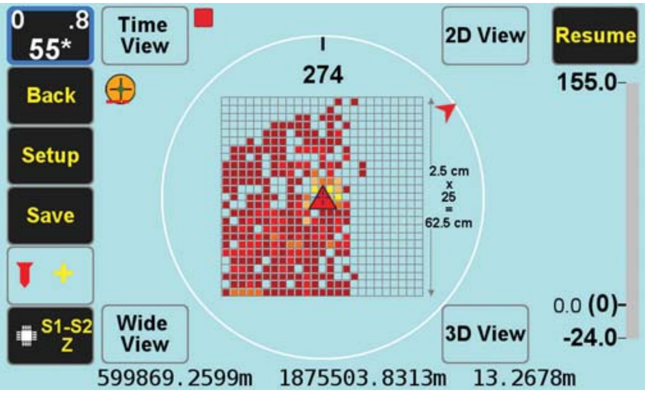
SW Arkansas, USA

J-Tip

Integrated Magnetic Locator

$850

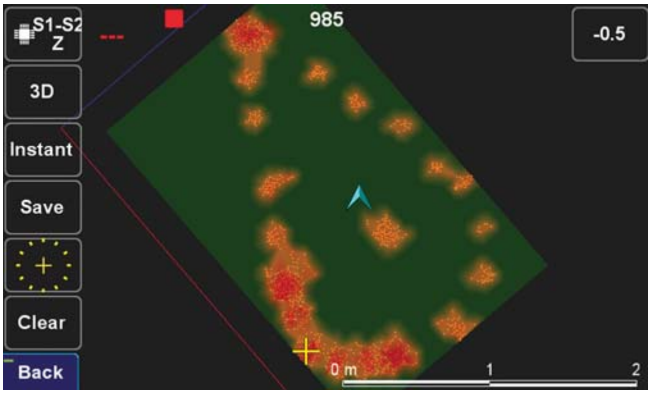
TRIUMPH-LS tags coordinates with magnetic values, It also guides you to top of the item to survey it.

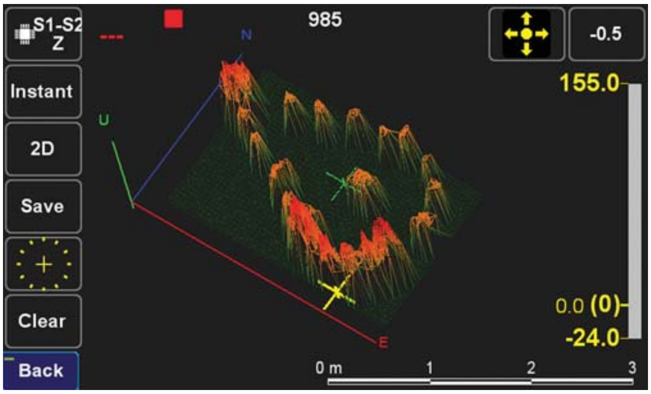


The Mag View focuses only on the mag object with the highest mag value.

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

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





The J-Tip has far exceeded my expectations. It is a tool that I have thought about daily my whole career. My thoughts used to be why can't they (whoever they are) make a metal locator that will fit in my pocket. Well, you did it! Yesterday, I was working on a 14 acre boundary survey in steep mountain country. I was able to recover every corner I searched for using the audible tones. I was more effective and efficient than in the past and realized that you have cut the weight and bulk of a metal locator to a fraction of what it was. The J-Tip is lighter than my phone and it fits in my pocket! The locators that I previously used are now collecting dust. They were heavy and cumbersome to tote around. One particular locator that I have used thru the years had a holster and would hang on your side. The back of my knees have taken a beating from that thing slapping the back of them with every step. The J-Tip proved itself to be tough and durable on the mountain survey project. I was also providing topography on a few acres of the site that was covered with green briars, saw briars, kudzu, and very thick. I left the J-Tip on the monopod while working in the brush. Minor scratches are to be expected in that type of environment, so it has a few but the J-Tip took a beating yesterday and worked like a mule. Very impressive!

Adam Plumley, PLS

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

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

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

J-Pod

A rugged Transformer-Pod

$850

Monopod, 8 and 40 sec level vials, compass, Accessory hooks.

Connect legs on demand to make bipod or tripod.

+ Bipod.

+Tripod.

Monopod >>> to + Bipod >>> to + Tripod... On demand.

Rugged, Light, Compact, Easy to level.

* Detachable landing and resting pads.
* Mace grips (concrete, asphalt, bricks, soil)

Travel mode.

Inside bag.

The most stable tripod. It will never collapse, even on wet glass.

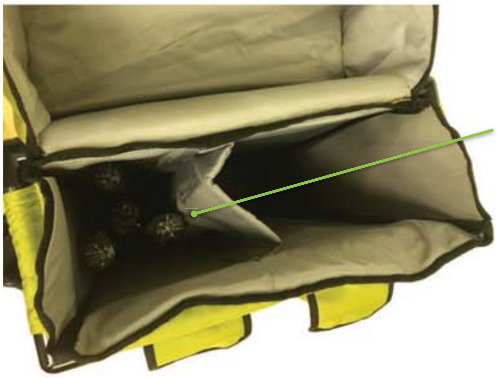
Think of it as a rugged Transformer-Pod, We call it **J-Pod.**

J-Pack

Nice and convenient survey bag

$290

It was not our job... You asked for it - we did it!



Javad......Bravo!!!!

The J-Pack is nicest bag I have ever seen for surveying. I especially like the pocket in the back and all of the places to tie down equipment and stuff.

Adam Plumley, PLS

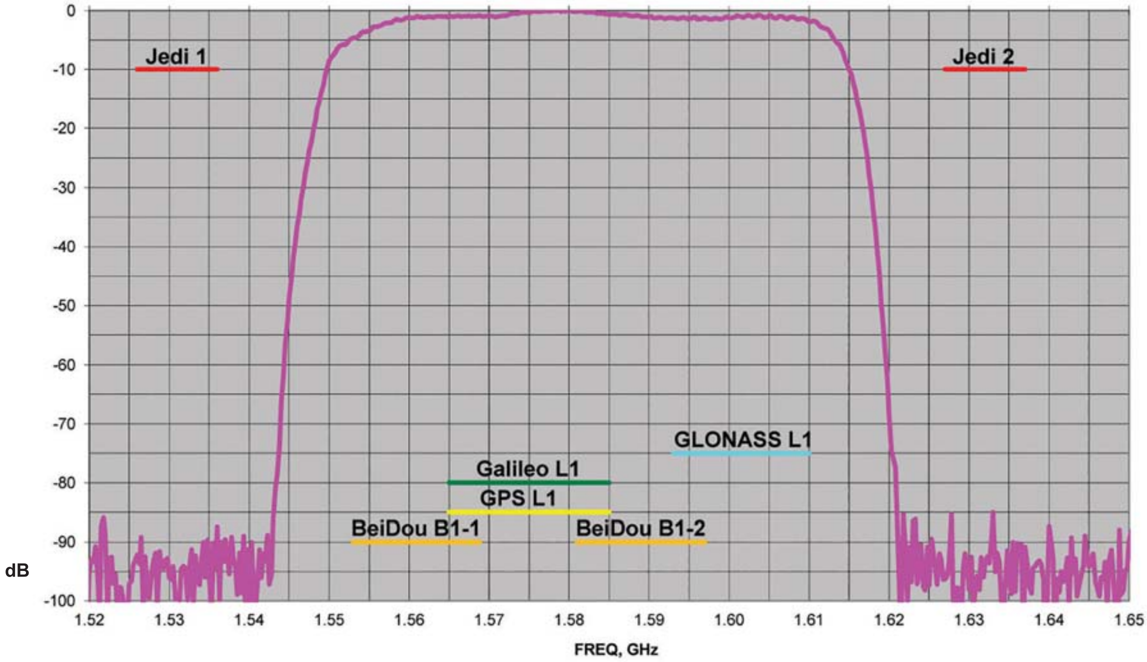
Ship date - January 2017

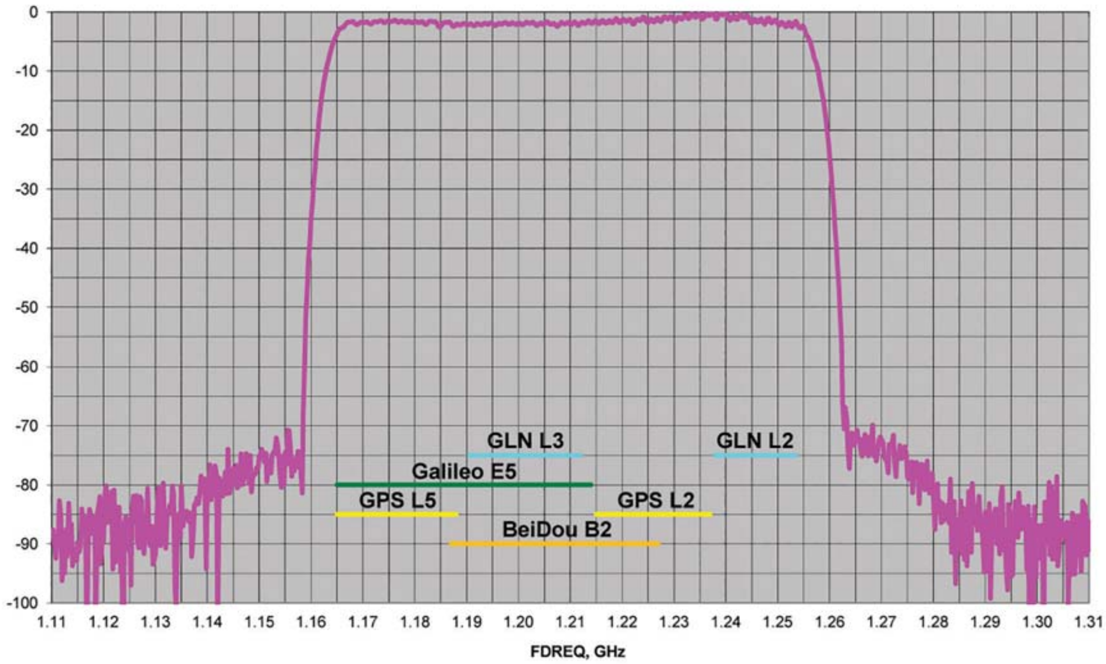
See full video "J-Pack & J-Tip in Use" www.javad.com

J-Shield

In case the **Jedi** returns

$450





J-Shield of TRIUMPH-LS
protecting all GNSS Bands.

To answer this question honestly, I'd have to say basically ALL of them! Sure, there were many that I could've done with the "other" guys equipment in a similar amount of time, but to second what Nate said, the data I acquired and have associated with even those simple jobs is better because of the LS.

That being said, the "simple" jobs (if there is such a thing in Surveying ;)), is definitely not where the LS is at its best. The large, heavily canopied, rough terrain jobs, of which we do many of per year, is where this machine sets itself apart - and therefore helps us set ourselves apart from our competition. With the Javad equipment, we can simply do those types of jobs in a third to half the time that we used to. This while still pricing them at relatively the same price that we always have. The same money on a job that takes one half to one third of the time it used to equals more profit!

I also agree with Jim on the statement that our quality of work has greatly increased due to the LS. We used the "other" guys GPS equipment for years in canopy where many others would not. We've always pushed the limits of where RTK could go. We spent hours some days verifying data on some suspect spots, only to end up sometimes having to run it in with a gun anyway "to be certain". It was definitely a trade off where we saved ourselves time in many areas, but cost ourselves time in others where it just wasn't meant to get RTK GPS. That has completely been taken away with the LS. There's hardly anywhere, especially when leaf cover is off, where it won't get great, reliable, verified, validated RTK. Then, in the few spots it doesn't, the PPK is just the absolute cherry on top of this machine.

I feel very fortunate to be a part of the growing Javad family and with now 20 months in, I shudder to even think about going back to any other kind of equipment!

