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# Coordinates

Volume XII, Issue 09, September 2016

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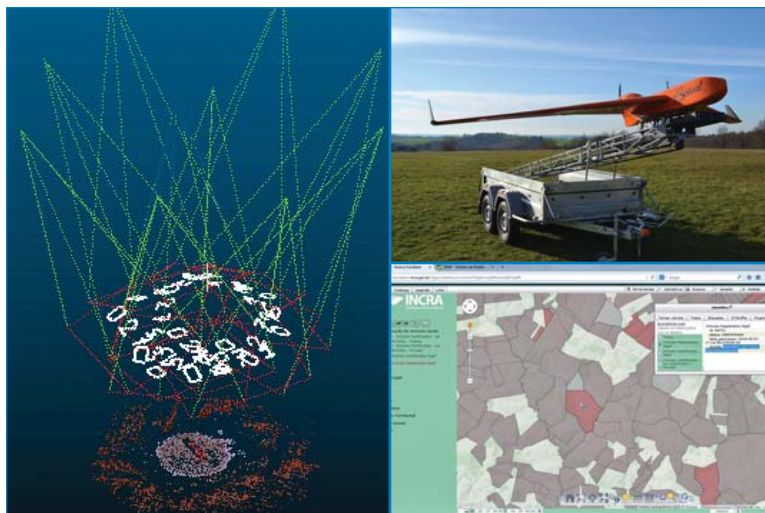


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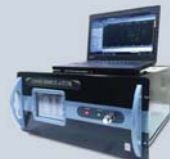
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## Save water

When the challenge is  
to produce 'more crop per drop',  
emergence of innovative applications  
appear promising.  
GNSS-Reflectometry sensor  
Embedded on the drone  
Using GPS and Galileo signals  
Flying over a given field  
To provide soil moisture maps...  
Technologies are converging,  
As highlighted appropriately in  
'GNSS to save water' (read page 8).

Bal Krishna, Editor  
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# GNSS to save water

First airborne campaigns demonstrated the feasibility of measuring soil moisture content using a GNSS reflectometry sensor embedded in a RPAS



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**B**etter management of water resources is one of today's biggest challenges.

At present, 70 percent of freshwater worldwide is used by agriculture. To feed an addition 2 billion people by 2050, the Food and Agriculture Organization of the United Nations (FAO) predicts a 300 percent rise in food production. As a result, water demand is expected to increase tremendously in the next few years. Farmers are challenged to produce "more crop per drop" (on the one hand, to reduce water consumption, and on the other hand, because of the increasing fuel price). In 2003, FAO reported that only 20 percent of arable lands are irrigated, but they almost produce half of global harvest, which means that irrigation more than doubles land productivity.

To face these upcoming challenges, it is key to raise water awareness and use this highly valuable resource in a more efficient way.

In order to optimize irrigation and avoid wastage, farmers have to provide the right amount of water at the right time, in the right place. To do so, better insights in the spatial and temporal patterns of soil moisture content (i.e., the water contained in the soil) are essential.

Although solutions for soil moisture measurements exist, they do not completely fulfil the agriculture needs: they either lack in spatial or temporal aspects (sometimes both).

When they don't rely on the nearest hydrological or meteorological station (that can be too far away to be representative), farmers use information from a single point sensor within the field. Even if continuous measurements (from a temporal point of view) can be performed, a single point does not allow to characterize

soil moisture spatial variability within the field. As a consequence, soil water content might be under or over evaluated for part of the field.

On the other side, satellite imagery can provide humidity indicators at global scale. Unfortunately, these images come with a low spatial resolution and with a consequent latency. For instance, SMAP mission (Soil Moisture Active Passive, NASA) final products, including soil moisture at 9km resolution, are available within 7 days after data acquisition. Another limitation of satellite measurements is that their periodicity is not flexible. For the ongoing soil moisture-dedicated satellites missions (such as SMAP or SMOS – Soil Moisture and Ocean Salinity, ESA), global earth coverage is achieved every three days.

To complement field measurements and satellite data, the objective of MISTRALÉ project (Monitoring soil moisture and water-flooded Area for agriculture and Environment) is to offer high resolution and on-demand soil moisture maps, based on a RPAS (Remotely Piloted Aircraft System)-embedded GNSS reflectometry sensor.

If soil moisture maps are an invaluable tool for farmers, monitoring the humidity content is also of prime importance to understand when excess rainfall will cause water logging and flooding.

## MISTRALÉ Principle

MISTRALÉ sensor relies on an innovative use of the GNSS (Global Navigation Satellite System) signals, which were initially designed for localization purpose. The well-known American GPS and European GALILEO systems are examples of GNSS that will be used to compute



soil moisture. The sensing technique is named reflectometry (GNSS-R). It consists in comparing the direct signals (i.e. the signals directly travelling from the satellite to the receiver) with those reflected by the ground. The comparison between the properties of the direct and reflected signals provides estimations of the soil water content. Thanks to the large flight envelope of the RPAS (low speed and low altitude), high spatial resolution of the soil moisture maps can be achieved.

## Sensor

GNSS-Reflectometry technique is especially appropriate for soil moisture monitoring. Indeed, at GNSS signals frequency (near 1.5 GHz), the characteristics of the reflection mainly depends on the Fresnel reflection coefficient, which is itself related to soil moisture content. Therefore, the computation the ratio between the ground-reflected GNSS signals and the direct one provides measurements of the soil's reflectivity, which can then be translated to humidity content. The direct GNSS signal is right-hand circular polarized (RHCP) by design. When reflected, the polarization is mostly inverted. The up-looking GNSS antenna is therefore RHCP, while the down-looking one is LHCP.

When it comes to soil moisture, using GNSS-R technique has several advantages compared to the other usual techniques such as visible/Near Infra-Red imagery.

Since GNSS signals lies in L-band, the GNSS-R is operational under cloud cover and during the night. In addition, it is less influenced by variation on the thermal background. Yet, it is worth noting that GNSS-R measurements are affected by soil roughness and by vegetation. Roughness impact can be mitigated using polarimetric measurements and computing the apparent reflectivity for both left-hand and right-hand circular polarizations reflected signals. Next to this, the attenuation of the reflected signal due to vegetation can be taken into account by using a corrective term (based on Normalized Difference Vegetation Index measurements).

## Platform

RPAS platforms have been chosen to carry the GNSS-R sensor above target fields. With respect to MISTRACLE goal, the expected advantages of an RPAS compared to manned aircrafts is the reduction of operational costs as well as a high flexibility to fly at the proper time.

Due to the high disparities between MISTRACLE potential users and missions, two types of RPAS have been identified: (i) a one-hour-endurance short-range RPAS, mainly for agriculture fields, and (ii) a long-range one, to monitor wider areas (required for flood-prone area surveillance or scientific purpose). The latter is able to fly continuously for 10 hours and has a range of 1000 km.

## GNSS-R techniques

Among the existing GNSS-R approaches, the two following have been considered: The waveform one (also called classical GNSS-R or cGNSS-R), which consists in comparing the amplitude of the direct and reflected GNSS complex waveforms (i.e. the correlator's output), and the SNR (Signal-to-Noise Ratio) method, based on the comparison of the SNR of the direct and reflected signal.

The advantage of the latter is that it does not require a reflectometry-dedicated GNSS receiver, since SNR is an output of classical GNSS receivers. Nevertheless, a strong specular reflection is needed to track the reflected component, which is hardly compatible with the high dynamics of RPAS flights.

If waveform technique suits MISTRACLE concept best, one main limitation is encountered at present time: the size and weight of this kind of sensors. Therefore, MISTRACLE aims at developing a dedicated waveform receiver with a form factor that makes the final product easy to install on a RPAS. This GNSS-R receiver uses both GPS and GALILEO signals, which improves the system performances. Thanks to a higher number of available satellites and to the GALILEO signals characteristics, the sensor's measurements accuracy is enhanced.

## MISTRACLE Processing chain

MISTRACLE processing chain is divided in onboard and ground parts. Coarse GNSS data processing is performed onboard in order to reduce the amount of data to be stored during the flight, then the soil moisture content computation is performed on the ground.

The different processing steps are gathered in Figure 2.

At first, inside the GNSS receiver, both direct and reflected Radio Frequency (RF) signals are down-converted to Intermediate Frequency (IF). Then, based on the IF signals, time stamped

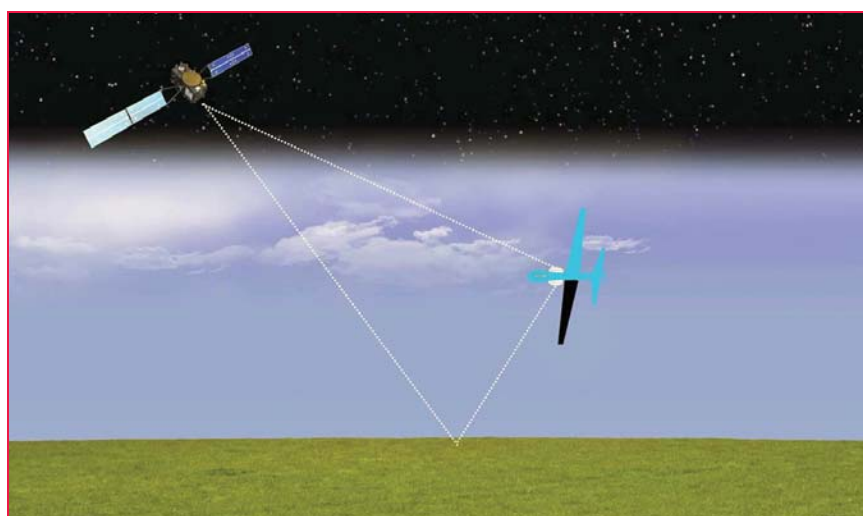


Figure 1: MISTRACLE Principle

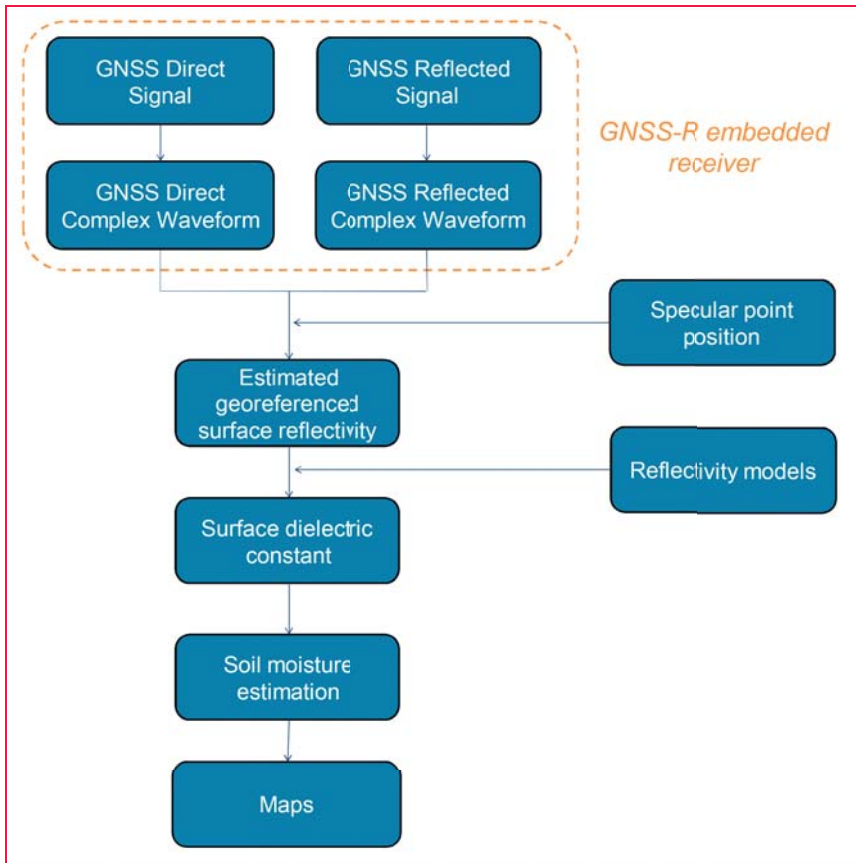


Figure 2: MISTRALE processing chain

complex cross-correlations waveforms and Doppler measurements are extracted (L0 data). In a third step, the direct and reflected complex cross-correlations waveforms are computed using the L0 data. These waveforms are the data stored during the flight.

Once back to the ground, the amplitude waveforms are obtained from the complex waveforms. After coherent and/or incoherent averaging (in order to reduce the thermal and speckle noise), the apparent reflectivity can be expressed as [1]:

$$|\Gamma'_{pq}| = \left| \frac{Y_{r,q}(\Delta\tau, f)}{Y_{d,p}(0, f)} \right|^2, \quad (1)$$

where  $Y_{r,q}(\Delta\tau, f)$  refers to the reflected waveform at RHCP polarization, and  $Y_{d,p}(0, f)$  refers to the direct waveform at LHCP polarization. The apparent reflectivity ranges between 0 and 1. The higher the reflectivity, the higher soil moisture content.