Darren Clemons

Central Kentucky

- Steve Hankins: *I am running J Field Pre Release 2.0.5.711. In the field yesterday I noticed the LS would have phantom clicks and random screen changes without and interaction from me. I was able to touch the screen and return to where I was at and complete my task. The screen seemed to be a little sluggish when this would occur but did not become unresponsive. I powered the unit off and rebooted, but that didn't fix the behavior. I then used the A/V button and calibrated the screen, this seemed to help and finished my field work. Later in the evening in the office with the LS on and setting on my desk it started to repeat the phantom clicks, sometimes changing the screen , then the next phantom click was audible only with no screen change. The unit appears to be working correctly in spite of the phantom clicks. Anyone else experienced this, or have any thoughts?*

- Javad: *Hold the A/V hardware button for three seconds. It will recalibrate the touch screen.*

- Steve Hankins: *Thank you sir, and thank you for the most awesome set of equipment I have had the pleasure of running in my 41 years of surveying. I am having the most fun I have ever had!*

TRIUMPH-1M

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

TRIUMPH-2

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

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

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

And all this with competitive prices!

HPT435BT/HPT135BT/HPT225BT*

$2,710

35 W UHF/VHF Transceiver

HPT404BT/HPT104BT/HPT204BT*

$1,640

4 W UHF/VHF Transceiver

HPT401BT/HPT101BT/HPT201BT*

$2,040

1 W UHF/VHF with internal battery

L-Band/Beacon*

$1,550

Receivers for multiple applications

JLink 3G LTE BAT*

$2,735

Web-interface Wi-Fi, Ethernet, 3.5 G, UHF/VHF/FH915, internal battery

OEM Solutions

$840

902-928, 360-470, 225-255, 138-174 MHz

*Power, data cables and antenna are included.

Space Weather, from the Sun to the Earth, the key role of GNSS

The goal of this paper is to give a clear view of the Sun Earth relationships that are complex. The phenomena acting at large scales and essentially related to dynamic and electromagnetic physical processes have been addressed. Besides physics, the work done to develop the training in Space Weather by focusing on Global Navigation Satellite Systems has also been presented. Readers may recall that we published the first part of this article which focused on physics of the relationships Sun, Earth and Meteorology of Space. In this issue, aspects of GNSS training and capacity building are discussed

Dr Christine Amory-Mazaudier
Senior Scientist, University Pierre and Marie Curie and Staff Associate at ICTP. Recently awarded Marcel Nicolet Medal for her work in Space Weather

Dr Rolland Fleury
Associate Professor, Microwave Department of the 'IMT Atlantique' School of Engineering, Brest campus, France

Sharafat Gadimova
Programme Officer, the United Nations Office for Outer Space Affairs, Leads the organization of the activities on GNSS and the development of the International Committee on Global Navigation Satellite Systems

Professor Abderrahmane Touzani
Director, African Regional Centre for Space Science and Technology Education - in French Language (CRASTE-LF), Rabat, Morocco was Professor in University Mohammed V, Rabat, Morocco

Part II: Training on daily Global Positioning System (GPS) data

This training was organized in the African Regional Centre for Space Science and Technology – in French Language (CRASTE-LF) in February 2015 and January 2017 and in school Mines-Télécom in 2011, 2012, 2014, 2015, 2016 and next in February 2017.

This training is centered on the use of GPS for ionospheric studies. It is composed of several courses. The content of this training is given below:

- Ionosphere
- Space Weather
- solar wind
- GPS system
- propagation through the ionosphere
- VTEC
- ROTI index, proxy of scintillation

In this part we will focus the GPS system, propagation through ionosphere, VTEC and ROTI index.

The standard format for the GPS data is the Rinex format. The first training is an introduction for processing the Rinex file. We use the example of ykro3500.09d.Z (site of Yamoussoukro/ Cote d'Ivoire on 16 December 2009). In the rest of this section we show all the parameters that the students can deduced from the GPS data during the training.

The GPS constellation

Two exercises make it possible to understand the relative complexity of the

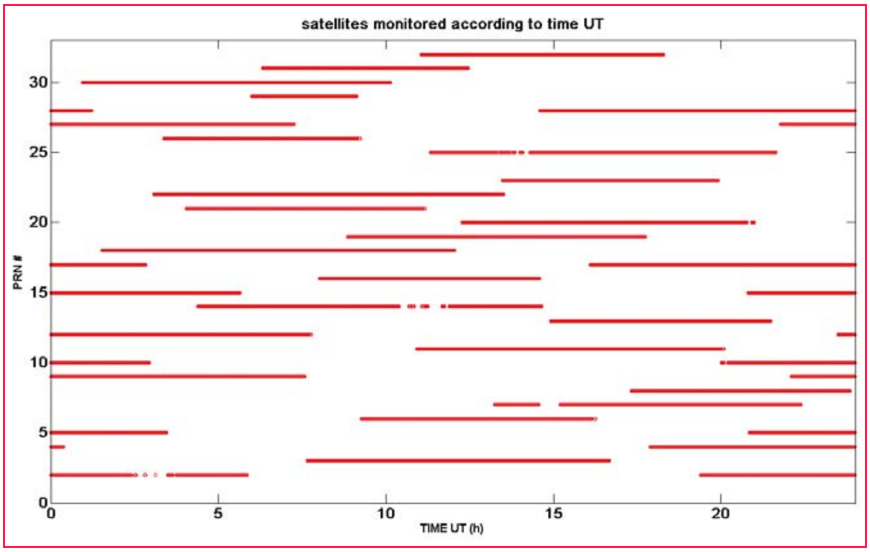


Figure II.1: Satellites PRN monitored during that day at YKRO

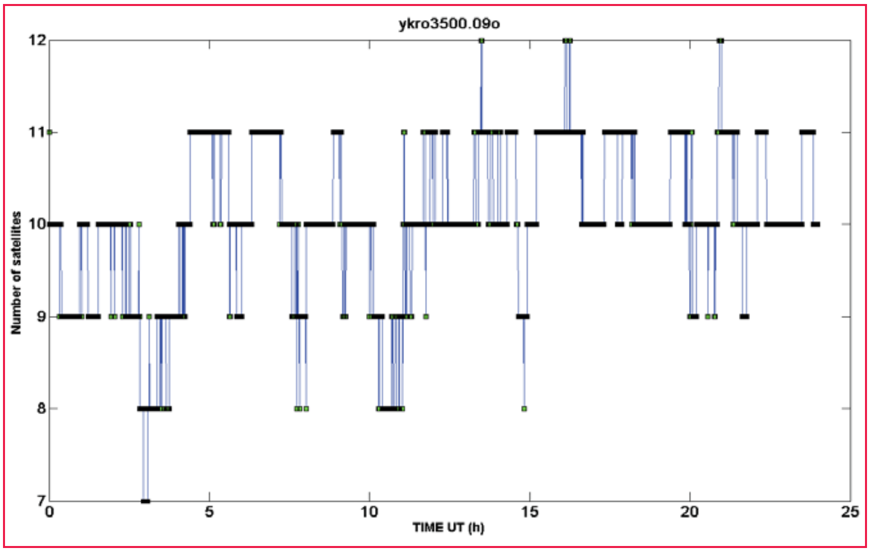


Figure II.2: The number of satellites in each 30s

Rinex 2.10 format (ftp://igs.org/pub/data/format/rinex210.txt) for recording GPS signal measurements. The visualization of the constellation of GPS satellites followed by this receiver makes it possible to develop a first Matlab script. Figure II.1 plot the distribution of the PRN satellites monitored during the day selected as a function of the UT time.

Figure II.2 gives the number of satellites monitored in each 30s time, according to the UT time for the selected station of Yamassoukro.

The GPS signal: STEC and VTEC

The following equations give the pseudo ranges and the phases for the two frequencies of the GPS receiver (Leick, 1995; Schaer, 1999; Hoffman-Wellenhof et al., 2001).

- Equation II.1, Pseudo range:

$$P_u^s(f)=\rho_u^s+c\left[b_u(f)-b^s(f)\right]+T_u^s+I_u^s(f)+\alpha_u^s(f)$$

where

ρ the geometrical distance,
b_u is the receiver bias, b^s is the satellite bias,
c is the light speed,
T is the tropospheric term,
I is the ionospheric term,

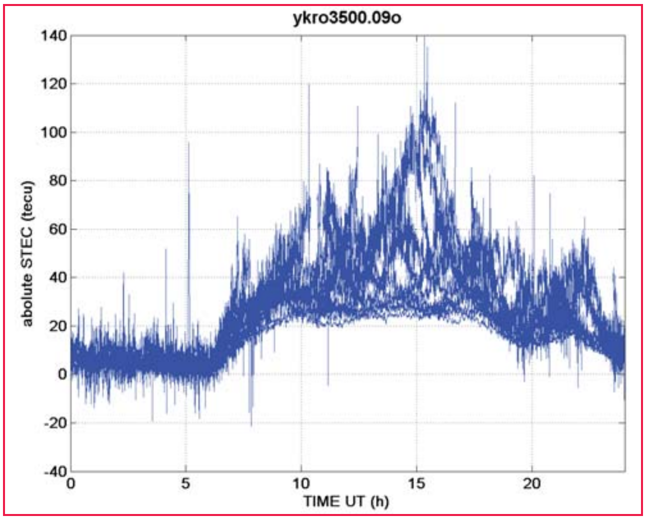


Figure II.3: STEC for the station of Yamassoukro on December 16, 2009

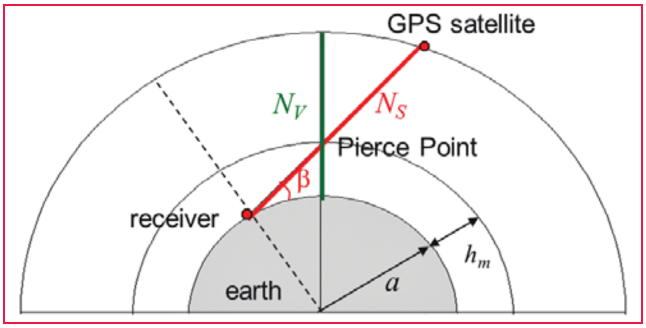


Figure II.4: Computation of VTEC from STEC

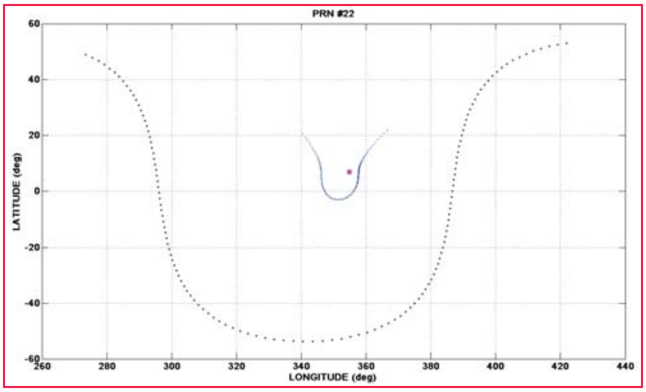


Figure II.5: GPS receiver is presented by a magenta star, the Pierce point location by blue line and the position of the #22 by the black dotted line

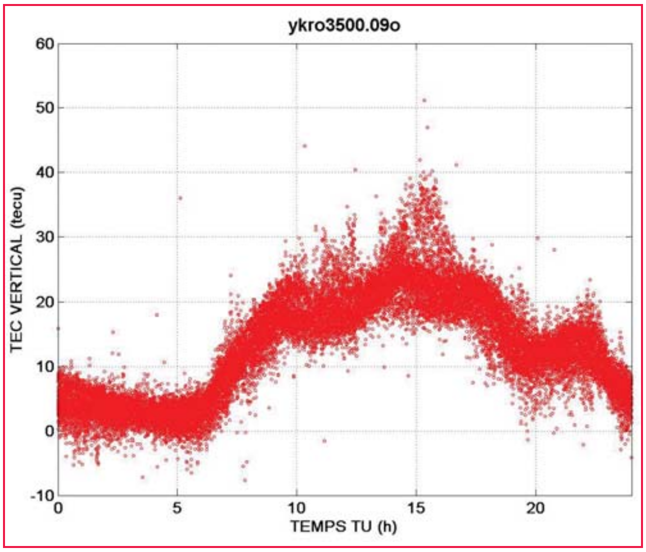


Figure II.6: VTEC at Yamassoukro on December 16, 2009

α are others terms which are in second order. P is the pseudo range in m.

Equation II.2, Phase:

$$L_u^s(f)=\rho_u^s+c\left[b_u(f)-b^s(f)\right]+T_u^s-I_u^s(f)+\lambda B_u^s+\alpha_u^s(f)$$

There is an additional term B which is the ambiguity function which is unknown. L is the length of the phase path expressed in m.

In the equations of the pseudo-range and phase, two layers traversed by the signal transmitted by the satellite modify this signal. These are the Troposphere and the Ionosphere (see figures I.4e and Figure I.5b).

During its crossing of the ionosphere the signal of the satellite is modified. It is affected by an additional delay. This delay is related to the total electron content of the ionosphere, and as a consequence this delay can be used to know the total electron content of the Ionosphere.

We can compute the Slant Total Electron Content (STEC) from the pseudo ranges and from the phase

Equation II.3: Expression of STEC

$$N_S=\frac{1}{C_I}\Big[\underbrace{(P1-P2)}_{\text{RINEX}}-c\underbrace{\left(\Delta b^s-\Delta b_u\right)}_{\text{DCB}}\Big]$$

Figure II.3 illustrates the diurnal STEC (N_s) deduced from the GPS signal by using the equation II.3, for the selected station of Yamassoukro in Côte d'Ivoire

We use of the law of the secant to determine the Vertical Total Electron (VTEC) (N_v) from the STEC (N_s); This computation requires the knowledge of the elevation angle β and therefore the position of the satellites. Figure II.4 presents the computation of the VTEC.

The Earth radius (6370 km) is given by the letter a, and hm is the height of reference which is taken at 420 km (this height is variable from one scientist to another).

We can calculate the position of each GPS satellite from YUMA almanacs available on the site. Figure II.5 presents the mapping of the passage of satellite #22 (in dark) and the position of the point of Pierce (in blue) in the geographical reference longitude / latitude. The magenta star is the position of the GPS receiver.

Equation II.4: Expression of VTEC

$$N_S=N_V\sqrt{1-\left(\frac{a}{a+h_m}\cos\beta\right)^2}$$

Figure II.6 presents the VTEC computed with the equation II.4. This figure makes it possible to appreciate the diurnal variation of the VTEC which grows during the day because of the photo ionization and which decreases at night.

The dispersion of the points at given instant is principally due to the fact that they are not on the same geographical position, the Pierce points are distant from the position of the station.

Index ROTI

The ROTI index is important as it gives information on the scintillation phenomena (see section on scintillations above). The ROTI index is calculated according to the development of Pi et al. (1977). From the 30s Rinex files, we calculate the gradient of STEC (ROT for Rate of TEC) in unit of tecu/mn

Equation II.5: Expression of the ROT index

$$\text{rot}=\frac{STEC_{k+1}-STEC_k}{time_{k+1}-time_k}*60$$

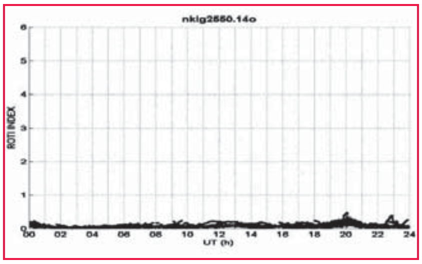
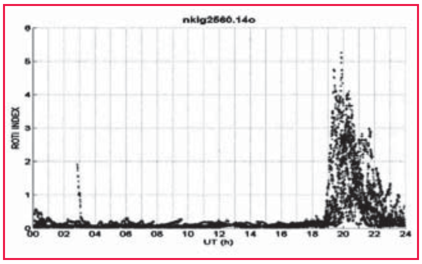


Figure II.7a: ROTI index on December 12, 2009



FigureII.7b: ROTI index on December 13,2009

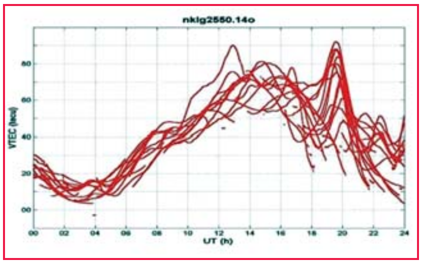


Figure II.7c: VTEC on December 12, 2009

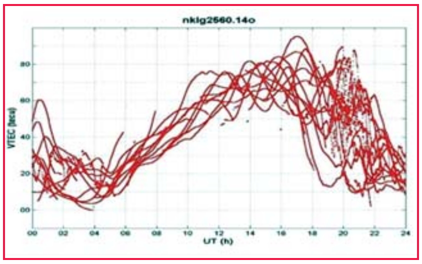


Figure II.7d: VTEC on December 13, 2009

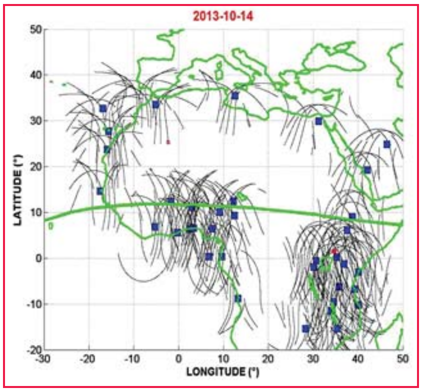


Figure II.8a: ROTI index on October 14, 2013

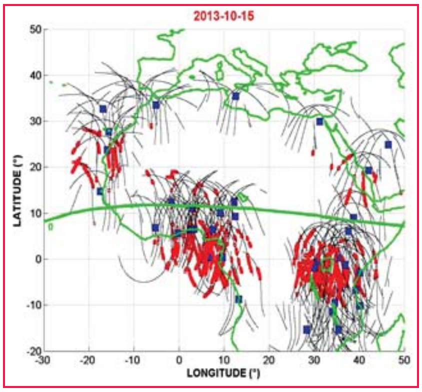


Figure II.8b: ROTI index on October 15, 2013

and then the ROTI index which is RMS of ROT values with a time span of 10 mn and only for data above 20° elevation to avoid the influence of multi paths.

Equation II.6: expression of the ROTI index

$$\mathbf{roti} = \sqrt{\langle \mathbf{rot}^2 \rangle - \langle \mathbf{rot} \rangle^2}$$

We have developed a Matlab software ('calcul_roti_v41.m') to calculate the ROTI index for daily Rinex files. An example is done for two consecutive days for NKLG (Gabon), on December 12 and 13, 2009 (DOY=255, DOY=256). We see no variation in the first day (Figure II.7a) and high Roti index after the sunset of the day after (Figure II.7b).There is another index for scintillation, the index S_4 which requires a dedicated receiver ISM (Ionospheric Scintillator Monitor).

Equation II.7: expression of the scintillation index S_4

$$s4 = \sqrt{\frac{< I^2 > - < I >^2}{< I >^2}}$$

where I is the intensity of the signal and <> is the mean.

From time series, we are able to plot some pertinent representation of the phenomena.

Figure II.8a shows no variations of the ROTI index in all the stations over Africa on October 14 October 2013. On the contrary, on October 15 2013, we can observe large values of the ROTI index near the northern and southern crests of the equatorial anomaly (red color). Azzouzi et al., 2015 explained the disappearance of the scintillations, revealed by the ROTI index, as due to a high speed solar wind flowing from a solar coronal hole. In this case the solar disturbance facilitate the propagation of the GPS signal

In the equatorial zone, after sunset, it is common to observe ionospheric scintillations, which are due to plasma bubbles with very low density. They are called equatorial plasma bubbles EPB. Figure II.9 shows the variations of the parameters STEC, ROTI and

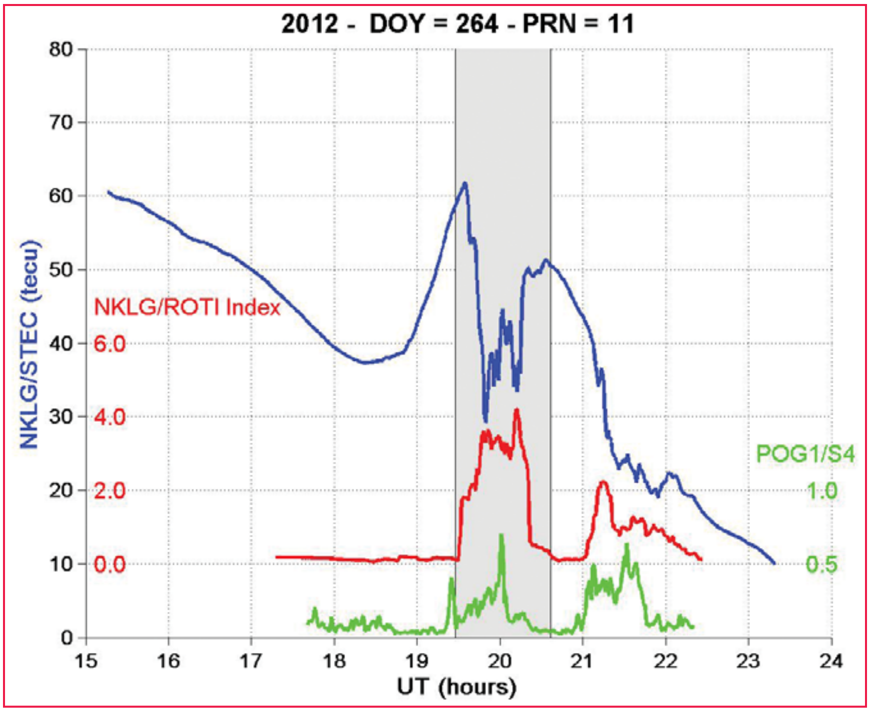


Figure II.9: The passage of a plasma bubble

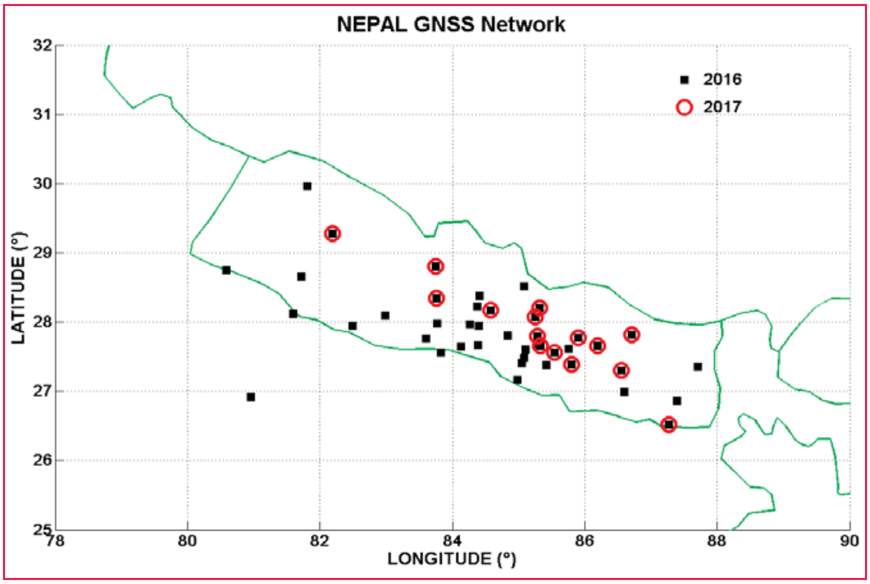


Figure II.10: Network of GPS in Nepal (UNAVCO)

the scintillation index S4, during the passage of an EPB plasma bubble. The STEC parameter decreases revealing the existence of a region of low ionospheric density (EPB). On the contrary, the ROTI index increases and indicates the existence of ionospheric scintillations. At the bottom of the figure, there is the index scintillation S4 (which gives directly the variations of intensity of the signal (see section on the scintillations).

Concluding remarks

In this part we have presented the ionospheric parameters that can be deduced from the GPS data, mainly the Vertical Total Electron Content (VTEC) and the ROTI index. These two parameters allow the study of the variations of the ionospheric ionization as well as the existence of ionospheric scintillations .There are many websites on which you can get free GPS data (daily 30s data) and study the ionosphere. These sites are given in table 1.

Figure II.10 presents the map of GPS stations in Nepal available on the UNAVCO website, black squares for 2016 and in red circles for the beginning of 2017 (until 27/01/2017). One point (around 27N, 81E) is Lucknow in India.

Part III.: Information Dissemination and Capacity Building

The International Committee on Global Navigation Satellite Systems (ICG), established in 2005, has encouraged tangible international cooperation. Leading global satellite operators have coordinated their GNSS services to provide global coverage in satellite-based positioning, navigation and timing in order to benefit civil, commercial and scientific users worldwide. ICG acts as a platform for open discussion and the exchange of information under the umbrella of the United Nations, and as such promotes the use of GNSS technology for environmental management and protection, disaster risk reduction, agriculture and food security, emergency response, more efficient surveying and mapping, and safer and more effective transportation by land, sea and air.