Each reflectivity measurement has then to be geo-referenced. The exact position

on the ground where the GNSS signal is reflected is called a “specular point”. The specular position of each reflectivity value is determined using both the position of the satellite and that of the GNSS-R receiver, coupled with Digital Elevation Map (DEM) of the area. The position of the receiver is computed based on the embedded GNSS/IMU hybridized receiver in order to account for the RPAS attitude.

By comparing the reflectivity values computed with theoretical model, the surface dielectric constant is determined.

Then, depending on the additional information available, different models can be applied to translate surface dielectric constant into soil moisture. For instance, Topp model [2] consists in translating empirically one into the other, whereas

Dobson one [3] expresses the soil moisture as a function of frequency, soil temperature, soil composition, bulk soil density, and soil particle density (in addition to the dielectric constant). The more ancillary data available, the more efficient the model.

Finally, the soil moisture maps are constructed using measurements of each specular point. The final map resolution depends on a high number of parameters (some being mutually dependent): the RPAS altitude and speed, the data sampling rate, the distance between two parallel tracks, and the GNSS constellation geometry (number of satellites and their altitude and elevation) together with the elevation mask. Last but not least, all these parameters have to be related to the RPAS endurance and the size and shape of the target area.

## Test flights and preliminary results

At present, the MISTRALE-dedicated sensor is being integrated and initial test have been performed. It is worth mentioning that several experimental flights have already been carried out.

The first ones took place in the South of France (Camargue & Pech Rouge) in July 2015 and aimed at validating the technical feasibility of MISTRALE concept. To this end, a high-end bit grabber was embedded on an ultra-light aircraft, its form factor not allowing integration on an RPAS. Two antennas were screwed into the plane (see Figure 3): one on the top, which receives the direct GNSS signal, and one on the bottom, which receives the reflected GNSS signal. The top antenna is Right Hand Circular Polarized



Figure 3: Antennas on the top (left) and on the bottom (right) side of the plane

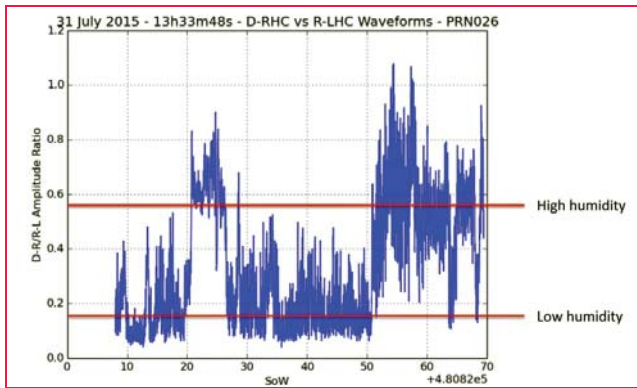


Figure 4: Surface reflectivity

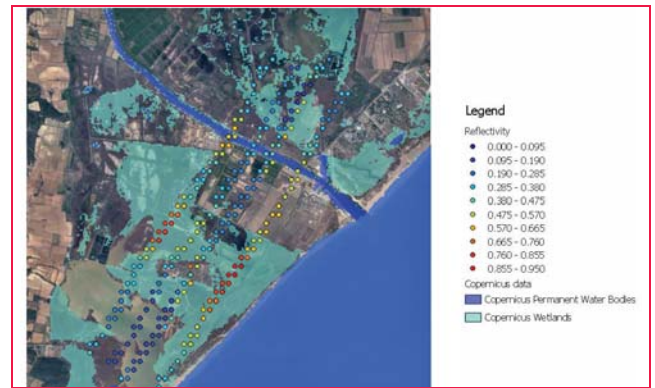


Figure 5: Comparison between MISTRAL reflectivity and Copernicus Data

(RHCP) whereas that of the bottom is Left Hand Circular Polarized (LHCP) (signal polarization changes when reflected).

Both direct and reflected signal have been recorded and a GNSS-R waveform software receiver was then used in post processing to compute the GNSS waveforms. Then, part of MISTRAL processing chain has then been performed to provide preliminary results. Figure 4 displays the estimated surface reflectivity for one satellite (PRN 26). High and low reflectivity areas can be distinguished. After cross validating with aerial photography as well as satellite imagery (see Figure 5), it appears they indeed corresponds to high and low humidity areas, which validates MISTRAL approach, i.e. performing soil moisture measurements with a waveform GNSS-Reflectometry sensor onboard flying platform.

The second flight campaign was conducted in Toulouse area in January 2016 using the Boreal RPAS (long-range RPAS from AJS, see Figure 6). This experiment aims at testing the other GNSS-R technique (SNR-based) with a low-cost setup: classical Ublox 6T GNSS receiver and low-cost GNSS antennas (both RHCP). This approach suffered from strong limitations due to the use of low cost antennas (both RCHP), making the reflected signal (which is mainly LHCP) hard to retrieve.

A third test campaign was scheduled in July 2016, using the same low-cost receiver as in the previous one, but this time with dual-polarized antenna, enabling to receive both RHCP and LHCP reflected signal. The data are under processing.

Finally, by end 2016, MISTRAL-dedicated reflectometry receiver will be ready for test flights on the Boreal RPAS.

## Conclusion

First airborne campaigns demonstrated the feasibility of measuring soil moisture content using a GNSS reflectometry sensor embedded in a RPAS, and produced valuable data for the development and calibration of the GNSS-R algorithm. MISTRAL-dedicated subsystems have been developed and their integration in the RPAS is ongoing. Field testing of MISTRAL prototype is scheduled for end 2016.

## Acknowledgments

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Figure 6: Boreal RPAS

# Brazil towards an effective cadastre with SIGEF

Brazil has developed the Land Management System - SIGEF: a cadastral digital platform for public and private lands, based on the Brazilian Public Records Act



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A fundamental problem for the Agrarian question in Brazil was and has been the lack of clear information of rural properties. The lack of Cadastre, according to international standards, is a notorious fragility over the time.

The description of rural properties, due to different interpretations of the object, is one of several reasons for land issues. In this situation is common the occurrence of differences between the current situation on the ground, and what is documented and formalized on Registry.

In this uncertainty scenario, over time, some situations occur such as:

- agrarian conflicts;
- misappropriation of public land;
- threats of territorial rights of traditional populations;
- environmental irregularity associated with criminal exploitation of natural resources and inability of accountability;
- reduction of productive potential.

However, this situation began to be changed with the advent the Law 10,267/2001, based on a solid concept of Cadastre. It established, at a glance: georeferencing as the method to represent land parcels; responsibilities of professionals and institutions for accountability; cadastral validation, called certification; the connection between the land institute and Registry for data exchange and mutual updates.

The certification process adopted and controlled by land institute, INCRA, established by Law 10,267/2001 and Decree 4,449/2002, consisted of a lengthy process that demanded the delivery of

papers. In addition, INCRA, responsible agency for operate certification process, did not have sufficient operational capacity to answer the demand. The institute also did not have sufficient number of specialized professionals to be allocated in this exhaustive process created, regarded to manual information conference.

To streamline the certification process of rural properties, some actions should be taken to tackle the above problems, focusing on the construction of a land cadastre to identify, clearly and precisely, the domain boundaries and allow the sharing of such information to perform land management. In this way, is was developed a tool called Land Management System (Sistema de Gestão Fundiária - SIGEF), to manage the certification process with a full digital approach.

## Objective

The purpose of this article is to show the approach applied to the cadastral surveyed data in Land Management System (SIGEF), in particular with respect to statement 3 of Cadastre 2014, regarding to the role of maps in Cadastre (Kaufmann and Steudler, 1998).

## Cadastre 2014

Cadastre 2014 was a FIG activity report, published in 1998, that, over the years, has been translated into 28 languages and was a topic in many forums, panel discussions, roundtables and journal articles. It became a reference publication in many teaching and research institutions, triggered researches, promoted

additional considerations on issues related to cadastral systems, including developments such as the “Cadastral Template” and in the field of “Spatial Data Infrastructures” (Stuedler, 2014).

The document brought, also, an updated concept of Cadastre (Kaufmann and Stuedler, 1998):

*Cadastre 2014 is a methodically arranged public inventory of data concerning all legal land objects in a certain country or district, based on a survey of their boundaries. Such legal land objects are systematically identified by means of some separate designation. They are defined either by private or by public law. The outlines of the property, the identifier together with descriptive data, may show for each separate land object the nature, size, value and legal rights or restrictions associated with the land object.*

The visionary publication made six statements about the Cadastre, presenting a clear vision for cadastral systems in the future as well as being an excellent review of the strengths and weaknesses of cadastral systems of that time (Kaufmann and Stuedler, 1998).

In this paper, we will focus on the Statement 3, that regards to The Changing Role of Maps, defined by the following concept (Kaufmann and Stuedler, 1998):

*If future cadastral systems are to meet the requirements, the function of maps must be re- defined. Maps will lose the function of information storage. They will serve in future simply to represent information derived from data stored in databases.*

*The new possibilities of information technology will change the work of surveyors significantly. In the past, the ability to survey objects and to represent them in a reference system needed very special skills. One of the most important things was the craft to represent measured objects in a comprehensible map.*

Then, the traditional Cadastral Cartography method consists in surveying and mapping. It is focused to

locate the land objects and draw them on a map. Looking to the future, based on available technology, (Kaufmann and Stuedler, 1998) proposed that:

*The modern method of creating maps and documents out of data models would correspond to the flow: localization of objects by surveying, calculation of coordinates, modelling of objects according to data model, storage of objects in an information system, plotting of maps and creation of other products such as statistics, reports, documents, etc.*

In this vision, the surveying is the way to product data that is formatted in a model and stored in a land information system, from which the documents, statistics and other information are provided to society, according to its different needs:

*Maps are created out of this model by using representation functions, operating plotters and drafting machines.*

*The distribution of information increasingly takes place with the help of data transfer possibilities. Geographic information is sent over the data highways. The Internet and its ability to facilitate worldwide data networks is playing an important role in the exchange of cadastral data. The exchange of data models will become common practice in the distribution of cadastral information.*

This new procedure has several advantages:

- *Flexibility in the representation of information of the data model. Type, scale, and content of a representation can be chosen according to the needs.*
- *The information is stored once and different products are derived from the same data.*
- *The digital model is easy to handle, and data representing the model cannot be destroyed physically as can traditional maps.*
- *Distribution and publication of cadastral information is easily possible with the help of the exchange of digital data models.* (Kaufmann and Stuedler, 1998)

From now on, we will show how we proposed to achieve this goal, at the same time, abolishing the use of paper, implementing a digital cadastral data model and generating products from it.

## The problem of reference

Following the concept of Cadastre seen previously, the purpose of a cadastral system is to identify legal land objects in a systematic way, with unique ID, and show, for each one, features like nature, size, value, associated rights and restrictions (Kaufmann and Stuedler, 1998). This means, at a glance, representing these objects, aggregate information to them and report the result.

To represent this legal territorial object, maps are traditionally used. In this paradigm, as shown in the previous section, the measured objects are drawn on a map. In cartographic terms, this means that the data is collected in the field and converted to a plane of reference.

From this plane are obtained position and form (angles and distances) informations, for one or more parcels, considering their individual and relative situations. While we understand that the coordinates of the vertices that define the limits are the most important data, is easier to “end users” that measures of angles and distances be available, as them deals with the physical measures of the land and are not specialists in topography. So, the plane of reference is important for cadastral mapping to generate these measures. If a very general reference plane is used, distortion can be generated compromising the cadastral purpose.

Since 2003, when the georeferencing of rural properties was regulated (In Brazil, the Cadastre is not unique: there are urban cadastres, controlled by municipalities, and one rural land tenure Cadastre, regulated by Federal Government.), the projection used to represent the property was the UTM (Universal Transverse Mercator). The UTM projection has a longitudinal range of about 800 km (on equator). So any other projection, it is more suitable

to represent areas compatible with its extent. In general, the greater compatibility between the reference plane and the spatial object, the greater proximity to surface measurements, due to distribution of the distortion by the extension. In UTM case there is a 1:2,500 reduction (0.9996) in the central meridian and the variation reaches 1 part in 1,000 from true scale at the Equator (SNYDER, 1987). For cases of rural properties that are located in central and extreme regions of projection, this is particularly harmful to obtain area and distances, so important to Cadastre.

Thus, one of the concerns when reviewing the cadastral data production process in Brazil, was the need to apply a new projection feature for territorial parcels, that was as close to reality as possible. It should allow to represent them individually, providing values compatible with the field and, at the same time, maintain such consistency considering neighbourhood. This should also lead to produce more intelligible information for the general public. This procedure was only possible, however, with an electronic tool capable to implement it.

## SIGEF

The Land Management System - SIGEF was, according to the regulations, developed to make the reception, validation, organization, regulation and availability of geo-referenced information limits of rural, public and private properties. Despite “Land Management” could be related to several applications, the focus of the system is to deal with land tenure.

At a glance, the system comprises the following features (INCRA, 2015b):

- Professional Accreditation to be able to submit cadastral data;
- System user authentication with digital certification, following patterns of Public Key Infrastructure (ICP-Brasil);
- Reception of standardized geo-referenced data via internet;
- Fast, impersonal and automated validation, in accordance with the established technical parameters;
- Automatic generation of technical parts

(plant and Legal Description), with the possibility of online authenticity check (via QR code or URL);

- Electronic management of requests concerning parts: certification, registration, dismemberment, merge, rectification and cancellation;
- Possibility of including updated information from the Land Registry (registration and owner) via the Internet, allowing an effective and fast synchronization;
- Management georeferencing service contracts with the government, with dedicated access to government agencies, companies, and tax officials;
- Public search of georeferenced parcels, requirements and credentialed surveyors;
- History of the parcels: access to requirements for each parcel, including dismemberment and merge possibility (not implemented yet).

## The cadastral model of SIGEF

To provide measures with values closest as possible to the cadastral territorial object, it was proposed to use a Local Topographical Plane (PTL) for each parcel, obtained from a Local Geodetic System (SGL) (MDA, 2013c).

Although it is closer to the form of land object, the use of PTL has the inconvenience of not providing homogeneous measures in neighborhood situations. As each parcel has its own plane of reference, for the same boundary (shared between two parcels) we would have two different angle and distance values.

Thus, to meet the goals of consistent representation of cadastral land objects, considered individually and together, a new model was built, based not only in one reference, but in three: one for each required measure.

## The Representation Model

According to the model applied, the land cadastral object would be represented by three elements: vertex, limit and parcel. For the purposes of this paper,

we will discuss only the geometrical characteristics of these objects.

The definition of these land cadastral objects are described in regulations for the execution of the rural land survey. They are: Norma Técnica de Georreferenciamento de Imóveis Rurais - Technical Standard for Georeferencing of Rural Property (MDA, 2013c), Manual Técnico de Limites e Confrontações - Technical Manual for Limits Identification (MDA, 2013a) and Manual Técnico de Posicionamento - Technical Manual for Positioning (MDA, 2013b). The first one regards to definitions and general parameters, as reference system, professional accreditation, positioning precisions among others. The second one discusses in more detail how the professional identifies the boundaries in the field, from legal definitions. The third one addresses techniques used to determine the coordinates of identified limits, composing parcels.

Another regulation, the SIGEF Manual, considers how to format, present and submit the data to the system, using its web interface (INCRA, 2015c).

## Vertices

The third edition of Technical Standard for Georeferencing of Rural Property (MDA, 2013c) define vertex as:

*the point where the rural property boundary line changes direction or where there is intersection of this line with any other boundary line of adjoining property.*

Presenting the results of the survey, the credentialed surveyor must describe it using geodetic coordinates ( $\varphi$ ,  $\lambda$ ,  $h$ ), referenced to the Brazilian Geodetic System (MDA, 2013c).

Upon receiving the data, after system validation and confirmation of the surveyor, the system stores the data in the database. At the vertex model, the geometry of the point is recorded using two different references: latitude, longitude and altitude ( $\varphi$ ,  $\lambda$ ,  $h$ ), the same as the inserted data; and also converted into Geocentric Cartesian Coordinates, as defined (MDA, 2013c):

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Geocentric Cartesian Coordinates are referenced to three orthogonal axes with origin at the center of mass of the earth, the "Z" axis oriented toward the Conventional Terrestrial Pole, the axis "X" in the mean direction of Greenwich meridian and the axis "Y" so as to make the system dextrorotatory.

All geometries are referenced to the GRS80 ellipsoid, used by the Geocentric Reference System for the Americas, in its 2000 realization - SIRGAS 2000 (IBGE, 2005).

## Limits

The limits indicate the change of rights in the territory. Geometrically, according to MDA (2013c), the limits are described by line segments. Thus are not allowed curved elements, such as circular arcs, elliptical arcs, and others, in the description of boundaries of rural properties.

The limit is modeled with line geometry. The representation is also recorded with two different references: one-dimensional latitude and longitude coordinates and another which corresponds to the calculated horizontal distance in space, from the geocentric Cartesian coordinates of the vertices (X, Y, Z).

## Parcels

According to MDA (2013b), the rural property to be considered in georeferencing is that object of the domain title, that origins the registration. A certificate will be awarded to each land parcel and this will be described in a separate registration in the land registry.

For land parcel model, are also used two geospatial references. The geometric type used to represent it is the polygon. One geometry is recorded with geodetic longitude and latitude coordinates and another one in plane coordinates.

To obtain the plane coordinates, two steps are performed. First is calculated a local geodetic system (MDA, 2013c):

*The Local Geodetic System (SGL) is a Cartesian system that consists of*

*three mutually orthogonal axes (e, n, u), where "n" axis points toward the north geodesic, the "e" axis points to the east direction and is perpendicular to the axis "n", both contained in the topographical surface and the axis "u" coincides with the normal to the ellipsoid passing through the vertex selected as the system origin.*

From this reference system are calculated the plane coordinates on the Local Topographical Plane (MDA, 2013b):

*Local Cartesian coordinates are Cartesian coordinates defined in a Local Topographical Plane, perpendicular to the ellipsoidal normal and tangent to the Earth's surface at the point of origin Local Geodetic System (SGL).*

$$\begin{bmatrix} e \\ n \\ u \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \sin\phi_0 & \cos\phi_0 \\ 0 & -\cos\phi_0 & \sin\phi_0 \end{bmatrix} \begin{bmatrix} -\sin\lambda_0 & \cos\lambda_0 & 0 \\ -\cos\lambda_0 & -\sin\lambda_0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X - X_0 \\ Y - Y_0 \\ Z - Z_0 \end{bmatrix} \quad (1)$$

where:

*e, n, u = local Cartesian coordinates of the vertex of interest;*

*X, Y, Z, = geocentric Cartesian coordinates of the vertex of interest;  $\phi_0, \lambda_0$  = latitude and longitude adopted as system origin;*

*X<sub>0</sub>, Y<sub>0</sub>, Z<sub>0</sub> = geocentric Cartesian coordinates adopted as the source of the system.*

The coordinate values e, n, u are used to write the second geometry of the parcel on the database.

## System outputs

Using the geospatial data presented, calculations are performed to obtain the data of area, angle (azimuth) and distance. Each calculation is performed using a particular reference, not the same for the three objects. Is important to note that the option to write the geospatial data using different spatial reference systems was made in implementation level. It would be possible to obtain the outputs with calculations on demand, but was considered that this could reduce performance over the time.

## Distances

The base formula for obtaining the distance is as follows (MDA, 2013b):

$$d_s = \sqrt{(X_A - X_B)^2 + (Y_A - Y_B)^2 + (Z_A - Z_B)^2 - (h_A - h_B)^2} \quad (2)$$

where:

*dh = horizontal distance;*

*X, Y, Z = geocentric Cartesian coordinates; h = ellipsoidal height.*

Using the data model of limit, the straight line information corresponding to the horizontal distance has been already recorded. The value of distance is obtained using the *st\_length* function (Postgis, 2015a), provided by PostGIS (PostGIS, 2015b), the spatial extension of PostgreSQL (POSTGRESQL, 2015), the database manager system used in SIGEF.

## Angles

To calculate angles (azimuth) was applied the inverse problem of Puissant, which uses the given position of two vertices ( $\phi, \lambda$  and  $\phi', \lambda'$ ) and ellipsoidal parameters to determine ellipsoidal distance and its azimuth (MDA, 2013c).

## Area

To obtain the value of area, the geometry used is that recorded in plane coordinates (e, n, u), over which is applied the *st\_area* function, provided by Postgis database extension (POSTGIS, 2015a). This function implements the Gauss formula, the same set by georeferencing regulations (MDA, 2013c):

*The area calculation must be performed by the Gauss formula, based on local Cartesian coordinates (e, n, u) and expressed in hectares.*

## Showing results

To provide the data, either individually or together, the different client applications (including SIGEF itself) use the geometries written in longitude and latitude. The use of



the same reference system for all datasets is what allows direct access to the database and overlay them on the map (Figure 1), using softwares like QGIS (QGIS Development Team, 2014). The data follow the Simple Features Specification (SFS) standard of the Open Geospatial Consortium (OGC).

Another example of data providing is available in <http://acervofundiario.incra.gov.br> (INCRA, 2015a) which allows the overview of the surveyed parcels with other geospatial data themes, via WEB, available for public consultation (Figure 2).

The parcel's details webpage (Figure 3) provides its geometric characteristics, nature, legal situation (with or without confirmation of Registry), holder (one or many) and other information:

- parcel code, area, input date and status;
- georeferenced area: other parcels related to the same property are linked;
- holder/owner;
- registry: Registry Office name, municipality, code, property id and status;
- map, with imagery on background;
- vertices: code, geodetic coordinates,

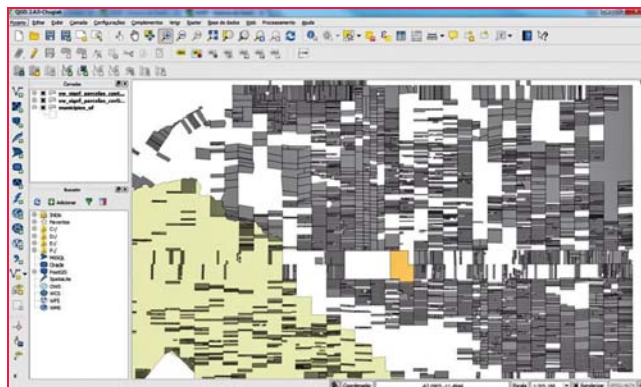


Figure 1: Land parcels visualized on desktop with QGIS

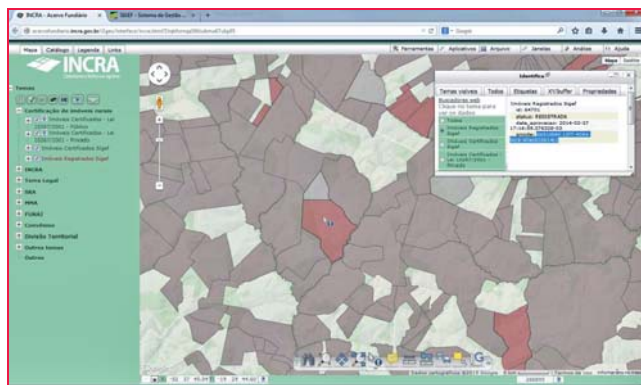


Figure 2: Land parcels visualized on the webmap interface called i3Geo

- high, precisions and method used;
- limits: vertices linked, type, azimuth, length and neighbour description;
- applications opened by surveyors, like cancelling or Registry information updates;
- data download: shapefile, kml and csv formats;
- credentialed surveyor's name and code, ART (code of technical responsibility document), link for parcel's submission web page and date of the submission.

### Documents

The functionality of document generation was developed to meet the need for communication with the end user. Also caters to the Registry, which still does not fully work in digital media.

The map provides geographical information of the parcels. The target parcel is shown with darker gray fill. The neighboring parcels are shown in light gray. The limits of

codes of the vertices, the numerical values of geodetic coordinates, heights, distances, azimuths and description of neighbours, informed by surveyor.

In both documents is generated a Quick Response Code (QR code), with the parcel unique code and the URL of your details page on the web, as shown above. This code may be used by optical readers connected to the internet, common in mobile devices such as smartphones. This functionality allows any user to check the documents and the current situation of the parcel without the need to enter codes manually, avoiding mistakes.

### Conclusion

The aim of this paper was to show some characteristics of Land Management

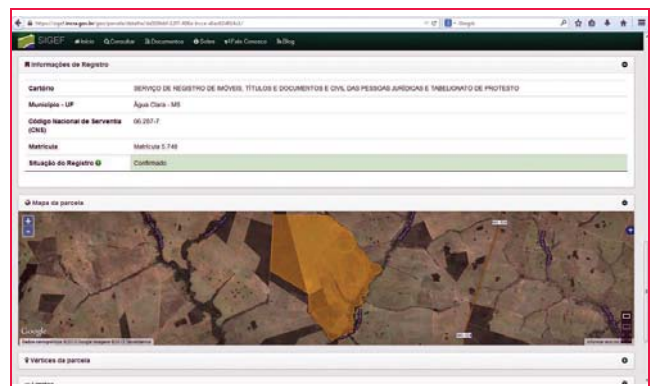


Figure 3: Partial visualization of land parcel webpage on SIGEF interface

the target parcel are represented in different line colors and thicknesses, according to the standard classification. The use of this symbology is aims to facilitate the interpretation of the map by the user.