To support the work of ICG, Office for Outer Space Affairs was designated as the executive secretariat of ICG.

In that capacity and as the body leading ICG's Working Group C on Information Dissemination and Capacity Building, the Office, through its programme on GNSS applications, each year co-organizes and co-sponsors a wide range of seminars, training courses and workshops. Those activities usually bring together a large number of experts, including specialists from developing countries, to discuss the GNSS applications in various fields of the world economy.

Pursuant to the ICG workplan and its recommendations, the ICG Working Group on Information Dissemination and Capacity Building, in partnership with members, associate members and observers of ICG and international entities focused on: (a) disseminating information through a network of the information centres hosted by the regional centres for space science and technology education, affiliated to the United Nations; (b) promoting the use of GNSS as tools for scientific applications; and (c) building the capacity of developing countries in using GNSS technology for sustainable development. The detailed information is available on the ICG information portal at: http://www.unoosa.org/oosa/en/ourwork/icg/activities.html

Information dissemination through a network of the information centres hosted by the regional centres for space science and technology education, affiliated to the United Nations

The ICG information centres are hosted by the regional centres for space science and technology education, affiliated to the United Nations. The regional centres are located in India and China for Asia and the Pacific, in Morocco and Nigeria for Africa, in Brazil and Mexico for Latin America and the Caribbean and in Jordan for West Asia. The main objective of the ICG information centres is to enhance the capabilities of member States to use GNSS and related applications at the regional and international levels so as to advance their scientific, economic and social development. The centres coordinate their activities closely with ICG and its Providers' Forum through the ICG executive secretariat.

Table 1: Sites where one can get free GPS data and study the ionosphere

IGS network:		http://www.igs.org/about/data-centers
CDDIS (USA)	- 1992-now:	ftp://cddis.gsfc.nasa.gov/gnss/data/daily/
SOPAC (USA)	- 1988-now:	ftp://garner.ucsd.edu/pub/rinex/
IGN (France)	- 1990-now:	ftp://igs.ensg.eu/pub/igs/data/
KASI (South Korea)	- 1993-now:	ftp://nfs.kasi.re.kr/gps/data/daily/
BKG (Germany)	- 1991-now:	ftp://igs.bkg.bund.de/IGS/obs/
China	- 1990-now:	ftp://igs.gnsswhu.cn/pub/gps/data/daily/
UNAVCO (USA)	- 1992-now:	ftp://data-out.unavco.org/pub/rinex/obs/
AFREF (South Africa)	- 2004-now:	ftp://ftp.afrefdata.org/ *(only stations in Africa)*
AuScope (Australia)	- 1993-now:	ftp://ftp.ga.gov.au/geodesy-outgoing/gnss/data/daily/ (stations in Australia and Pacific)
TIGA	- 1990-now:	ftp://ftp.sonel.org/gps/data/ *(stations near sea)*
NOAA	- 1994-now:	ftp://geodesy.noaa.gov/cors/rinex/

Conclusion

This paper presented the physics of space meteorology as well as the teaching developed for the use of GNSS in meteorology of the Space. The representatives of the following countries participated in the training courses: Algeria, Burkina Faso, Cameroon, Côte d'Ivoire, Egypt, Morocco, Niger, the Republic of the Congo (RC), the Democratic Republic of the Congo (DRC), Senegal, Tunisia, and Vietnam.

To date, following the training carried out since 2 decades, there are research groups in meteorology of the Space in Algeria, Burkina Faso, Cameroon, Côte d'Ivoire, Egypt, Morocco, RC, DRC, Senegal and Vietnam. Each 2 years a regional school is carried out in Africa. The next will take place in Abidjan in Ivory Coast from 16 to 28 October 2017, the professors are from Algeria, Burkina Faso, Côte d'Ivoire, France and Morocco.

The schools aimed to promote (1) the emergence of students on Space Weather with works that can lead to PhD (38 PhD in 25 years), (2) to work in an international context giving rise to publications and (3) To favor the implantation of GNSS receivers for scientific purposes, especially in Africa, which lags far behind other continents.

Galileo update

UK may lose access to Galileo after Brexit

The United Kingdom may be cut off the new EU global positioning system (GPS) Galileo, which has been developed with active participation of British companies, and will have to hold separate negotiations to obtain access to the system after London leaves the European Union, media reported.

"There is technology there reserved for member states to use for public services, and the UK could be locked out. I'm sure that a deal will be done, and the UK could pay its whack and get access, but it's just another part of Brexit that no one's actually thought about," Scottish National Party Member of Parliament George Kerevan was quoted as saying by the Independent.

The Galileo system is a joint project between the European Union and the European Space Agency (ESA), autonomous from the block. According to the media report, Britain will need to work out a third-party agreement with the European Union to conserve its participation in the project, like Norway and Switzerland, who brokered their deals and now carry out project-specific work for the block. *https://sputniknews.com*

Falsifying Galileo satellite signals will become more difficult

Researchers from the Department of Electrical Engineering at KU Leuven (University of Leuven, Belgium) have designed authentication features that will make it even more difficult to send out false Galileo signals.

Navigation systems are based on satellites that send out signals, including their location. The distance to four or more satellites makes it possible to determine someone's geographical position and time. But this process may go wrong when hackers send out signals of their own that drown out the real ones. As the authentic signals are blocked, the position information for the navigation system is no longer correct.

Professor Vincent Rijmen and doctoral student Tomer Ashur from the Department of Electrical Engineering (ESAT) at KU Leuven have now advised the European Commission on ways to make Galileo signals more difficult to falsify. Their authentication method involves electronic signatures, similar to methods used for online banking.

To avoid delaying the launch of Galileo the researchers could only use the remaining 'bits' in the signals for authentication purposes. "This is why we support the TESLA method for electronic signatures," Professor Rijmen explains. "TESLA signatures fit into 100 bits. They quickly expire, but this is not a disadvantage in the case of satellite navigation because the location is authenticated every 30 seconds or less anyway."

The method still needs to be tested and validated before it can be made available to the general public. *https://www.eurekalert.org/pub_releases/2017-02/kl-fgs020917.php*

The activities and opportunities provided through the ICG result in the development and growth of capacities that will enable each country to enhance its knowledge, understanding and practical experience in those aspects of GNSS technology that have the potential for a greater impact on its economic and social development, including the preservation of its environment.

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Fit for Purpose Parcel Mapping Methodologies for a Seamless Cadastre Database

Parcel mapping that ensures secure land tenure for a large percentage of a nation's citizens can be produced at an acceptable and Fit-for-purpose level of accuracy using general boundary survey techniques that are a small fraction of the cost of parcel mapping created using fixed boundary survey techniques. Readers may recall that the first part of the article was published in the last issue. We present here the concluding part of the paper

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The Seamless Cadastre Database

There are several compelling reasons for surveying a property parcel that will become part of a comprehensive fiscal cadastre:

- Problems with inadequate cadastres, lax and inequitable tax policies and practices hinder the revitalization and maintenance of neighborhoods and prevent local governments from collecting revenue needed to support public services.
- Provide documentation in the form of a parcel survey to help citizens achieve secure land tenure
- A property owner desires to know as accurately as possible the value of his or her asset when selling a property or seeking a mortgage on it, and;
- A taxing agency needs to know the area of a parcel in order to apply the correct property tax rate to it

Parcel corners locate parcels on the surface of the earth, to one level of accuracy or another, resulting in a coordinate-based cadastral mapping system that is improved and updated as new parcels are surveyed or mapped over time. An important role that is played by parcel corners is the ability to calculate the area of a parcel based on the parcel corner coordinates. Therefore, the more accurate the parcel corner coordinates, the more accurate is the resulting parcel area calculation.

The Surveyor Pin Cushion
Photo: Dietz Surveying, Maryland

Regardless of the methodology employed for the location of parcel corners on the earth's surface, it is impossible to calculate any parcel area with 100% precision.

There are two primary technologies employed today in the task of locating parcels on the earth's surface.

1) Land surveying: Land surveyors use a total station (a tripod mounted optical instrument that measures angles and distances between parcel corners along a parcel boundary) and GPS receivers that locate a position on the ground based on time and distance measurements to satellites that are in orbit above the earth. When parcel corners are surveyed using either total station or GPS technology, the resulting fixed boundary accuracy of parcel corners can be calculated to within a few centimeters of their true position. A two man field survey crew can survey fixed boundary parcels at the rate of 3 to 10 a day, depending on the complexity of the parcel boundaries.
2) Aerial surveying: Aerial surveying, or photogrammetry, is widely employed throughout the world to create general map boundary databases over very large portions of the earth's surface. When parcel corners are surveyed using photogrammetric technology, their resulting accuracy can be calculated to within 5 centimeters to three meters, depending on the level of accuracy of the underlying photogrammetric

map that has been created. Individual mapping technicians (using inexpensive office-based workstations) can survey general boundary parcels at the rate of 40 to 50 per day, depending on the complexity of the parcel boundaries.

The major differences between land and photogrammetrically surveyed parcel corners are the accuracy, cost and time required to create the parcel corner coordinates. (McKenna, 2016)

Deferred Monumentation – Good Idea or Bad Idea?

In his excellent, informative and mostly pragmatic paper, "*Deferred Monumentation and the Shakedown Factor*", D. Goodwin discusses how surveyors and legislators, in their efforts to define land unambiguously, have had to consider a number of models including the general boundary system, even though the physical boundary features such as fences and walls sometimes disturb or destroy boundary marks when they are erected. Additionally, they usually are not erected exactly on the legal boundaries, either to avoid disturbing boundary marks or else in ignorance of their position. In another widespread model, the fixed boundary system, corner boundary marks are the norm. Goodwin raises two questions. First, whether it would be better for surveyors to place boundary marks after the erection of physical boundaries, roads and services, and second, whether it is necessary to place boundary marks at all, or whether these should be placed only to resolve conflict where this arises.

Goodwin discusses his Case Study 1: High Density Developed Townships in Zimbabwe. HDDTs, which make up a significant percentage of dwellings in Zimbabwean urban centres, typically cater to lower income residents. The townships were originally set out by the Department of Physical Planning to non-title specifications, and core houses were built, amounting to approximately half of the final residential unit. Non-title pegs that were placed were necessary for the orderly building of roads and houses, and guiding the erection of physical boundaries. Despite having no legal weight, these pegs also assisted from time to time in arbitrating disputes.

The following are thought to be the most significant questions asked of residents in Goodwin's research:

Question: How long does it take right holders to enclose their properties with some form of physical boundary?

- About 20% of physical boundaries are built in the first year of occupation
- Approximately 50% of the properties are enclosed by about four years
- Approximately 66% of the properties are enclosed after about seven years
- After 17 years, 90% of properties are enclosed by physical occupation lines.

Question: What form is the physical boundary?

- Fence 63%
- Hedge 16%
- Concrete wall 9%
- Brick wall 3%
- Other 3%
- No physical boundary 6%

Question: What is the reason for erecting a physical boundary?

- 50% Increased security
- 25% To keep animals from eating their vegetables
- 10% To remind neighbours of where the boundary was (i.e. it was some kind of territorial statement)
- 5% For aesthetic reasons.

Question: Is there any dissention with neighbours over the common boundaries?

- Ninety-eight per cent of respondents had achieved amicable consensus over the common boundaries, even where these departed from the pegs originally placed.