The Legal Description (called Memorial Descritivo, in portuguese) document contains the

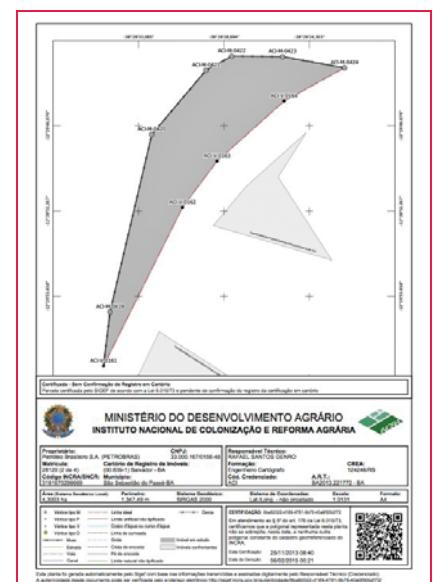


Figure 4: Map downloaded from SIGEF, in Portable Document Format (PDF)

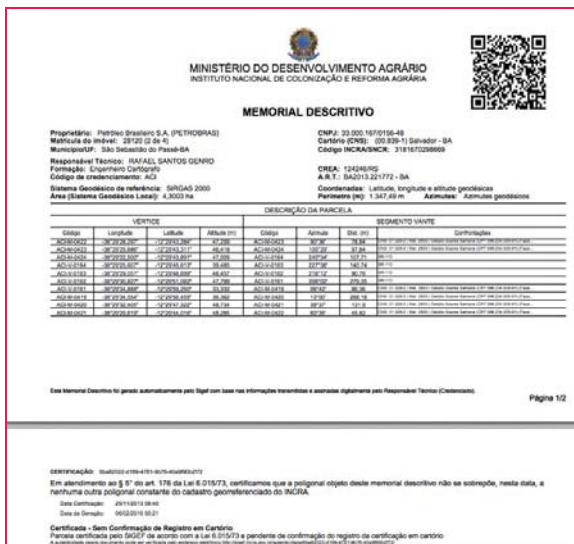


Figure 5: Memorial Descritivo document, downloaded from SIGEF

System (SIGEF) regarding to the statement 3 of Cadastre 2014 (Kaufmann and Steudler, 1998): that in future cadastral systems, with the utilization of information technologies, the direct drafting of objects on a map would be superseded by the creation of objects in an information system and, then, the data should be provided to different needs in different formats.

It was shown that, with the conceptual model implemented with SIGEF, was possible to receive cadastral surveyed data in one geospatial reference system and, using information technological resources, to transform and provide them to end users, according to their needs. These products include web pages, dynamic maps and documents. At the same time, due to the spatial references used, the measuring data provided are more accurate than if were used a conventional reference system for cadastral cartography.

Therefore, we conclude that the treatment given to cadastral data, implemented with SIGEF, accomplishes the statement number 3 of Cadastre 2014. This represents a breakthrough for Brazil in cadastral management.

However, we treated here of only one aspect of Brazilian Cadastre. Despite this and some other achievements, Brazil has big challenges to establish an effective Cadastre of its lands. Even using a tool like SIGEF

to manage cadastral data, it is not possible to go further without facing and overwhelm some big challenges, like establish synergy among governmental agencies to perform, together, land governance using complementary cadastral concepts.

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# An SDI model to spatially enable peri-urban areas in Mozambique

The City of Maputo lacks accessible telecommunications spatial datasets and databases for its planning community, local governmental agencies, local businesses, utilities and telecommunications companies, and the general public



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The majority of telephony service subscribers in the City of Maputo – Mozambique’s capital and largest city – are from mobile networks. However, the level of Quality of Service (QoS) and mobile coverage offered by current licensed carriers remains a challenge in peri-urban areas, which are areas with mixed rural and urban features with a lack of urban attributes such as accessibility, services, infrastructure, etc., (Allen, 2003).

The current spatial distribution of 3G mobile cell towers is not in accordance to the dynamics caused by the population growth since the last national census. It requires improvement, achieved by the formulation of spatial planning frameworks. The National Institute of Communications of Mozambique (INCM) – the telecommunications regulatory authority – lacks an appropriate framework to monitor QoS in a common environment to spatially evaluate the coverage of licensed carriers and protect the interests of mobile subscribers.

In this context, open source tools such as QGIS and paid software from Esri (ArcGIS)

were used to allow manipulating, visualizing and analysing INCM captured data in 2013, used to visualize the full distribution of 3G cell towers across Maputo. The results were linked to the census data provided by the National Institute of Statistics (INE) to evaluate the appropriateness of the current allocation of telecommunications resources. This is where the focus of the data analysis relied: evaluating how the distribution of current 3G cell towers accommodates the five urban zones from Maputo, and how the visualization could support decision-making to INCM as a regulatory authority, to improve QoS and mobile network performance.

The findings from the case study served as an input to develop a specific Spatial Data Infrastructure (SDI) model for Maputo to help respond to the research problem of this study – *the non-existence of a common platform for data sharing and exchange to facilitate decision-making for infrastructure planning (especially in the context of telecommunications)* – using three-tier architecture, to offer holistic and more coordinated planning in peri-urban areas in the City of Maputo.

Table 1: Summary of spatial development initiatives in Mozambique (1995 – 2013)

	1995	1999	2011	2012	2013
Jurisdiction or Organization	Ministry of Agriculture	The Catholic University of Mozambique	Institute of Agricultural Research of Mozambique	Ministry of Planning and Development & Ministry of Transport and Communications	Ministry of Mineral Resources
Initiative Program	CENACARTA (National Cartography and Remote Sensing Centre)	Centre of Geographical Information (CIG)	WEB-GIS Moçambique	National Spatial Development Program (SDP)	Mozambique Mining Cadastre Portal
Status	Operational	Operational	Unknown	Unknown	Operational

## Introduction

The need is growing for data to be organized across different organizations and jurisdictional levels for planning purposes. The City of Maputo lacks accessible telecommunications spatial datasets and databases for its planning community, local governmental agencies, local businesses, utilities and telecommunications companies, and the general public. There are SDI and spatial development initiatives in Mozambique (shown in Table 1), however, neither of them established a common platform with shared access to integrate telecommunications spatial data and services for infrastructure planning.

Further, INCM's current framework does not provide spatial visualization to allow effective decision-making over current issues associated with public telecommunications services. For instance,

licensed carriers are required to submit statistical reports to INCM on a regular basis. One of the things being reported is the complete inventory of cell towers, also used to evaluate the level of QoS and mobile coverage over a certain area. The reports are submitted on a previously agreed template, in Excel format. Proximity patterns however, are hard to see in spreadsheets. These are not effective to support decision-making.

## About the study area

Mozambique is located in the South-East part of Africa (Figure 1). It has boundaries with six countries: Tanzania to the north, Malawi and Zambia to the north-west, Zimbabwe to the west, South Africa to the south and Swaziland to the South-West. It has a coastline on the Indian Ocean to the east of approximately 2500 kilometres. The country has an overall area of 799,380 square

kilometres and a population of 26,423,623 million people (INE, 2014). The major cities are Maputo in the south, Nampula in the north, and Beira in the centre. As a previous Portuguese colony, Mozambique adopted Portuguese as its official language. Metical is the national currency and the greatest contributors to the economy are agriculture, fisheries and exports.

## Study area: the city of maputo

The City of Maputo has an area of 347 square kilometres (INE, 2011) divided into



Figure 1: The geographic location of Mozambique. Source: Operation-World (2016)



Figure 2: The study area: the five administrative zones of the City of Maputo

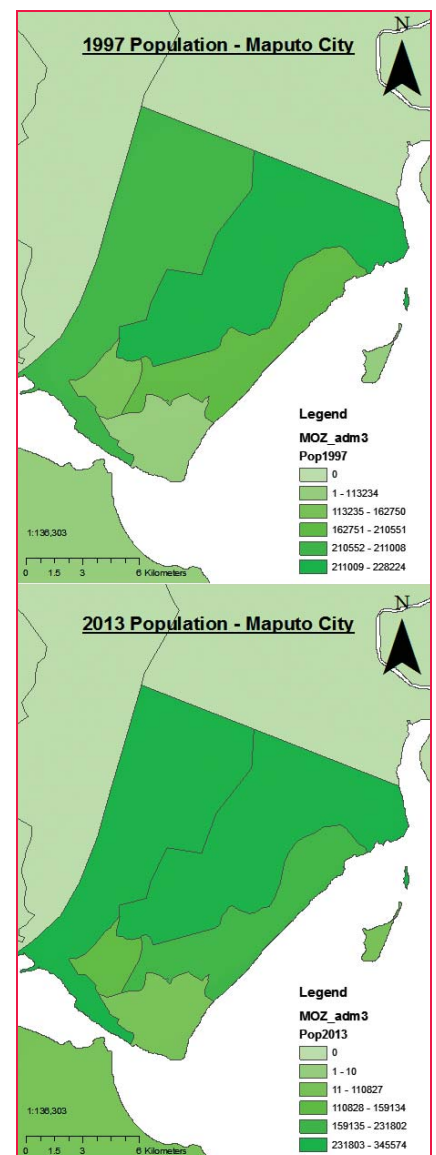


Figure 3: Visualization of the population trends and dynamics in Maputo, between 1997 and 2013. Six classes were used to map the suburbanisation process that occurred. Data source: INE (2010a)

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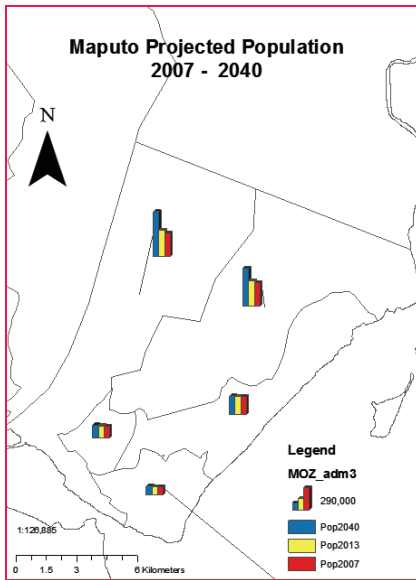
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**Figure 4: Visualization of the projected population between 2007 and 2040.**  
Data source: INE (2010b)

seven administrative zones: KaMpfumo (zone 1), KaNhlamankulu (zone 2), KaMaxakeni (zone 3), KaMavota (zone 4), KaMubukwana (zone 5), KaTembe (zone 6) and KaNyaca (zone 7). Figure 2 shows the selected study area. Zones 6 and 7 were not considered for being geographically displaced from the mainland.

Since the late 1990s, Maputo population has been migrating from dense metropolitan areas to adjacent and accessible peri-urban areas in search of better residential and lifestyle opportunities while continuing to work in the city. KaMavota (zone 4) and KaMubukwana (zone 5), were the urban zones which registered the greatest impact on population growth. These are considered peri-urban regions, which are areas with mixed rural and urban features with a lack of urban attributes such as accessibility, services, infrastructure, etc., (Allen, 2003). The result of the suburbanisation process occurred is presented in Figure 3, as mapped in ArcGIS using six distinct classes.

According to INE data, Maputo will be experiencing further suburbanization until 2040. Figure 4 maps the projected population for the 2007-2040 period, according to INE (2010b), also produced in ArcGIS.

## SDI and latest trends in development models

The literature revealed that the effective use of general infrastructure for developmental purposes (whether for telecommunications, water systems, transportation, strategic planning, etc.), is dependent on the availability of *Spatial Information* (Isa (2016)). This is supported by SDI as a strong decision-making tool. The concept of SDI, however, has evolved over the past decade. Its evolution divides SDI into three generations as suggested by Sadeghi-Niaraki et al. (2010): data-centric SDI, process-centric SDI, and user-centric SDI. In the first two generations, SDI users were passive recipients of the spatial data being shared, whereas in the user-centric generation, the users are active receivers as their interests are taken into account.

Several ways were found to define *SDI* as a tool to improve decision-making. Toomanian (2012) defined SDI as a mechanism to facilitate spatial data by providing an environment for essential collaboration and cooperation among different organizations. SDI pioneers Rajabifard and Williamson (2001), defined it as an initiative intended to create an environment in which stakeholders are able to cooperate and interact with technology to better achieve their spatial information objectives at different political and administrative levels.

Also from the literature, Roche (2014) proposed that for a society to be regarded as spatially enabled, citizens must be spatially literate followed by the existence of an environment to open and share spatial data. Therefore, Maputo should be able to support critical spatial thinking if it considers the adoption of certain components to facilitate the coordination of comprehensive strategic spatial policies.

Various SDI models and architectures were reviewed in different contexts of planning, including telecommunications. Mansourian et al. (2005) model, initially developed to facilitate disaster response, presented a high level of detail clarifying the five SDI components originally proposed by Rajabifard and Williamson (2001), making it almost a classic template for SDI modelling.

The model proved to be useful, particularly in reducing the time response by a third. This was achieved by having the required information available and accessible, as well as conducting appropriate planning prior to operational responses, crucial in disaster and emergency situations. This relates to what the problem is in Maputo, although in a different context – that is, resolving spatial data issues within the telecommunications sector for proper resource allocation to serve the growing demand in a timely and effective manner. Recent models from Coutinho-Rodrigues et al. (2011), Barik and Samaddar (2014) and Painho et al. (2015), showed that trends in SDI conceptual models and architectures used for planning applications are oriented to:

1. SDI as a *Spatial Decision Support System (SDSS)*
  - Specifically, SDI as a decision-making tool for investment options for infrastructure planning;
  - Using multi-criteria decision support methods (MCDA).
2. SDI models with *3-tier architecture*, consisting of client/presentation layer, application/service layer and data storage layer *based on open source software*.
3. SDI third generation: *process-centric to user-centric models, supported by questionnaires and interviews methodology*, to better consider the interests of stakeholders.
4. Naming *SDI models and initiatives with a suggestive acronym* based on context and applicability.




These four points summarize the contributions of the literature to this research. Specifically, *The Modelo Digital* – the name of Painho et al. (2015) system – was of relevance as it is a complete SDI for managing and sharing spatial data for partnerships, developed in the Zambezi Valley in the Central-North of Mozambique. Finally, frustrated SDI initiatives in Western Africa inspired Dekolo and Oduwaye (2014) to develop a generic roadmap for SDI development in African cities in the context of urban and spatial planning. This was used in this study, supported by a case study approach in the telecommunications sector, to benefit the planning community in Maputo.

## Case study: Mobile telecommunications operators

According to INCM's 2013 annual report, Mozambique had 71 telecommunications service providers. This included 1 fixed operator, 3 mobile operators, 3 broadband operators for national access, 2 broadband operators for international access, 25 internet service providers, 3 cable TV operators, 3 satellite TV operators, 1 global mobile operator, and 30 value-added services operators.

The current mobile licensed carriers are summarized in Table 2. They operate in both 2G and 3G technologies with fairly good coverage in metropolitan areas. Moçambique Cellular (MCEL) was the country's very first mobile service provider, established in 1997. It is owned by TDM and holds about 48% of the market, corresponding to 5,884,808 subscribers. In 2003, Vodacom Moçambique (VODACOM) was established – the country's second mobile service operator. It is owned by Vodafone South Africa and holds about 30% of the market, or 3,729,549 subscribers.

Table 2: Mozambique's major mobile telecommunications licensed carriers. Data Source: INCM (2013)

Mobile Operators			
Established	1997	2003	2012
Background	TDM (Mozambique)	Vodacom (South Africa)	Viettel (Vietnam)
Market Share	48%	30%	22%
Subscribers	5,884,808	3,729,549	2,490,310
Global Subscribers	12,104,667		
Country Population	24,366,112		

Movitel is the country's third licensed carrier, established in 2012. It is owned by Vietnam's Viettel and holds about 22% of the market, corresponding to 2,490,310 subscribers (INCM, 2013).

Figures 5 visualises the complete 3G cellular antenna distribution for each mobile operator, as produced in QGIS using the INCM collected data and INE projected population until 2013. During this period, half of the city population lived in KaMubukwana (zone 5) and KaMavota (zone 4). According to the last census, these were also the peri-urban areas with the greatest impact on population growth, and are darkly shaded. KaMaxakeni (zone 3) followed in population growth and is shaded with neutral gray. The city metropolitan centre – KaMpfumo (zone 1) and KaNhlamankulu (zone 2) – registered little impact on population growth and are mapped in lighter grey tones.

The maps show that, except for Movitel, the current allocation of 3G cell towers is inappropriate particularly for Mcel and Vodacom, in zones 4 and 5. This will not allow for acceptable QoS levels if mobile subscribers in the affected areas wish to use media services apart from web browsing. In addition, the allocation of the telecommunication antennas is not in accordance to the area size of each urban zone in Maputo. KaMpfumo (zone 1), KaNhlamankulu (zone 2) and KaMaxakeni (zone 3), have an area as small as 12, 8 and 12 square kilometres, respectively. The areas of KaMavota (zone

4) and KaMubukwana (zone 5), however, are of 108 and 53 square kilometres, respectively. Yet, the higher density of tower distribution is in zones 1 and 2.

## The SDI development model

Recent trends in SDI development models suggest the adoption of *three-tier architecture* with: database, application/service and presentation/client tier layers. As stated by Roche (2014), the unification of geospatial standards is one of the requirements to achieve spatial enablement. Therefore, *Open Geospatial Consortium (OGC) standards along with e-Government interoperability framework for Mozambique (eGIF4M)* are proposed in the SDI model to freely open and share spatial data. Based on the findings and results in the context of the literature, the following SDI model was proposed.

In the *database layer*, QGIS is proposed to create the geospatial database of the telecommunications resources and other fundamental datasets. PostgreSQL is to be implemented as a DBMS with the aid of PostGIS to support geometry, topology, data validation, coordinate transformation and network analysis (Painho et al., 2015). MySQL is proposed to store security aspects as well as non-spatial data for decision-making, as suggested by Barik and Samaddar (2014).

Following Barik and Samadar's modular concept to allow for (1) publishing web service descriptions, and (2) submitting requests to discover web services of relevance to SDI users, the *application*

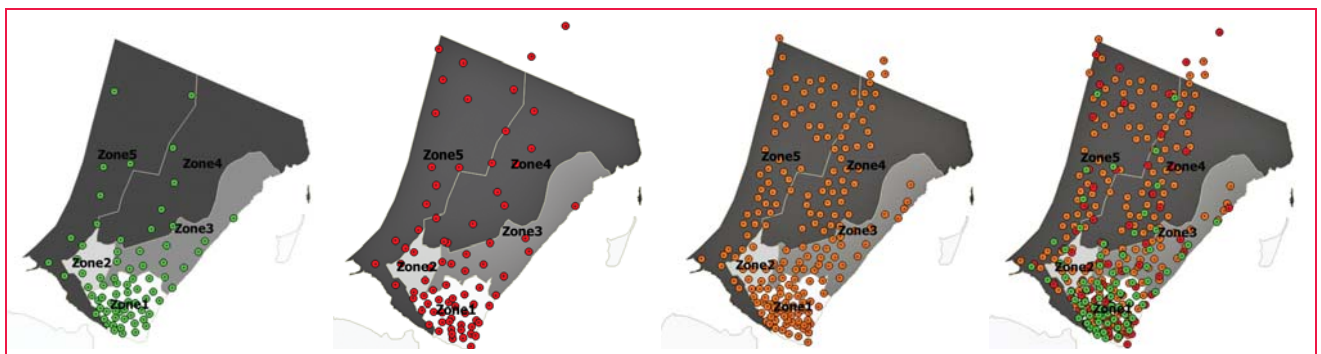


Figure 5: Complete MCEL (in green), VODACOM (in red) and MOVITEL (in orange) 3G cellular antenna distribution across Maputo. On the fourth image, the layers from each mobile operator were overlaid into a single image

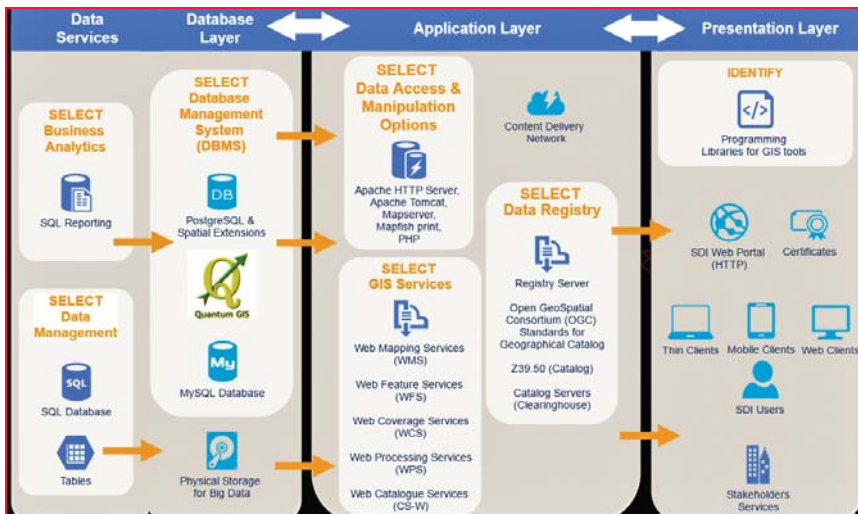


Figure 6: Proposed SDI development model to enable spatial planning in Maputo

layer is suggested to handle one application server and one GIS server. Web Map Service (WMS), Web Features Service (WFS), Web Coverage Services (WCS), Web Catalogue Service (CS-W) and Web Processing Services (WPS) are proposed for impairing geospatial web capabilities through GeoServer, GeoNetwork, GeoWebCache and WAMP. For alphanumeric and GIS data sharing, exchange and manipulation, Apache HTTP Server, Apache Tomcat and Mapserver are proposed. Mapfish Print is suggested to facilitate map print reports in various formats such as PDF, PNG and JPG (Painho et al. (2015). PHP is proposed as a programming language for its wide compatibility with most web servers and operating systems. The data registry is to

allow for data discovery and access to the metadata and clearinghouse using OGC standards for Geographical Catalogues. Protocol Z39.50 allows searching and retrieving data from the database.

The authors of the SDI Cookbook recommended organizations use OpenGIS Consortium Catalogue Services Specification – version 2.0.2 – for metadata publishing. They also recommended SDI participants to register the catalogue servers with GEOSS Component and Service Registry (CSR) for easy data discovery (Infrastructures, 2004). As well, this can be used to discover relevant spatial data for telecommunications network propagation planning purposes.

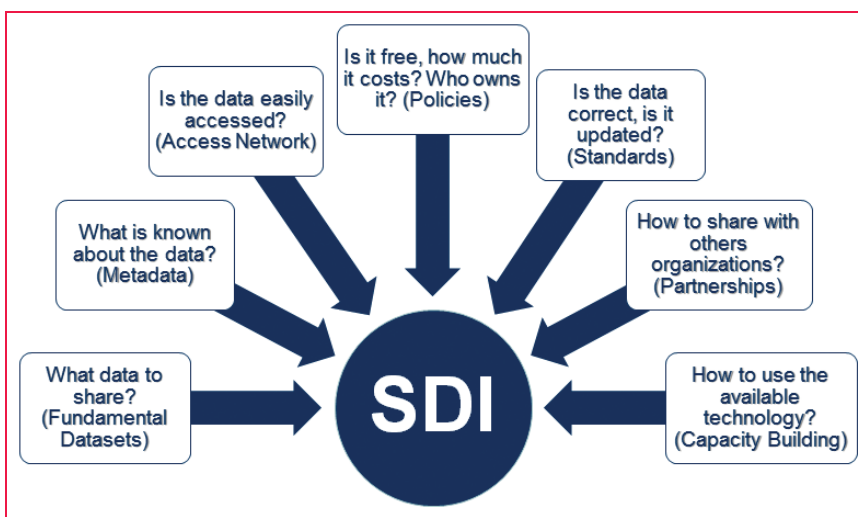


Figure 7: How SDI can facilitate data sharing and exchange.

Source: Adapted from Oduwaye (2014)

Finally, for the *presentation layer*, programming languages that allow the development of GIS tools for the internet should be identified accordingly. PHP (Hypertext Pre-Processor), JSP (Java Server Pages) and GeoExt (GeoExtension) languages can be used to allow for scripting and integration with Open Layers. As suggested by Coutinho-Rodrigues et al. (2011), a human interface such as a user friendly web portal should support visualization alternatives and spatial analysis. To enhance mobility and data access at anytime and anywhere, it is proposed that the SDI web portal be accessible from mobile devices and thin clients.

### Lessons learnt and recommendations to INCM

Urbanization triggered by suburbanization has been reforming Maputo. The results revealed that urban zones 1, 2 and 3 will notice minimal variance while zones 4 and 5 are expected to increase by 62% and 92%, respectively. This means that by 2040, at least 65% of Maputo’s population is expected to be living in the current peri-urban regions of KaMavota and KaMubukwana. In addition, these are Maputo’s largest urban zones with areas of 53 and 108 km<sup>2</sup>, respectively. Yet, Mcel and Vodacom lack 3G cellular antennas within these locations.

Current SDI initiatives in Mozambique do not have telecommunications layers to support future development planning in the sector, and there is no metadata information in most of the layers available. Overall, current GIS projects and SDIs are private and corporate. They are not connected to a common platform to be shared with other corporations and jurisdictions, targeting investment and development in the same region, or to promote reuse of the data. Hence, some of the current SDI and spatial development initiatives do not provide a holistic approach to maximising the interconnectivity and shareability of spatial information between government institutions.



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Two government agencies in Mozambique with interests in telecommunications policies were found from the case study: the ICT National Institute (INTIC) and INCM. INTIC is responsible for all Internet and ICT policies, including the implementation of the e-Government Strategy approved in 2006 (INTIC, 2016). In 2010 it developed the e-Government interoperability framework for Mozambique (eGIF4M) to enable interoperability access in the public sector where a total of 125 standards were considered: 39 for Networks and Infrastructure, 19 for Process Interoperability, and 67 for Semantic Data Interoperability. The second agency with interests in telecommunications policies is INCM, responsible for regulating the telecommunications and postal sectors. Due to bureaucracy, the licencing process becomes a long process as opposed to if the information was strategically shared and exchanged on a common enabling platform, easily accessible to every stakeholder (Figure 7).