According to Goodwin, the gains accruing from deferring boundary monumentation are seldom justifiable, and boundary marks should have well defined centre-marks and be surveyed to accuracies comparable with survey control marks in order to densify control and to act as witness marks. The research summarised by Goodwin suggests that, although right-holders generally regard physical boundaries as the primary boundary evidence, departures with legal boundaries are seldom a threat to secure title. Finally, wherever there is doubt, dispute or disaster, it is important that a dense network of surveyed points exists, whether control marks or boundary marks, that can be used in arbitration and re-instatement. All compromise is based on give and take, but there can be no give and take on fundamentals. Goodwin draws the conclusion that any compromise on mere fundamentals is a surrender. He states that physical boundaries erected by abutting right holders exhibit a degree of give-and-take, and right-holders tend to regard these positionally-flawed physical boundaries as the primary source of boundary evidence, but the underlying fundamentals of well-defined marks, both control marks and well defined boundary marks, should not lightly be surrendered. (Goodwin, 2013)

Author note: In a world where time and money are not a consideration, Goodwin's conclusions are beyond reproach. Like Goodwin, the author of this paper has densified control networks through the use of accurately surveyed permanent parcel boundary marks (all photo identifiable for use within aerial triangulation block adjustments) for inclusion in the national network. However, the cost to install parcel corner boundary markers that will then be surveyed in the field is simply prohibitive to most national and local governments in developing countries. The urban area around, for example, Nairobi, contains approximately 1.5 million parcels. How long would it take and how much would it cost to install and survey boundary marks to each of those parcels? Maybe $50, more likely $100 per parcel, and very likely more than that. This is too much time and money for government agencies who urgently desire to have a functioning and affordable revenue-generating fiscal cadastre as soon as possible. Digital orthophotography will provide the means to create as many as 75% of those parcels at a fraction of the cost ($10 approximately) required for general boundary parcels compared to the cost of fixed boundary parcels. Well-defined boundary marks can be installed and surveyed for those parcels that cannot be mapped using general boundary mapping techniques. Likewise, any general boundary *surveyed parcels whose ownership is transferred can have well defined boundary marks installed and surveyed (at the seller's expense) with a subsequent upgrade of its status within the cadastre to a fixed boundary parcel. The unfortunate reality is that monumentation of all parcel corners will result in deferred revenue collection.*

Goodwin did not mention the shortcomings of the physical flaws involved with the recovering of fixed boundary markers: namely the "Pincushion Effect". The "pincushion corner" is a term coined by surveyor and author Jeff Lucas to describe the phenomena of multiple boundary markers being set by land surveyors when only one boundary corner exists under the law. It is common knowledge that no two surveyors can agree on the location of any given property corner. The pincushion is physical proof of that notion. Is the pincushion also physical proof that the entire 2cm accuracy fixed boundary claim is a tad over rated?

Area Calculation Comparisons of a Fixed Boundary and a General Boundary Surveyed Parcel

The diagrams (Figures 1, 2 and 3) show how the area of a hypothetical 2 Ha parcel is calculated using fixed boundary survey coordinates values (theoretical 100% precision) and using general boundary coordinate values (a 3 meter off-set to reflect the maximum error obtained from a 1:5,000 digital orthophoto). The maximum coordinate off-set (outward or inward) results in an area calculation for the parcel that is within 8% of the actual parcel area. It should be noted that a coordinate error of 3 meters is associated with mapping accuracy that is inferior to Class 2 accuracy as defined in the ASPRS Map Accuracy Table shown in Table 1. Class 2 accuracy should be the minimum accuracy level applied to cadastre creation.

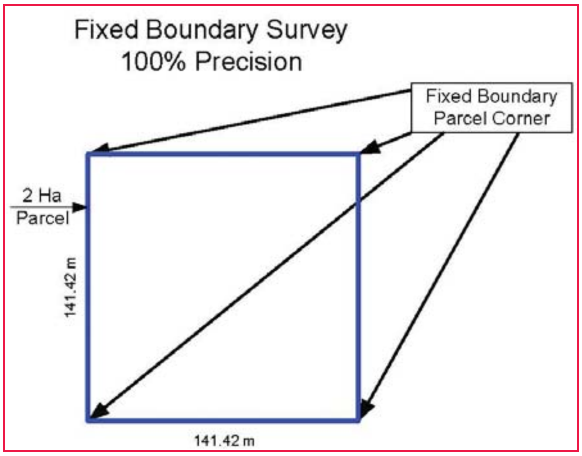

Figure 1: Fixed Boundary Survey Parcel. This 2 ha parcel has been surveyed to a theoretical 100% accuracy

What is a Cadastre?

A Cadastre is a public record that contains a delineation of individual parcel boundaries, attributes for ownership information and the rights associated with each parcel that is used to confirm ownership and as a basis of property taxation. When all ownership information is accumulated a modern land administration system is developed which is used to feed a GIS (in addition to a variety of land records management software such as modules for land registry, cadastre and valuation records keeping), maintain cadastral mapping databases and enable property tax revenue calculation.

Most countries that use modern GIS, total station, GPS and photogrammetric mapping techniques to create a contiguous parcel database (cadastre) for the calculation of property taxes primarily use the general boundary survey methodology to create a database of calculated parcel areas based on general boundary parcel corner coordinates. Because of the reality that the resulting calculated areas are in error from 3% to 8% for ASPRS Class I or Class 2 mapping at a

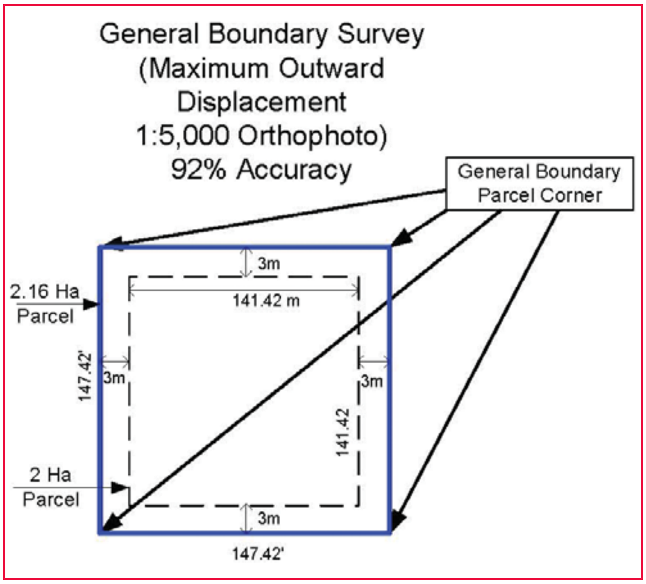

Figure 2: This graphic shows a general boundary 2 ha parcel (located on a 1:5,000 scale orthophoto) with the maximum outward displacement of 3 meters applied to the parcel corners. As a result, the parcel area calculation of 2.16 Ha is off by 8% approximately

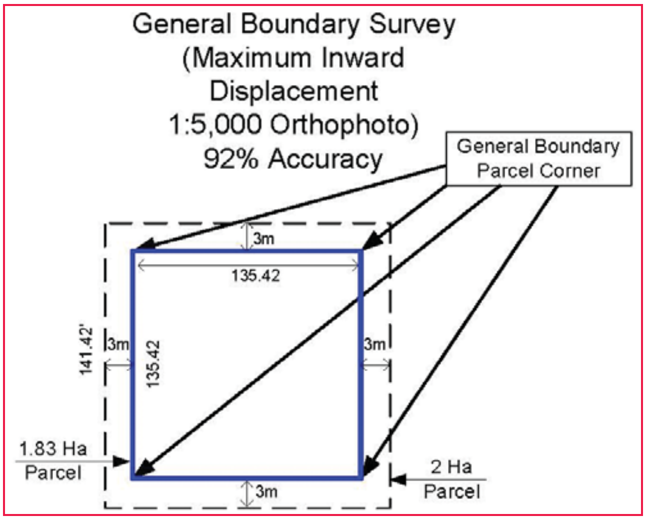

Figure 3: This graphic shows a general boundary 2 ha parcel (located on a 1:5,000 scale orthophoto) with the maximum inward displacement of 3 meters applied to the parcel corners. As a result, the parcel area calculation of 1.83 Ha is off by 8% approximately

Table 1: ASPRS Map Accuracy

Map Scale (Metric)	Class 1 Planimetric Accuracy limiting RMSE (cm)	Class 2 Planimetric Accuracy limiting RMSE (cm)	Class 3 Planimetric Accuracy limiting RMSE (cm)
1:1,200	30	60	90
1:2,000	50	100	150
1:2,400	61	122	183
1:4,800	122	244	366
1:5,000	127	254	381

Table 2:

Map Scale	Class 1	Class 2	Class 3	Map Type
1:5,000	99%	98%	97%	(20 Ha parcel)
1:5,000	98%	96%	93%	(5 Ha parcel)
1:5,000	97%	93%	90%	(2 Ha parcel)
1:2,000	97%	95%	92%	(0.5 Ha parcel)
1:2,000	94%	88%	83%	(0.1 Ha parcel)
1:1,250	88%			(0.1 Ha parcel)

scale of 1:5,000 (Class 3 mapping is rarely used due to the higher errors achieved) the billing area for each parcel could be reduced by 10%. That is, if the parcel area calculated from a general boundary survey is, for example, 2.39 Ha, then the area billed by the tax office could be 2.39 Ha less 0.24 Ha, or 2.15 Ha. This 10% buffer ensures that owners have confidence that they are not being over-billed for the taxes associated with their property. In the event that the owner needs to determine his property area with greater accuracy, for example when applying for a mortgage or selling the property, then a 2cm accuracy fixed boundary survey can be carried out at the owner's expense.

The Table 1 shows the level of accuracy that is achieved utilizing photogrammetric mapping techniques that are based on internationally accepted mapping standards. American Society for Photogrammetry and Remote Sensing (ASPRS) mapping accuracy is reported as *Class 1, Class 2, or Class 3*. Class 1 accuracy for horizontal and vertical components is shown below. Class 2 accuracy applies to maps compiled within limiting RMSE's twice those allowed for Class 1 maps. Similarly, Class 3 accuracy applies to Federal Geographic maps compiled within limiting RMSE's three times those allowed for Class 1 maps.

ASPRS Accuracy Standards for Large-Scale Maps evaluates positional accuracy for the x-component and the y-component individually. Positional accuracy is reported at ground scale.

The table 2 shows the accuracy obtained for general boundary parcel calculation for parcels of varying areas, depending on which accuracy class and map scale has been used for the digital orthophoto production.

Note: Parcel calculation accuracy increases when the map scale is smaller and the parcel area is larger.

Note: Whatever the level of accuracy that is achieved using general boundary survey methodology, it is important to note that the cost of creating a general boundary parcel is typically 5% to 10% of the cost of creating a parcel using fixed boundary survey methodology. Parcels measuring 0.1 Ha or less could be placed in a uniform category for taxation purposes.

Large Administrative Area Parcel Databases

When parcel corner coordinates are acquired for a large number of parcels, for example for a village, a city or an entire country, a cadastral geodatabase is created. A cadastral database represents and contains ownership data for a continuous surface of connected parcels. If a parcel split occurs, two new parcels are added to the cadastral database and the original parcel database is maintained as part of the historical record. In a geodatabase, the parcel-based topology of the database determines how parcels, boundary lines, corner points and other features share coincident geometry. Parcel polygons are defined by a series of boundary lines which can store recorded dimensions as attributes in a lines data table. Specific topological conditions support multiple survey records for adjacent parcel boundaries whose dimensions are specific for each parcel, even when the boundaries are shared. Topology is a branch of geometrical mathematics which is concerned with order, contiguity and relative position, rather than actual linear dimensions.

Parcel polygons can be connected to each other by connection lines, for example those parcels that cross roads. Because each parcel is either linked or connected, a seamless network of connected parcel boundaries (i.e., the contiguous cadastral database) is formed. Parcel corners are the endpoints of parcel lines and they are common between adjacent parcel boundaries. This establishes connectivity and maintains topological integrity within the contiguous parcel database.

For a parcel survey that is being submitted in support of an application for a mortgage loan, marked parcel corners can be very accurately located using total station or GPS surveying equipment. The resulting survey of parcel corners in this manner is known as a "Fixed Boundary" survey. Often, even though the parcel is surveyed with great precision, the parcel corner coordinates are not produced on the national grid, but are created with parcel corner coordinates that are on a local grid specific to that parcel only. This is a major drawback when the parcel information is required to become part of a national cadastre.

The parcel corner coordinates are not intended to provide the true legal representation of a cadastral parcel. They are merely a part of the methodology developed to represent all the historical and legal record information available within a land administration system. Some GIS software packages (such as Esri's Parcel Fabric) support a coordinate-based cadastre with the goal to continually refine and establish digital representation of coordinates at the corners of parcels.

Surveyors have traditionally recorded parcel boundaries through the use of bearings and distance dimensions. For many years cadastral boundary networks were created with no accurate reference to real-world coordinate locations as surveyors did not tie into the national grid. With the advent of high accuracy total station and GPS surveying equipment it has become significantly easier to use coordinates to geographically define parcel locations. Traditional survey methods used for relocating property boundary corners may be interpreted in different ways. When different surveyors use different positioning data to re-establish the location of a boundary, boundary location disputes often arise. A coordinate provides a unique and unambiguous record of a point and can be quickly and accurately relocated with the use of total stations and GPS receivers.

To gain maximum benefit from the use of coordinates, a system needs to be in place within the cadastre that provides a measure of the reliability, consistency and accuracy of coordinates in a parcel boundary network. Traditional parcel data management has focused on entry of individual parcel and subdivision plans that use coordinate geometry (COGO) to enter high accuracy metes (bearings and distances) and bounds (neighboring lands) descriptions. The following is a typical metes and bounds example: "Commencing at the point of beginning then North 44°35'16" East 100.26 meters, then Northwest 26° 14'58" 195.37 meters". Using such a workflow, individual parcels or subdivision plans are entered independently of all other survey plans. While such a workflow is adequate for management of individual parcels, a contiguous parcel database across an entire jurisdiction is difficult to assemble in this manner.

Efficient management of a government cadastre demands the utilization of a contiguous parcel database. New and cost effective photogrammetric mapping technology has resulted in the availability of affordable high resolution and geospatially accurate digital orthophotography. The digital orthophoto imagery (from satellite or airborne sensors) provides a very affordable option for the creation of a contiguous cadastral database. The technique used to locate cadastral parcels onto a digital orthophoto back drop is known as "Best-fit to Ortho Parcel Mapping"**.**

The best-fit-to-ortho mapping technique involves use of geo-referenced images of digital orthophotos that have been created for a given jurisdiction (for example a municipality). Using this mapping technique, cadastral maps are completed to the same level of accuracy as the digital orthophotos based on the visual fit of the parcel boundaries to photo identifiable features that appear in the digital orthophoto image.

The following steps are taken in the cadastral mapping workflow:

- Analyze the location of roads, tracks and trails that appear on the digital orthophotos and use those features as guidelines for the placement of road Rights-of-Way (ROW) and road centerlines.
- Analyze ground evidence on the digital orthophotos pertaining to structures, fences, walls, hedges, hydrographic features, vegetation lines and agricultural lines and use these features as guidelines for the placement of parcels.
- Place the pertinent data for parcels on a block-by-block or small-cluster basis.
- Create a unique parcel identification number (PIN) for each parcel.
- Place Errata Notes for areas of conflict that will require adjudication.

It is important to take note of the fact that when fixed boundary parcel surveying techniques are used to create individual survey plans with *survey precision*, that precision is lost when the parcels are re-created as a contiguous parcel database using topographic maps or digital orthophotos as a backdrop. The resulting contiguous parcel cadastre acquires *map accuracy* and results in the creation of a "General Boundary" survey based cadastral database. (McKenna, 2016)

Conclusion

Parcel mapping that ensures secure land tenure for a large percentage of a nation's citizens can be produced at an acceptable and Fit-for-purpose level of accuracy using general boundary survey techniques that are a small fraction of the cost of parcel mapping created using fixed boundary survey techniques. Most modern cadastres, including most of the 3,000 American county cadastres, are mapped according to internationally recognized mapping standards for map scales of 1:1,250 (urban), 1:2,500 (peri-urban), 1:5,000 (rural) and 1:10,000 (rural).

Note US map scales are typically 1:1,200 (urban), 1:2,400 (peri-urban) and 1:4,800 (rural).

As a result of the reality that there is a choice of utilization of two different survey techniques (fixed boundary and general boundary) for the creation of cadastral maps, it is essential for users of a cadastre to be aware of the fact that parcel corner coordinates can be provided in two options:

1) Fixed Boundary Parcel Corner Coordinates
2) General Boundary Parcel Corner Coordinates

A map accurate contiguous general boundary cadastral database is cheaper, faster to produce and considerably more efficient to manage topologically than an individual parcel, fixed boundary, based cadastral database. As stated above, it is important to note that individual parcels created using fixed boundary survey techniques eventually need to be reassembled into a contiguous parcel database that inevitably involves use of a digital orthophoto or topographic map database that relegates them to general boundary status.

Cadastral databases must have a continuous parcel network that can be managed and referenced to real-world coordinates using a comprehensive geospatial framework. The feature geometry of many GIS data layers is required to fit onto, and be coincident with, the cadastral database. The result is a highly accurate GIS database that meets the goals of surveyors, registry and cadastre offices, tax offices, multiple government agencies and GIS professionals and supports multiple GIS applications that must have geospatially accurate data layer representations.

It has been demonstrated above that a general boundary parcel corner accuracy of 3 m (1:5,000) or better (easily attainable using even satellite imagery) is capable of parcel area calculation that is within 92% of the parcel's actual area. Using the latest available technology, digital orthophotos can be created that enable general boundary parcel mapping that is accurate to 30 cm. Such accuracy produces digital orthophotos to 1:1,250 map accuracy standards, an accuracy that has been, and still is, internationally regarded as a very acceptable accuracy for topographic and parcel mapping.

Many so called "fixed boundary" parcels are surveyed by less than competent surveyors (for sure the pincushion practitioners!) using inferior optical equipment for angle measurement and less than adequate distance measurement techniques (e.g. un-calibrated measuring tapes) that are fortunate to achieve survey traverse closures of 1:5,000. Using modern optical survey equipment there is no reason why 1:25,000 should not be the minimum standard for a traverse closure for a parcel survey.

Note: The traverse closures quoted above are not to be confused with mapping scales.

Cost effective photogrammetric mapping technology and the use of Best-Fit-To-Ortho mapping techniques enables creation of affordable and accurate general boundary mapping. Digital orthophoto imagery (from satellite or airborne sensors) provides a very affordable option for the creation of a Fit-for-purpose contiguous cadastral database.

Even the poorest of countries sometimes insist on creation of a fixed boundary cadastre, while overlooking the absence of an exact definition of a fixed boundary survey. Instead the demand is often made for all parcels to be surveyed to an accuracy of 1 or 2 cm.

When does a fixed boundary survey become a "real" fixed boundary survey? Is it when parcel corners are surveyed to 1 cm accuracy? Or 2 cm accuracy? Or 10 cm accuracy? There are those who are of the opinion that even at 1 cm parcel corner accuracy, the parcel is still a general boundary survey. Perhaps the only "true" fixed boundary survey is one that is surveyed with 0 cm accuracy. And that will never happen: even minor tectonic shifts will ensure that is the case. If a homeowner or bank must have a 1 cm accurate survey plan then that homeowner, not the other citizens, can pay to have that survey completed at a cost, depending on the country, between $200 and $1,500. Compared to the approximate $10 per parcel cost for general boundary parcel mapping. And besides, the fixed boundary parcel is no more efficient at being the repository for all parcel attributes (rights, owner name, valuation, etc.) than a general boundary parcel. The reality is that a general boundary parcel is a really good location for "parking" the scanned image of a fixed boundary survey plan of the same parcel. It is a simple matter to attach that scanned fixed boundary survey plan as an attribute to a general boundary centroid, click on the centroid and display and print the survey plan.

General boundary surveys can result in cost and time savings of as much as 90%. The question must be asked: "Is the relatively exorbitant cost and huge increase in time required to create a fixed boundary cadastre a technologically, financially and politically prudent direction to take?" This paper demonstrates that general boundary parcels are created with Fit-for-purpose accuracy, quicker and cheaper per the FIG and World Bank Fit-for-purpose objectives. Realistically, the cost for cadastre creation should be a hybrid of both surveying methodologies: general boundary parcels using photogrammetric data (topographic mapping or digital orthophotography) and fixed boundary for the parcels that cannot be derived by any means other than field surveying. It is time to stop thinking of parcel corner accuracy in terms of centimeter accuracy for creation of most fiscal cadastres. It is time to create affordable revenue-generating cadastre databases, based on the UK Land Registry model, which comply with the accuracies of time-honoured map scales of 1:1,250, 1:2,500, 1:5,000 and 1:10,000 and put the cost savings to good use on other aspects of land administration activity.

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Victoria State Government, *What is the Torrens Title System?*

http://www.dtpli.vic.gov.au/property-and-land-titles/land-titles/torrens-titles

what3words.com, *what3words is a unique combination of just 3 words that identifies a 3mx3m square, anywhere on the planet*

The paper was presented at FIG Working Week 2016, Christchurch, New Zealand, May 2-6, 2016

EuroGeographics enhances open data for 2017

Users of EuroGeographics pan-European open data will benefit from a series of enhancements to the latest release of EuroGlobalMap. Forty-five members of the Association for the European National Mapping, Cadastre and Land Registry Authorities have contributed to the 1:1 million scale dataset which includes an administrative theme providing boundary information. It also features a settlement theme with the addition of populated places and populated place ID for built up area feature classes. *www.eurogeographics.org*

OS International helps the UAE manage Climate Change

Ordnance Survey International and Deimos Space UK are to work with the Mohammed bin Rashid Space Centre in Dubai to help the United Arab Emirates (UAE) improve how it plans and manages its natural resources and infrastructure. OS International will establish a strategy for the development of a single source of digital geospatial data for UAE government departments to enable a variety of key policy initiatives. Advanced data analytic tools developed by Deimos Space UK and the Mohammed bin Rashid Space Centre will demonstrate the value of new geospatial data extracted from high-resolution satellite imagery. *os.uk/international*

Hyderabad launches geo-tagging

Hyderabad may soon become the first city in India to have unique house addresses based on the geo-spatial location of each home. The Greater Hyderabad Municipal Corporation (GHMC) has begun the process of allotting digital house numbers for all dwelling units in the city. The agency for executing the project is expected to be identified and finalised soon. Once the project is over, anyone can locate a house by keying in the unique house number of a particular dwelling unit in a cellphone app, which will then provide directions to that house. Since the project is based on a geo-spatial solution, the app will provide navigation details and address location services within the GHMC's jurisdiction. *http://timesofindia.indiatimes.com*

Hyderabad-based firm to map solar energy potential

The Bangalore Electricity Supply Company (Bescom) chose a Hyderabad-based company for aerial mapping of the city to study its rooftop solar energy generation prospects.

The aerial mapping exercise will use the light detection and ranging (LIDAR) technology, which is said to be a first in the country. An aircraft will fly over the city, sending pulses of light, which will get reflected back from objects on the ground. Bescom has partnered with the Centre for Study of Science, Technology and Policy (CSTEP) and Karnataka Renewable Energy Development Limited (KREDL) for the project. *www.thehindu.com*

PCTEL and TRX Systems Automate Indoor Mapping of Cellular Networks

PCTEL, Inc. (PCTI) and TRX Systems Inc. have announced the first scanning receiver-based cellular network test and measurement solution with automated indoor/outdoor geo-referencing. With the PCTEL-TRX solution, engineers will be able to easily collect and geo-locate RF (radio frequency) data where GPS signals are not available. The system's automatic 2D and 3D mapping supports engineering activities for DAS, small cell, and heterogeneous wireless networks. *www.trxsystems.com*

MapmyIndia introduces a new digital address system in India

MapmyIndia has announced the release of MapmyIndia eLoc, a simple and easy to use digital addresses, in India. Through this feature, users will be able to search, share and navigate to destinations' exact doorstep easily.

eLoc is the Aadhaar of digital addresses. It is basically a short 6 character code given to any building, flat, office, business, city, village, locality, road and so on, which can be used to get the precise map location of that place. Through this feature, one can also see information about that place beside its location, such as reviews, photos and other information provided by the place's owner, businesses and governments. *www.themobileindian.com*

HERE and Pioneer partner on global map solution

HERE, the Open Location Platform company, and Pioneer Corporation (Pioneer), the global car electronics company, have announced their intention to enter into a strategic partnership to enable industry-leading global mapping solutions and next generation location-based services for the automotive and other industries. The agreement follows the companies' recent cooperation exploring the application of Pioneer's 3D-LiDAR sensor technology in the development of a data ecosystem for autonomous driving. *http://pioneer.jp/en/*

uAvionix announces TSO for FYXNAV GNSS Position Source

uAvionix Corporation has announced FAA TSO C-199 approval of its FYXNAV GPS position source. Weighing only 27 grams, the $500 combination GPS receiver and antenna provides high integrity GPS inputs to drone autopilot navigation systems and ADS-B equipment. Integrity is a key part of aviation GPS systems, such as those used in Performance Based Navigation (PBN) principals – whereby aircraft systems are required to achieve certain specifications in order to perform specific functions, such as be used in a GPS approach to a runway. In order to meet the requirements of TSO C-199, FYXNAV implements integrity algorithms which monitor the health of each of the GPS satellites and excludes any from position calculations that exhibit anomalous behavior. Non-aviation grade GPS receivers typically do not include an integrity processor.