Governments need to leverage the current spatial information technologies to enable informed decision-making on social, economic, and environmental issues. As a governmental agency, the demonstrated spatial visualization will support INCM in:

- Assessing licensed carriers' network performance and respective QoS;
- Evaluating how mobile operators can improve their network planning. This can be achieved by spatially allocating future antennas in a more coordinated manner to accommodate the growing demand, particularly in KaMubukwana and KaMavota areas;
- Monitoring if 2G antennas should be replaced by 3G antennas at certain sites. As per International Telecommunications Unit (ITU) reports, mobile data usage is increasing. Data services should be provided at acceptable speeds; and
- Creating new products to generate more revenue, if implemented accordingly.

A planning framework is thus required to bring together a divided sprawling city and achieve effective city planning. Maputo needs a framework that accommodates data sharing and exchange

across multiple disciplines (including telecommunications), encouraging creativity and the development of new products and services. The foundation of an SDI to support infrastructure planning through SDFs will aid addressing these and more, including the dataset's high cost and the need for consistent, well-documented and accurate data.

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We give you more than just a Buzz ...



... We give you  
a Smart Tip!



and a  
conductor



# This is the Smart Tip

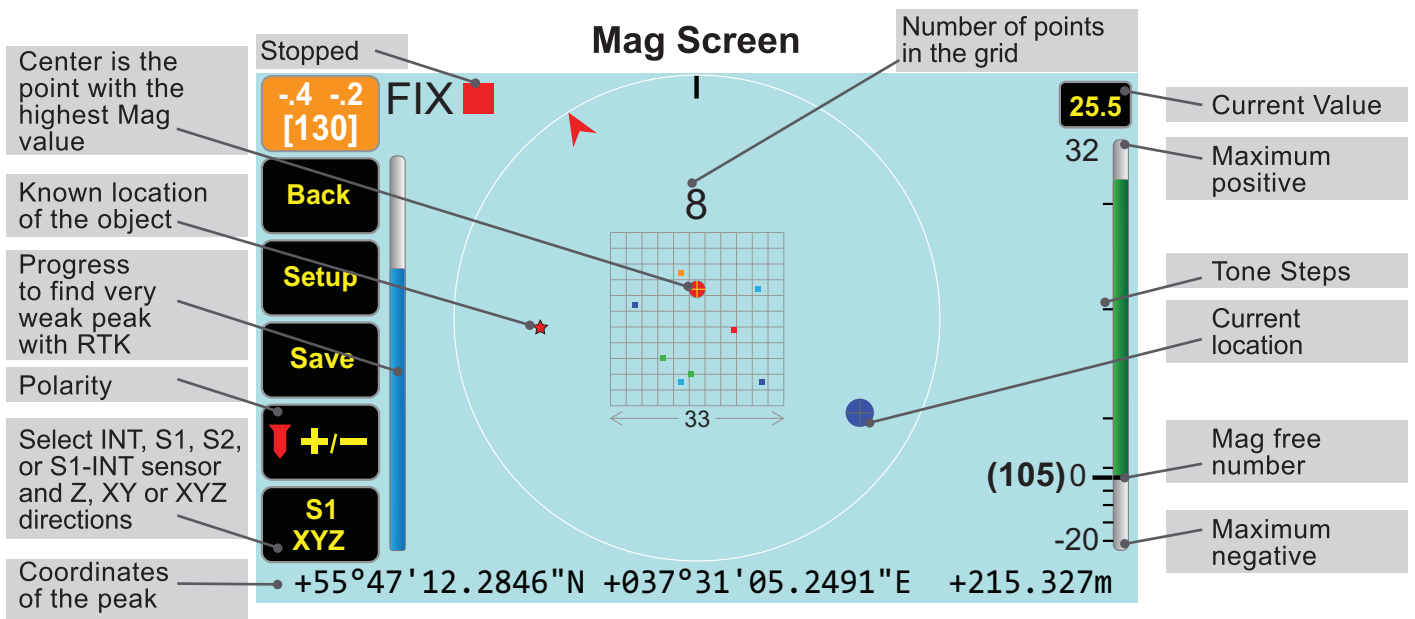


It replaces the tip on the bottom of your rover rod/monopod.


It has two magnetic sensors inside which send magnetic values to the TRIUMPH-LS via Bluetooth 100 times per second.

TRIUMPH-LS scans the field and plots the 2D and 3D magnetic characteristics and the shape and the centre of the objects under the ground and it guides you to it.

Integrated magnetic locator  
in TRIUMPH-LS



To see Mag screens you must first click the A/V hardware button and pair the TRIUMPH-LS with your Smart Tip (and to the Bluetooth headset, if you want to.)

In Action screens of Collect or Stake, click the  icon to get to the Mag screen.

Smart Tip has three search modes of "Positive", "Negative", and "Auto". The search for Positive or Negative objects is fully automatic, for all levels of magnets, and you can start search from anywhere. There is no "Gain" knob to adjust.

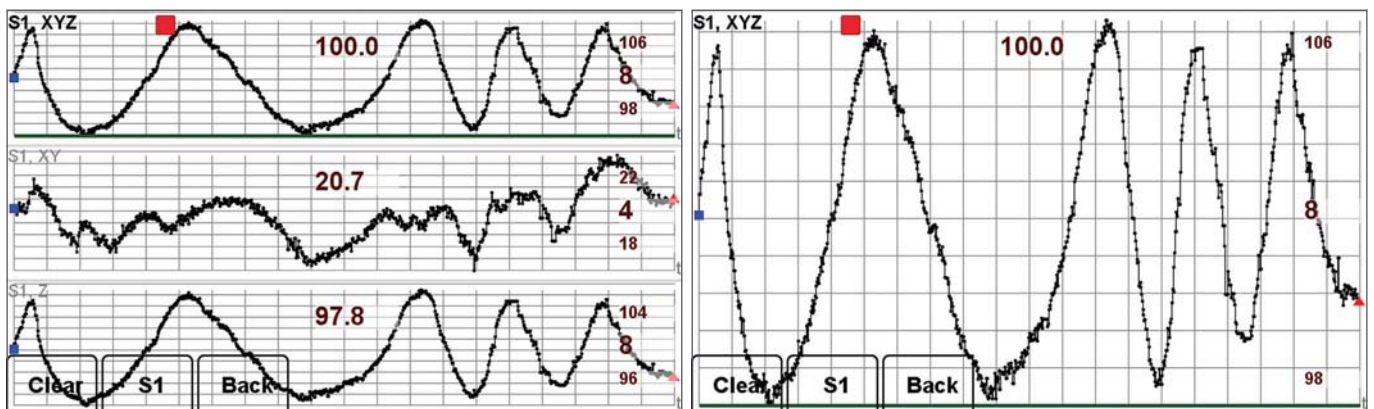
In the "Auto" mode, when you don't know the polarity of the object, you must Start/Clear scanning away from magnetic objects. This records the mag free condition of the field. Then again, the search is fully automatic. Variations

from the Start condition automatically guide you to any positive or negative polarity object of any magnetic value without needing to play with any gain button or orienting the sensor in any specific direction. You can also view the positive and negative values simultaneously on the same bar which may give an indication of the shape of the object.

You can also alternate between Positive and Negative modes.

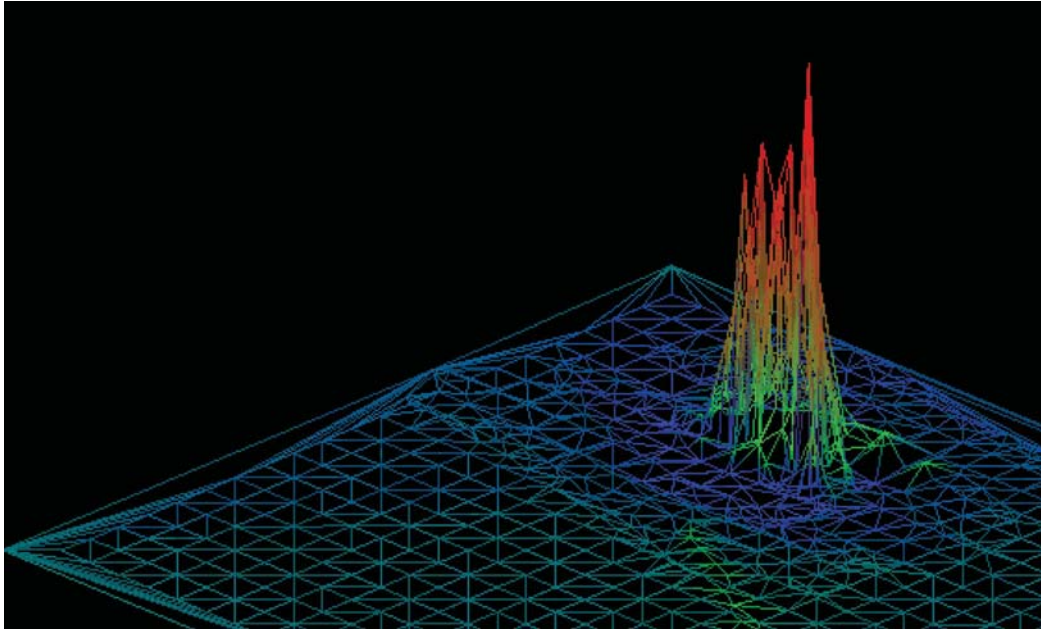
Unlike conventional magnetic detectors which sense magnetic values only in one direction, the Smart Tip has three dimensional magnetic sensors. You can view magnetic values in **XY** (horizontal), **Z** (vertical), and **XYZ** (combined) directions.

In addition to the two three-dimensional



Time view of S1 XYZ, XY, and Z components for the last 100 seconds. Click on any graph component to see the expanded view.

## 3D magnetic view of the scanned field



magnetic sensors (**S1** and **S2**) in the smart tip, there is also a three-dimensional magnetic sensor inside the TRIUMPH-LS (**INT**).

In addition to the audio notifications, the Smart Tip shows magnetic values in “**Time View**” (always), and in “**Spatial Views**” (**Mag**, **2D**, and **3D** views) when you have RTK solutions.

You can view the 2D and 3D graphs by clicking on the top part of the Mag screen. Click the bottom part of the Mag screen to see the Time View.

Scan the area until the spread of mag values are higher than **2\*** (**Start to Beep**). Audio beep rates of **2, 4, 6, 10 Hz** or **tones** are automatically assigned to magnetic values according to the weights assigned in the **Dynamic Beep** Screen and based on Min and Max mag values. There will be no tone when mag value less than **0.5\*** (**No Beep** <)

When you have fixed RTK, hold the monopod vertical (within 5 degrees) to tag mag values with their coordinates. The Smart Tip scans the area 100 times per second and stores the 121 highest mag values and shows them in 11x11 cells of **3\*** cm (**Digitizing Size**) wide. In Spatial Views, the **graphs are centered on the cell**

**with the highest mag value**. Only points that fit in the 11x11 grid will be shown. The number of such points is shown above the progress bar. The “Clear” button restarts the process.

In Mag mode, pole tilts are corrected automatically and RTK is set to extrapolation mode.

When there are enough points in the 11x11 grid (a bar shows progress), it stops and you can save the point. You can also **stop** scanning and then click the “**Save**” button to save point name, the peak magnetic value and the Mag Screenshots.

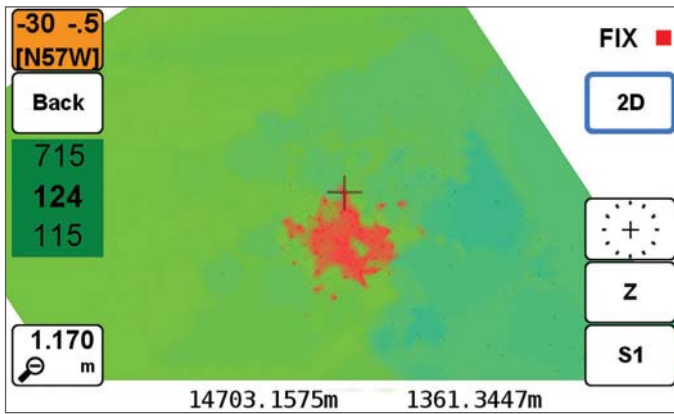
The calculated coordinates of the object is shown in the bottom of the Mag screen.

When pole is tilted less than 5 degrees, solutions will be corrected for pole tilt, otherwise points will be ignored. Time Plots show mag values at all times.

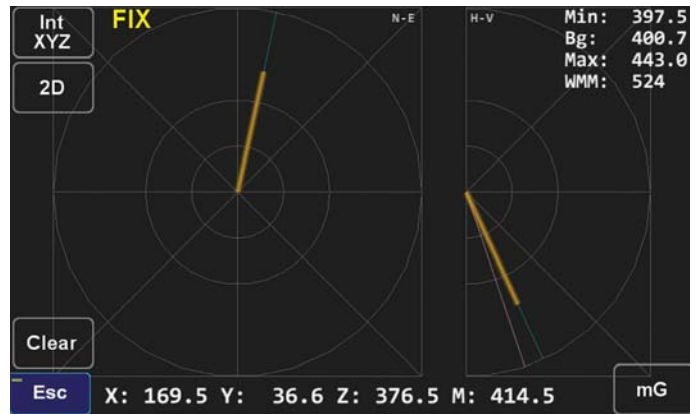
Smart Tip finds the Minimum and the Maximum automatically. If you disturb the normal field scan by exposing the Smart Tip to an external mag object, click the Start button.

The hardware Start and Stop buttons start/reset

**\*Red numbers** are the default values for their respective items (in **bold**) in Setup screen.



**2D magnetic view of the field**



**Horizontal and vertical magnetic vector**

and stop scanning. You can stop scanning, view the results in different screens and settings, and decide the next step.

You can assign gestures (like tilt and shake) for different functions. Tilt-and-back resets.

The known position of the object (entered in the Stakeout screen) is shown on the Mag, 2D and 3D screen if this option is selected.

Time graphs show the magnetic values of the selected sensors in Z, XY and XYZ directions during the past 100 seconds. It also shows the Min and Max values since the Start/Rest. Click on any of the three graph component to expand it.

The Smart Tip is 48 millimeter longer than the metal tip that the monopod is graduated for. Add this to the antenna height offset when in survey mode.

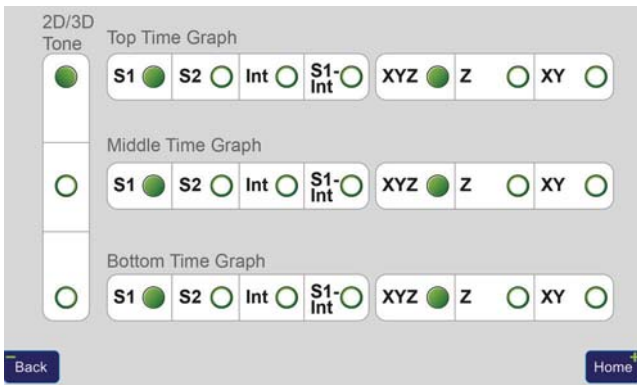
When not “Paired”, the Bluetooth LED of the Smart Tip blinks red. When “Paired” it is red. When Paired and Connected, it is blue. The power LED shows charge level with green, yellow, and red colors. Hold the “On/Off” button for three seconds to turn off. Click it 3 times to unpair it from the TRIUMPH-LS.

You can set the Smart Tip to turn itself off after some time of inactivity.

We keep improving the Smart Tip. You can update the firmware of the Smart Tip via TRIUMPH-LS similar to updating the TRIUMPH-LS.

### The Smart Tip advantages:

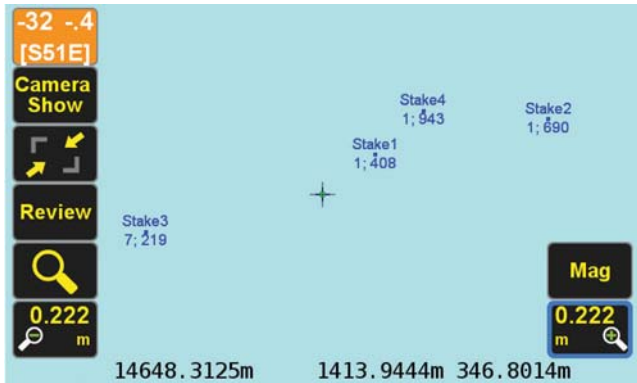
- The Smart Tip does not have “null” points around the peak and will not produce false alarms.
- The Smart Tip is fully automatic for all levels of magnets. There is even no “Gain” button to adjust.
- The Smart Tip senses the mag values in all directions. You don’t need to orient it differently in different searches.
- The Smart Tip gives a 2D and 3D view of the field condition when you have RTK and will guide you to the object. You can actually see the shape of buried object.
- The Smart Tip, In Time View, shows positive and negative mag values of the last 100 seconds and the Min and the Max since Start.
- The Smart tip shows the instantaneous magnetic vector in horizontal and vertical directions.
- The Smart Tip works as a remote control for the TRIUMPH-LS
- The Smart Tip weighs 120 grams and replaces the standard pole tip. In balance, it weighs almost nothing.
- The built in camera of the TRIUMPH-LS documents the evidence after digging.
- And... you don’t need to carry another bulky device.



Sensor and Direction selection screen allows you to select the type of mag data to be shown in Time View and in 2D/3D and Mag screens and for tones.

All values are recorded in parallel. You can stop the scan and then click to see different sensors or sensor/direction combinations. You can tune the Smart Tip to your preference or for special tasks. Default values work just fine. We show flexibility in examining the internal parameters.

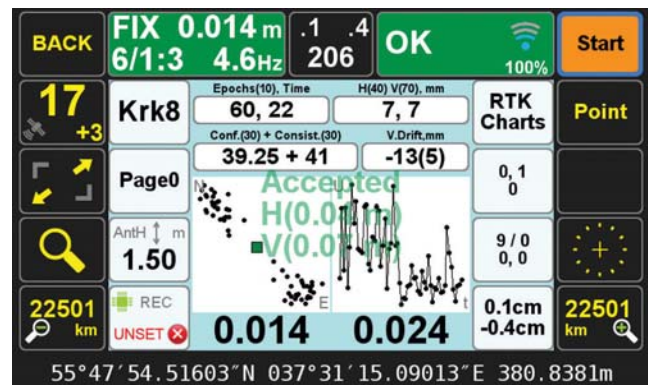
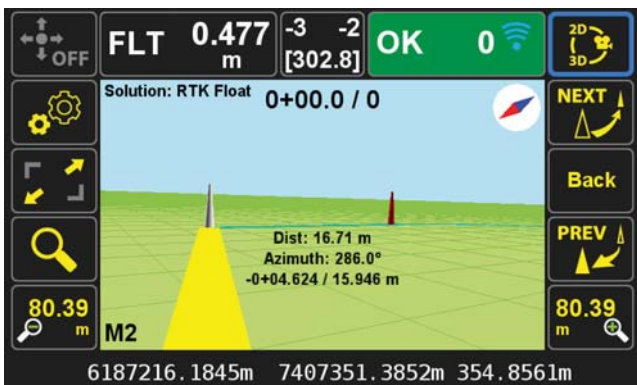
## Field View



When you scan a large area, you can save all possible peak points, view them on the map and select the point with the highest peak to dig.

When you save a point, you can also save all the raw Mag sensor data for future view and research. We also plan to give you the ability to share that data with us by transferring it directly to our server for analysis and improvement.

## Work Flow



We have not only integrated a sophisticated magnetic locator in the TRIUMPH-LS, but we have also streamlined the whole process. First the “Stakeout” screen will guide you toward the target. Then the “Mag” screen locates your underground target and gives you its estimate of the coordinates of the underground target and a button to save it “as staked”.

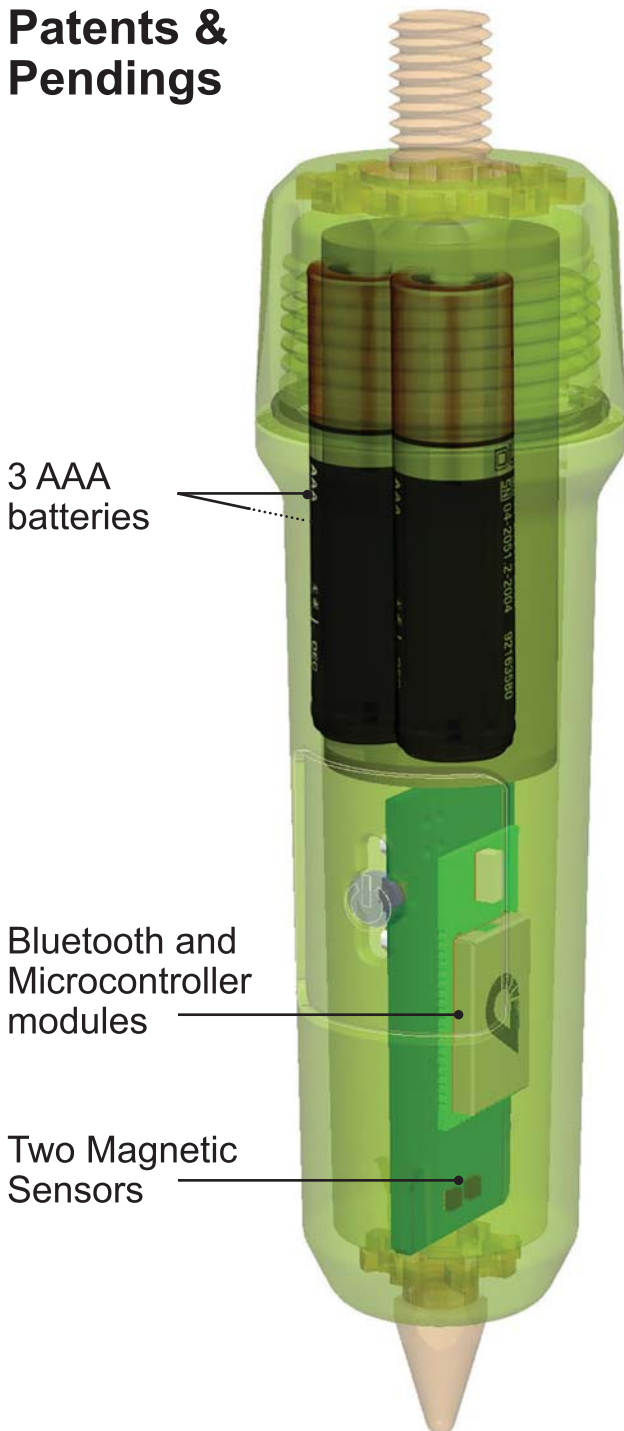
And finally in the “Collect” screen you can survey the target point which you have dug up and exposed. This is also the time to use the built in camera of the TRIUMPH-LS to photograph and fully document the evidence which you have recovered.

We have shown many Smart Tip internal details to show the sophistication embedded in it. Its operation is much easier than conventional magnetic locators.



It sends 100 Hz magnetic values to the TRIUMPH-LS via its Bluetooth.

## Patents & Pendings



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

# And Now... you are the conductor!



While not in magnetic locator mode, you can use the Smart Tip as a remote control for the TRIUMPH-LS. Shake, move up, move down, single bang, double bang, etc. can perform different functions (like Start and Stop survey) as you assign gestures to different function.



Head-on-Shoulder



Witch-on-Broom



Tango



Baby Hold



The Cane

# GNSS interference and signal degradation events assessment

This paper compiles all the events (interference or signal degradation) detected by ENAIRE in several Spanish Airports during 2015 in order to provide a snapshot of how these threats are affecting GNSS performances

**E**NAIRE, as the Spanish Air Navigation Service Provider (ANSP), contributes to the PBN policy and its implementation in Spain. PBN makes use of GNSS systems, such as GPS, as a primary source for position and navigation. One of the steps included in a PBN GNSS (both GPS/RAIM and SBAS) and GBAS based procedure implementation is an assessment of the GNSS interference in the vicinity of the airport.

GNSS interference detection and mitigation has become a topic of utmost for all the stakeholders in aviation. GNSS systems are increasingly being used to perform Instrument Flight Procedures, and interference may lead to a loss of navigation capabilities when a procedure is being flown.

The GNSS Intentional Interference and Spoofing Study Team (GIIST) stated [2] some findings that are confirmed in this paper:

- Civil aviation use of GNSS is vulnerable to intentional interference/spoofing.
- Threat of interference and spoofing is likely to increase.

This paper is aimed to present a summary of all the interference degradation events registered in different Spanish Airports during 2015, focusing on jamming events. Additionally, other objective is to open a debate in the navigation community about the risks of GNSS interference in aviation and study if further measurements or regulation could be introduced.

## Interference detection process in ENAIRE

For the reasons presented in the introduction, ENAIRE has built a wide network of GNSS receivers and interference detectors, among other capabilities, in many airports in Spain. The interference detection capability is part of the ENAIRE GNSS Lab. As it can be seen in the following sections, a very simple approach to GNSS interference detection has been established based on two different methodologies.

## GPS L1 band spectrum monitoring

**srx-10i/DINTEL** [3] is a complete GPS/Galileo spectrum monitoring, interference detection and analysis system in the L1/E1 bands fully developed by GMV [4] following the ICAO Annex 10 [5] and Doc 8071 [6] recommendations.

The system has been designed to fulfil the need of spectrum monitoring whenever GPS (and Galileo in the future) is used in support of the operation of critical infrastructures such as airports.