SpaceX completes space station delivery after navigation problem caused delay

SpaceX has completed its delivery to the International Space Station after fixing a navigation problem that held up the shipment by a day. Everything went smoothly the second time around as the station astronauts captured the SpaceX Dragon cargo ship as the two craft sailed over Australia.

Recently, a GPS system error prevented the capsule from coming too close.

Now leased by SpaceX, the pad had been idle since the close of the shuttle programme almost six years ago. The Dragon will remain at the space station for a month before it is cut loose to bring back science samples and other items. It is the only supply ship capable of returning intact to Earth, as all the others burn up during re-entry.

SpaceX is one of two private companies flying up supplies for Nasa. Besides the French astronaut, the space station is home to two Americans and three Russians. *www.belfasttelegraph.co.uk*

GPS resiliency tests for critical infrastructure devices

The Department of Homeland Security in the USA is offering critical infrastructure component manufacturers a chance to test their wares against GPS disruption. Though GPS is best known to consumers for accurately determining locations, many of its most critical uses are from accurately determining time. GPS outages are not common, but are more than theoretical. In 2009, for example, Newark Liberty International Airport suffered GPS outages in an air traffic control system whenever a man, named Gary Bojczak, drove by.

Bojczak worked for an engineering firm that tracked the locations of company trucks through GPS and used a GPS jamming device to shake his boss's surveillance. But whenever he passed the airport, a GPS outage passed with him. GPS signals can be disrupted through jamming, taking a device out of contact with the GPS satellite; or spoofed, tricked through a fake signal to miscalculate location or time. *http://thehill.com*

NZ government contributes AU$2m to join Geoscience Australia's positioning project

It is expected that the AU$2 million will be used to trial Satellite Based Augmentation System (SBAS) technology over two years, and will also see Land Information New Zealand; the New Zealand Transport Agency; the Ministry of Business, Innovation and Employment; the Ministry of Transport; and New Zealand Cooperative Research Centre for Spatial Information (CRCSI) work with Geoscience Australia, which has been charged with overseeing the project on behalf of the Australian government.

Lockheed Martin US, alongside Inmarsat and GMV, will be partaking in trials of the SBAS technology. The global giants will be testing two new satellite positioning technologies -- "next generation" SBAS and Precise Point Positioning -- which Geoscience Australia said provides positioning accuracy of several decimetres and five centimetres, respectively. The SBAS test bed will also utilise existing national GNSS infrastructure developed by AuScope as part of the National Collaborative Research Infrastructure Strategy. *www.zdnet.com*

Europe's TREASURE

A consortium of European universities, institutes and companies thinks it can do better by integrating the world's four main GNSS constellations. It's called TREASURE, squeezing all these words into the acronym: Training, REsearch and Applications network to Support the Ultimate Real time high accuracy EGNSS solution. The TREASURE team plans to integrate signals from the GPS, GLONASS, BeiDou and Galileo. This multi-GNSS would provide accuracy within just a few centimeters in real time.

"Although accuracy is at the core of our vision, the improvement we are aiming for is not only to do with accuracy—we are also especially concerned with robustness," according to project lead Marcio Aquino, from the Nottingham Geospatial Institute. "The big challenge today is to enable centimeter-level accuracy anywhere, anytime in the world." It won't be easy. For example, GPS uses a different transmission system than Russia's GLONASS. Signals from Galileo are similar to GPS but with slightly different carrier frequencies, according to Aquino. Not to mention that the various constellations use different time and geodetic reference systems. One of the goals of the TREASURE project is to reduce atmospheric disturbances to the signals beamed from satellites back to Earth. *https://singularityhub.com*

India to expedite 'Space Centric' warfare command using GLONASS

Amid buzzword of 'Cold Doctrine' and delay in obtaining dedicated frequency band for military satellite, India has stepped up effort to provide sufficient number of satellites to Indian military with the help of Russia. Indian scientists have expressed satisfaction over progress in recent agreement signed between India and Russia which allowed Russia to deploy its GLONASS system ground stations in India.

"GLONASS will be of help to India because it will be integrated into military equipment that comes from Russia and apart from that it will also serve civilian purpose as it is compatible with Indian satellite system NavIC. Because it is compatible with NavIC it will have increased area coverage and accuracy," says Group Captain Ajey Lele, Senior Research Fellow at the Institute for Defense Studies and Analyses, New Delhi. *https://sputniknews.com*

Pentagon's DARPA tests underwater drone positioning system

New "GPS-like" technology for undersea drone communications is being developed by BAE Systems and the Pentagon's Defense Advanced Research Projects Agency (DARPA). The new program will be put in place to conduct surveillance during combat missions, find enemy submarines and identify mines. The

Positioning System for Deep Ocean Navigation (POSYDON) system is a joint developmental effort between DARPA and industry and will coordinate GPS signals, underwater acoustic signals and a surface buoy to transmit location coordinates from undersea drones to onboard command and control systems rapidly *https://sputniknews.com*

Emergency 112 calls in Europe saving lives with GNSS

On Feb. 11, the European Union (EU) celebrated 112 Day in honor of the single European emergency phone number. The 112 system uses Advanced Mobile Location (AML) to receive location information from mobile phones.

Every year, about 300,000 people who call the emergency services cannot describe their location because they may not know where they are, because they are too young to say or they are too injured to communicate. In these situations, knowing the exact location of the caller can help emergency services react quickly and save lives, according to the European Commission. An EU-financed project — HELP 112 — looked into how GNSS can improve caller location using the AML solution. It was tested in the United Kingdom, Lithuania, Italy and parts of Austria.

Israel Aerospace unveils anti-jamming system

Israel Aerospace Industries Ltd. (IAI) has unveiled ADA - an advanced system that protects avionic systems from GPS jamming. ADA was developed by IAI's MALAM Division, a national center of excellence for Anti-Jamming protection of GNSS receivers. Under the terms of the project with the Israeli Air Force, IAI will deliver a turnkey solution based on its multi-channel Controlled Reception Pattern Antenna (CRPA) technology. The ADA integration will ensure the operational continuity of the aircraft fleet, allowing avionic systems which rely on satellite navigation systems to continue uninterrupted operation even under direct electronic attack, when the enemy uses GPS jammers or other methods of interference. *www.globes-online.com*

BRICS nations to share data from remote sensing satellites

The five-nation group of BRICS will share spatial data on natural resources from their remote-sensing satellites for utilising space assets optimally.

"Space agencies of BRICS have agreed to share and exchange data, including images of natural resources from our remote-sensing satellites for mutual benefit," said Indian Space Research Organisation (ISRO) Director M. Annadurai recently.

Five major emerging economies -- Brazil, Russia, India, China and later South Africa -- came together to form BRICS, which represents 43 per cent of the world population, 30 per cent of the world GDP (Gross Domestic Product) and 17 per cent of the world trade. Though only four of them -- Brazil, Russia, India and China -- have remote-sensing satellites in the sun-synchronous orbit, they will give data to South Africa (SA) as it does not have a satellite of its own.

Top space officials of BRICS, including Annadurai, met at the United Nations Committee on the Peaceful Uses of Outer Space Scientific and Technical Subcommittee's 54th session at Vienna in Austria from January 30 to February 10. *http://zeenews.india.com*

PSLV-C37 successfully launches 104 satellites in a single flight

In its thirty ninth flight (PSLV-C37), ISRO's Polar Satellite Launch Vehicle successfully launched the 714 kg Cartosat-2 Series Satellite along with 103 co-passenger satellites today morning (February 15, 2017) from Satish Dhawan Space Centre SHAR, Sriharikota. This is the thirty eighth consecutively successful mission of PSLV. The total weight of all the 104 satellites carried on-board PSLV-C37 was 1378 kg.

The total number of Indian satellites launched by PSLV now stands at 46.

After separation, the two solar arrays of Cartosat-2 series satellite were deployed automatically and ISRO's Telemetry, Tracking and Command Network (ISTRAC) at Bangalore took over the control of the satellite. In the coming days, the satellite will be brought to its final operational configuration following which it will begin to provide remote sensing services using its panchromatic (black and white) and multispectral (colour) cameras.

Of the 103 co-passenger satellites carried by PSLV-C37, two – ISRO Nano Satellite-1 (INS-1) weighing 8.4 kg and INS-2 weighing 9.7 kg – are technology demonstration satellites from India. The remaining 101 co-passenger satellites carried were international customer satellites from USA (96), The Netherlands (1), Switzerland (1), Israel (1), Kazakhstan (1) and UAE (1). *www.isro.gov.in*

DLR commissions Airbus for MERLIN

Airbus Defence and Space has signed a contract with Space Administration at the German Aerospace Center (DLR) to develop and build all components of the German contribution to the German-French Earth observation mission MERLIN. Starting in 2021, MERLIN (MEthane Remote sensing LIdar missioN) will deploy a LIDAR (Light Detecting and Ranging) instrument to monitor the methane content in Earth's atmosphere from an altitude of around 500 kilometres, and additionally make possible the first-ever global map of concentrations of this critical greenhouse gas.

MDA to acquire DigitalGlobe

MacDonald, Dettwiler and Associates has announced that it will acquire commercial remote sensing company DigitalGlobe for $2.4 billion, the biggest deal to date in the ongoing consolidation in the Earth imaging market. The boards of both companies have approved the deal, which they expect to close in the second half of this year. DigitalGlobe will retain its name and Colorado headquarters. It will operate as a subsidiary of SSL MDA Holdings, a U.S.-based operating company that MDA, based in Canada, established in 2016. *http://spacenews.com/*

LabSat releases LabSat 3 Wideband GNSS Simulator

LabSat has launched the new LabSat 3 Wideband, which can record multiple signals from different constellations, simultaneously, and the company also is developing an updated version of its SatGen software. The LabSat 3 Wideband can record GPS L1, L2 and L5 at the same time as GLONASS G1 and G2, and BeiDou B1 and B2. The company describes the lightweight unit as its most powerful to date, yet the small, easy-to-use LabSat 3 Wideband retains the one-touch recording and playback of files.

LabSat 3 Wideband can record a range of additional signals, synchronized to the GNSS input: dual-CAN, RS232, and digital inputs are simultaneously captured increasing the level of playback realism and allowing for a wider range of testing. The GNSS simulator features a removable battery pack that provides two hours of use, and the 1TB Solid State Disk drive can be swapped in seconds. LabSat 3 Wideband is housed in a 167 x 128 x 46 millimeter enclosure and weighs 1.2 kilograms, so it is designed to use to record GNSS signals anywhere, according to the company.

LizardTech releases MrSID SDK Version 9.5.4

LizardTech has announced the release of the MrSID® Generation 4 Decode SDK Version 9.5.4 to compliment the release of LizardTech's GeoExpress® Version 9.5.3. This latest SDK release includes support to view MrSID compressed Harris Geiger-Mode LIDAR point clouds, paralleling previously incorporated tools for viewing MrSID compressed LAS and LAZ point clouds. *www.lizardtech.com*

Microsoft, Airbus climb aboard drones software firm AirMap

AirMap, a start-up which has become the world's top supplier of air traffic management software for drones, is raising $26 million in new financing from a group of industry investors led by the venture capital investment arm of Microsoft.

AirMap provides real-time traffic management services for 80 percent of all drones, including millions of robotic aircraft from hundreds of manufacturers, allowing drones and their controllers to share data needed to fly safely at low altitudes. The company was founded only two years ago. Its software works on both piloted and autonomous drones used in both commercial and recreational applications. *http://in.reuters.com*

Luminent provides cost effective solutions

Luminent LLC has announced the release of the Regulatory Accelerator, an innovative new geospatial software application that uses intelligent automation to acquire data from a company's existing databases in order to automate required regulatory compliance while using that same data to provide the company's leadership with predictive and actionable insights. Designed to be a distributed system that integrates data from multiple databases or GIS, Luminent's Regulatory Accelerator can also track real-time changes to a physical facility such as a complex pipeline system, further simplifying regulatory filings and strategic decisions. *Luminent.com*

Septentrio GNSS technology guarantees DEME's operations

The Belgian dredging, environmental and engineering group DEME relies on the accuracy and reliability of the AsteRx family of precise GNSS positioning solutions from Septentrio. DEME began using Septentrio's solutions over 10 years ago. While dredging in the Belgian town of Oostende, they were unable to obtain a reliable RTK position from their GNSS equipment because of interfering radio signals from a local radio tower. Septentrio worked with DEME to identify the source of the interference and modified a standard RTK receiver with special firmware to address the jamming problem. *www.septentrio.com*

Seafloor Systems introduces its Echoboat-G2 Survey Boat

Seafloor Systems has designed the EchoBoat-G2™ Unmanned Survey Vessel (USV) that can execute survey missions via remote control or semi-autonomous, utilizing its modified Mission Planner Drone software. With on its AutoNav™ auto pilot module, the operator can pre-plan survey waypoints, upload via RF to the vehicle, and the EchoBoat drone will automatically execute the mission, going from waypoint to waypoint, then return to base. Government and private organizations can inspect, secure, and maintain harbors worldwide with the EchoBoat-G2 USV integrated with a Sidescan Sonar, Multibeam sonar system, or real-time 2D/3D imaging sonar. *www.seafloorsystems.com*

Oncor upgrades to Hexagon Safety & Infrastructure solution

Oncor Electric Delivery Company (Oncor) has selected Hexagon Safety & Infrastructure to deliver geospatial data across the company's operations. Its GIS and network modelling solution will coordinate with other business systems to streamline network design and documentation and asset and project management. The real-time connectivity model will go beyond standard GIS capabilities and will serve as a single source of truth for location-based network information at Oncor.

Oncor distribution engineers will use Hexagon's software to maintain the electric distribution network model, plus a secondary network and a fiber network, to support the company's operations. *www.hexagonsafetyinfrastructure.com*

M3 Systems' GNSS Simulator sold as part of Averna's test platform

Averna and M3 Systems agreed to distribute M3's StellaNGC GNSS Simulator on VST NI Platforms for the Automotive infotainment market. M3 Systems' GNSS Simulator Is made available as part of Averna's AST-1000 platform, extending its capability to Navigation and GNSS testing.

Averna's AST-1000 RF solution is designed for Radio, Navigation, Video and Connectivity testing. By using NI VST and featuring Averna'sRF and test expertise, the software-defined AST-1000 supports all common Infotainment RF signals, including AM/FM, DAB, RDS, HD Radio, and Sirius/XM, as well as Navigation (GNSS). *www.eeherald.com/*

Topcon launches MR-2 GNSS Modular Receiver System

Topcon Positioning Group has announced the launch of the MR-2, a new modular GNSS receiver system. According to the company, the system combines all current and planned constellation tracking with a comprehensive set of communication interfaces to service any precision application requiring high performance RTK (real-time kinematic) positioning and heading determination. The MR-2 can perform as a mobile RTK base station, marine navigation receiver, mobile mapping device and as a GNSS receiver for agricultural, industrial, military, or construction applications.

Leica SPL100 brings up to 10x more efficiency to airborne LiDAR mapping

Combining the SPL100 single photon LiDAR (SPL) and imaging sensor with Leica HxMap, the scalable post-processing workflow software, RealTerrain enables, for the first time in history, the efficient collection and rapid processing of large area LiDAR data sets. SPL100 collects an unprecedented 6 million points per second with 100 output beams, and HxMap provides a complete single-interface post processing platform to create industry standard LiDAR and image data products. The efficiency gained by SPL100 acquisition and HxMap data processing enable larger and more frequent LiDAR data acquisition for applications such as dense vegetation mapping and change detection.

SPL100 is the first sensor to be released by Leica Geosystems using Sigma Space technology since its acquisition by Hexagon last year. This new and innovative technology was originally developed in collaboration with NASA. Single Photon LiDAR technology will launch on its first space application, the Ice, Cloud and land Elevation Satellite-2 (ICESat-2), used to measure the elevation of Earth's ice, in 2018. leica-geosystems.com/realterrain.

FORM IV

Place of publication:	New Delhi	Publisher's name:	Sanjay Malaviya
Periodicity:	Monthly	Nationality:	Indian
Printer's name:	Thomson Press	Address:	499D, Shipra Sun City, Indirapuram, Gaziabad
Nationality:	Indian	Editor's name:	Bal Krishna
Address:	Mathura Road, Faridabad, India	Nationality:	Indian
		Address:	A 002, Mansara Apartments, C 9, Vasundhara Enclave, Delhi – 110096

I, Sanjay Malaviya, hereby declare that the particulars given above are true to the best of my knowledge and belief.

March 1, 2017 Signature of publisher

Teledyne Optech Announces the New ALTM™ Galaxy T1000

Teledyne Optech announced the latest addition to its innovative line of airborne laser terrain mappers, the ALTM™ Galaxy T1000. This new system combines a 1000-kHz effective ground measurement rate with Optech's award-winning SwathTRAK™ technology to create the most compact, most efficient, and most versatile lidar sensor available today.

Core to the Galaxy T1000's enhanced collection efficiency is a doubling of the laser pulse repetition frequency and a further increase to its variable-terrain capability with SwathTRAK technology, which reduces the number of flightlines by up to 70% over traditional fixed-FOV sensors. SwathTRAK leverages the Galaxy's programmable scanner by dynamically adjusting the scan FOV in real time during data acquisition, enabling constant-width data swaths and constant point density even in highly variable terrain. The result is far fewer flightlines to collect and process, and a consistent point distribution whether on hill peaks or valley bottoms — in fact, the steeper the terrain, the greater the cost savings!

Trimble acquires Beena Vision to expand its rail portfolio

Trimble has acquired privately-held Beena Vision Systems Inc., a manufacturer of vision-based automatic wayside inspection systems for the railroad industry; headquartered in Norcross, Ga, USA. Beena Vision provides vision-based wayside detectors for the rolling stock maintenance market. Its non-contact measurement technology enables highly detailed condition assessment of train components—ranging from wheel surface condition to full train inspection—on trains operating in service and at high speeds. Its wayside systems, coupled with software applications and image analysis technology, enable Train Operating Companies (TOCs) to manage fleet maintenance and operation through automatic measurements and inspections. Real-time alarms, alerts and reports enable significant reductions in maintenance costs and increase fleet availability for revenue generation. *www.trimble.com*

MARK YOUR CALENDAR

April 2017

SPAR 3D Expo and Conference
3 - 5 April
Houston, USA
SPAR3D.com

ISDE10 & Locate17
3 - 6 April
Sydney, Australia
www.digitalearthsymposium.com

UNMANNED WORLD
5 - 7 April
Doha, Qatar
www.unmanned-world.com

GIS-Forum 2017
19-21 April
Moscow
www.gisforum.ru/en

International Navigation Forum / Navitech'2017
25 - 28 April
Moscow, Russia
www.navitech-expo.ru/en/

GISTAM 2017
27 - 28 April
Porto, Portugal
http://gistam.org

May 2017

MMT 2017: The 10th International Symposium on Mobile Mapping Technology
6 - 8 May
Cairo, Egypt
http://mmt2017.aast.edu/index.php

XPONENTIAL
8 - 11 May
Dallas, USA
http://xponential.org

11th Annual Baska GNSS Conference
7 - 9 May
Baska, Croatia
www.rin.org.uk

The European Navigation Conference 2017
9 – 12 May
Lausanne, Switzerland
http://enc2017.eu

GeoBusiness 2017
23 - 24 May
London, UK
http://geobusinessshow.com

FIG Working Week 2017
29 May - 2 June
Helsinki, Finland
www.fig.net

June 2017

10th International ESA Conference on Guidance, Navigation & Control Systems (GNC)
29 May - 2 June
Salzburg, Austria
http://esaconferencebureau.com

TransNav 2017
21 - 23 June
Gdynia, Poland
www.transnav.eu

July 2017

IGS 2017: International GNSS Service Workshop
3 - 7 July
Paris, France
www.igs.org

IEEE Frequency Control Symposium and European Frequency and Time Forum
9 - 13 July
Besançon, France
www.eftf-ifcs2017.org

Esri User Conference
10 – 14 July
San Diego, USA
http://www.esri.com/events/user-conference/papers

August 2017

SEASC 2017
15-17 August
Brunei Darussalam
www.seasc2017.org/

September 2017

Interdrone 2017
6 - 8 September
Las Vegas, USA
www.interdrone.com

ESA-JRC Summer School on GNSS 2017
4 - 15 September
Svalbard-Spitsbergen, Norway
www.esa-jrc-summerschool.org

56th Photogrammetric Week '17
11-15 September
Stuttgart, Germany
www.ifp.uni-stuttgart.de/phowo

ION GNSS+ 2017
25 - 29 September
Portland, USA
www.ion.org

Intergeo 2017
26 - 28 September
Berlin, Germany
www.intergeo.de

October 2017

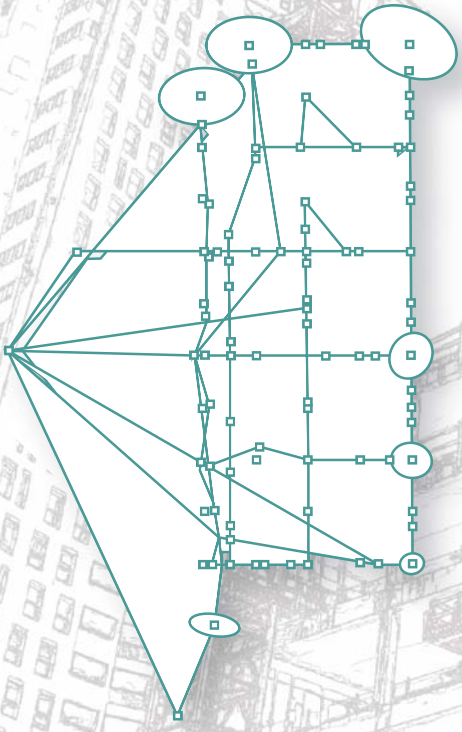
ACRS 2017
23 - 27 October
New Delhi, India
www.acrs2017.org

3D Australia Conference 2017
26 - 27 October
Melbourne, Australia
http://3dgeoinfo2017.com

Software you can build on

MicroSurvey STAR*NET and FieldGenius are used around the World by thousands of users each day and you can too!

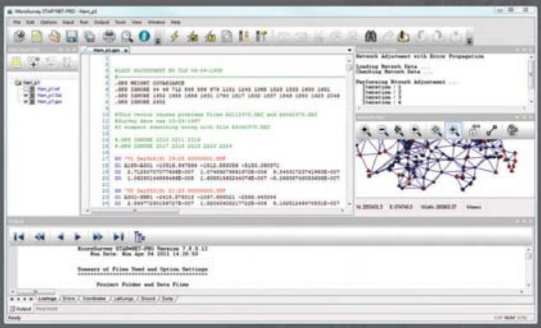
MicroSurvey STAR*NET



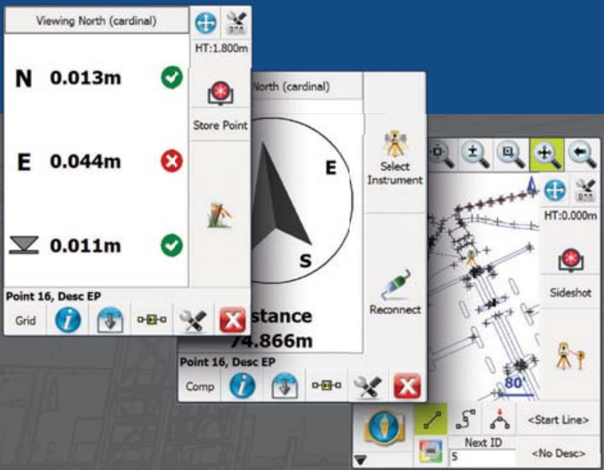
MicroSurvey STAR*NET is the world's best least squares adjustment software on the market

Network adjustments run much faster than previous versions, and the new Adjust Network with Cluster Detection command lets you combine measurement data for points with different names that fall within a specified 2D or 3D proximity of each other!

Download a free demo from our website:
www.microsurvey.com/starnet/demo



MicroSurvey FIELDGenius



MicroSurvey FieldGenius is the most easy-to-use survey data collection software in the world!

The latest release introduces some new productivity features and capabilities, improves the user interface and overall user experience, adds support for various new hardware models, and improves support for older hardware models.

Download a free demo from our website:
www.microsurvey.com/fieldgenius/demo

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Trimble RTX

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Challenging environments will no longer be a nightmare for you or your crew.

The SP60 offers a high level of flexibility to cover any survey demand from simple post-processing, through UHF or Long Range Bluetooth base and rover systems to sophisticated RTK and RTX rover solutions.

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Z BLADE TECHNOLOGY INSIDE

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