The system offers the following benefits:

- Uninterrupted, automatic operation for continuous monitoring of disruption events due to interference in the GPS/Galileo L1/E1 bands
- Identification and characterization of interference sources (spectrum, power and time)

The srx-10i/DINTEL records raw digital samples whenever an interference event is detected, and includes a built-in analysis tool for later post-processing and detailed assessments.



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Doing an internship at ENAIRE, GNSS Department, ENAIRE [1], Madrid, Spain

The system can be easily integrated in already existing GNSS monitoring networks (e.g. GPS or EGNOS monitoring systems) and with existing alert management systems.

Finally some of the main features of this system are:

- Supported bands: GPS L1 and Galileo E1
- Bandwidth: 16 MHz (1575.42 ± 8 MHz) @ 1 bit
- Configurable interference mask. Default mask is defined as Annex 10 [5]
- Configurable spectrum resolution (100 Hz to 50 KHz)
- Outputs:
  - Power Spectral Density (PSD) in the L1/E1 bands
  - Detected interference features: central frequency, bandwidth, power.

## GPS Signal to Noise ratio analysis

With the objective of completing the detection of any degradation in GPS signals, a recurrent study of behaviour of GPS Signal to Noise ratio was introduced. Signal to noise ratio is one of the Interferences parameters defined in ICAO 8071 Document [6]. This checking uses all the data stored by the ENAIRE Receivers Network (RECNET) (See section III for more information). In consequence, 24h/7d data from all the receivers is taken into account.

The process consists of a C/N0 trend analysis of each GPS and EGNOS satellite in an individual manner. Some previous parameters must be configured before launching the analysis. These parameters are the following:

- Signal to Noise drop threshold.
- Time window in which the drop is produced.
- Number of GPS satellites affected.

Previous experience has demonstrated that low restrictive conditions on these parameters could lead to a vast number of events to be analyzed while high restrictive conditions could lead to some degradation misdetections.

Once the degradation events are identified, they are crosschecked against sr-x-10i/ DINTEL and against some GNSS parameters such as tracked satellites, used satellites, position accuracy or EGNOS Protection Levels.

It has to be remarked that the events detected using this technique are only treated as signal degradation. If there is no spectrum recorded the interference cannot be confirmed. It could be provoked by an out of band interference or any other issue that could not be defined.

These two techniques have led to a surprisingly high rate of interference and potential signal degradation detected. All the background obtained from this analysis, represents just first milestone if real and effective GNSS spectrum protection wants to be achieved. Interference localisation, GNSS spectrum protection, mitigation or transnational regulations are topics that will need further efforts in the future.

## Enaire GNSS Laboratory Capabilities [7]

ENAIRE GNSS lab was established as an independent way of analyzing GNSS performances, detection and first analysis of GNSS interference. Lab objectives help to demonstrate GPS and SBAS can meet the required navigation performances and to verify Service Level Agreements (SLA). This functionality will be increased with the capacity to analyse periodically GBAS CAT I performances and possible interference in Málaga Airport.

Performance monitoring is also needed to warn users about any service gap or degradation to take appropriate recovery actions. In this context, the lab is responsible of issuing EGNOS performance weekly reports in the Spanish airports, GPS monthly reports in Spain and identifying and characterizing GNSS L1 interference in Spanish airfields.

The foundations of ENAIRE GNSS lab are its network of GNSS stations distributed throughout the Spanish geography.

With a total of ten receivers, nine are located in the control towers of Almería, Gerona, Jerez, La Palma, Lanzarote, Menorca, San Sebastián, Santander and Vigo, while the remaining two are set in the Valencia TACC and the RIMS shelter in Málaga Airport (*This station was not operative in 2015 and no results have been included in this paper*). The network of GPS and EGNOS receivers and GPS L1 interference detectors stores data 24h/7d which is later on analyzed by GNSS performance experts.

Each station is composed by a GNSS antenna, a GNSS receiver and a GPS L1 interference detector. All the stations are installed on the rooftop of control towers of the airports mentioned above.

ENAIRE lab is concerned about the intentional or unintentional use of L1 jammers in the proximity of civil aeronautics receivers. Certified receivers are not specifically designed to track GNSS in an environment with interfering



Figure 1: GNSS Receiver Network Locations

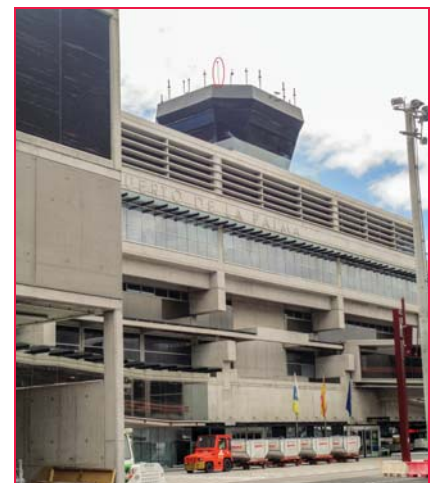


Figure 2: GNSS Antenna location at La Palma Control Tower



Figure 3: GNSS Receiver and GPS L1 Interference Detector

signals. ICAO clearly defines what kind of signals and level of received power can be considered a threat [6]. Through the commercial front-end srx-10i/DINTEL [3] (see section II), the GNSS lab identifies GNSS L1 interference according to ICAO. The front-end installed at the GNSS stations automatically analyzes GPS L1 spectrum and sends alarms every time interference appears. Data is logged and analyzed by DINTEL software. Interference events are characterized by the frequency of each peak [MHz], power of the peak [dBm], estimated bandwidth [KHz], and total interference power. The monitor of GPS spectrum is done automatically 24h/7d.

A second analysis is performed in order to ensure that all possible signal degradation or potential interference events are actually affecting navigation and GNSS performances. Signal to noise ratio analysis of the GPS and EGNOS signals could lead to a second GNSS signal degradation detection. ENAIRE studies C/N0 for all the data stored from the GNSS receivers and analyses the effect of any deviation of a nominal behaviour of this ratio.

### Interference events detected with DINTEL

This section of the paper is intended to present the main statistics of all the interference events detected by srx-10i/DINTEL during 2015 in the airports where GNSS receivers and interference detectors are installed.

Every interference event has been classified by airport, day of week, hour, and frequency as a first step to obtain a pattern leading to a better future identification and localisation. Table 1 summarises all the events detected in every airport and the most common measurable in which the events were classified.

Table 1 shows very different results depending on the location. La Palma Airport (GCLA) is the only one without any event detected during 2015. This behaviour is completely different to the other station located in the Canary Islands (Lanzarote (GCRR)) where interference events were detected the 0.2% of the total time in the year.

On the other hand, there are some aspects that are common to all the locations. The most common day of the week and hour when interferences were detected, were labour hours and days. If a location is studied in detail, it can be easily found the repeatability in the occurrence of the interference events. One of these scenarios is Vigo Airport, where 9580 aircraft movements were registered during 2015[8].

In 2015, Vigo interference detector

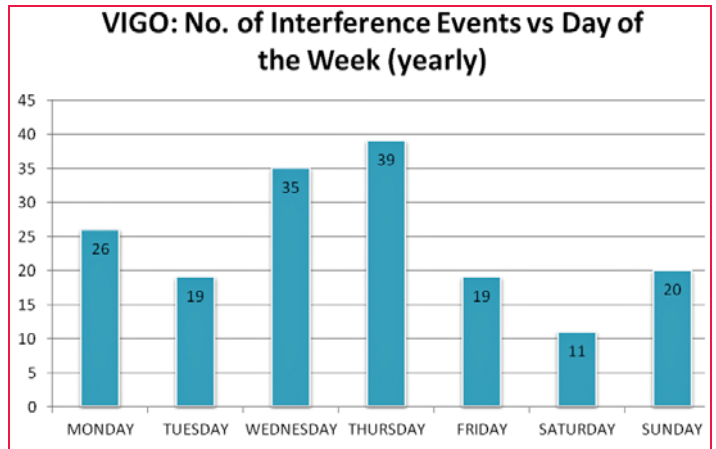


Figure 4: Vigo Airport. Number of interference events vs. Day of the week (Year 2015)

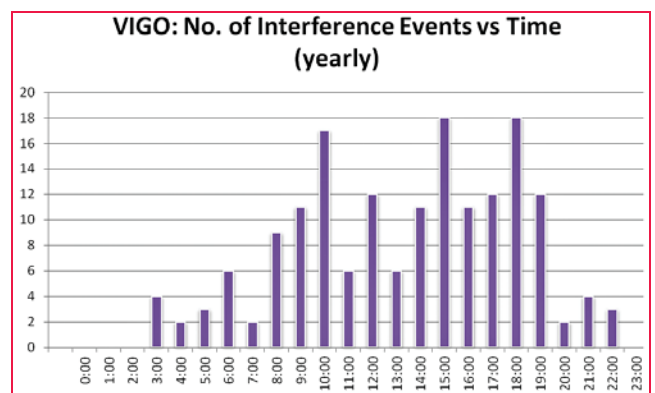


Figure 5: Vigo Airport. Number of interference events vs. Hour (Year 2015)

station registered 169 interference events with a total duration of 15197 seconds. It represents a medium duration of 90 seconds each event.

In order to better characterize the repeatability of the events, all of them have been classified by day of week and hour of occurrence. The results are shown in Figure 4 and Figure 5.

Vigo Airport hours of operation are comprised between 06:30 to 00:30 UTC [9]. 155 of the 169 interference events registered took place during the hours of operation in the airport. In addition, Thursday is the day when more regular operations are scheduled.

The frequency of the events has also been classified depending on the season of the year. In Table 2, it is shown a comparison between the number of interference events and the number of operations according to AENA Air Traffic

Table 1: Interference detected during 2015 with srx-10i/DINTEL

Station (ICAO Code)	Number of events	Total duration (seconds)	Most common day of week	Most common hour (UTC)	Most common frequency (MHz)
GCLA	1	538	Monday	07:00-08:00	-
GCRR	147	62933	Tuesday	13:00-14:00	1574-1575
LEAM	106	10777	Thursday	18:00-19:00	1573-1574
LECL <sup>1</sup>	400	12372	Friday	10:00-11:00	1579-1580
LEGE	78	2995	Wednesday	07:00-08:00	1571-1572
LEJR	69	3425	Wednesday	20:00-21:00	1580-1581
LEMH	9	216	Sunday	17:00-18:00	1579-1580
LESO	288	13644	Tuesday and Friday	15:00-16:00	1570-1571
LEVX	169	15197	Thursday	15:00-16:00 and 18:00-19:00	1575-1576
LEXJ	210	20239	Wednesday	05:00-06:00	1575-1576

### GNSS signal degradation detected with C/N0 analysis

Derived from the analysis of the signal to noise ratio of the GPS and EGNOS satellites, a wide number of events has been categorised as possible interference.

Due to the amount of data obtained in 2015, no statistics have been obtained. In next section, it will be shown all the interference events that actually have affected GNSS performances. It includes all the events either detected by DINTEL or by C/N0 analysis.

Regarding the C/N0, other possible affections of GNSS signals have been detected. These events have helped to better understand and explain some misbehaviour of GNSS performances. Scintillation, mainly located at south Iberian Peninsula and Canary Islands, and EGNOS GEO malfunction are some of these events.

statistics [8] separated by season.

It can be also seen how the seasons with the highest number of operations (spring and summer) have also the highest number of interferences events.

Finally, all the events were classified by the frequency in which a peak exceeding ICAO mask was detected. It was used a step of 1MHz from 1567 to 1584 MHz.

In this case, no conclusions can be derived from the results since no clear

repeatability is detected. Nevertheless, frequency will be observed in each airport to flag any interference whose rate of occurrence were remarkable.

In Almería and Lanzarote airports a clear pattern can be found, regarding frequency of occurrence. In Almería 44 of 106 events affected at 1573 MHz and in Lanzarote 99 of 147 events affected at 1574 or 1575 MHz.

Table 2: Number of operations per season. Vigo Airport 2015

Season	Number of interference events	Number of operations
Winter	20	1989
Spring	56	2475
Summer	52	2877
Autumn	41	2239

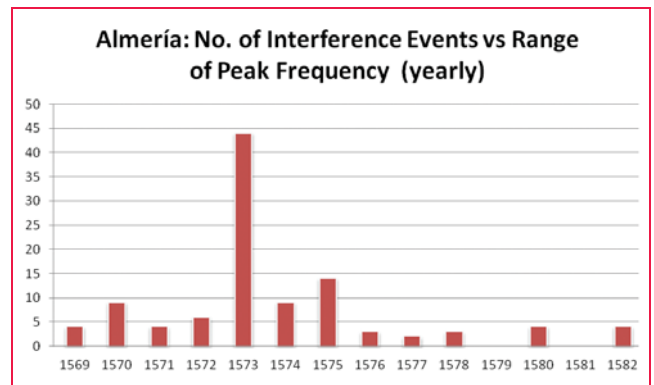


Figure 7: Almería Airport. Number of interference events vs. Frequency (Year 2015)

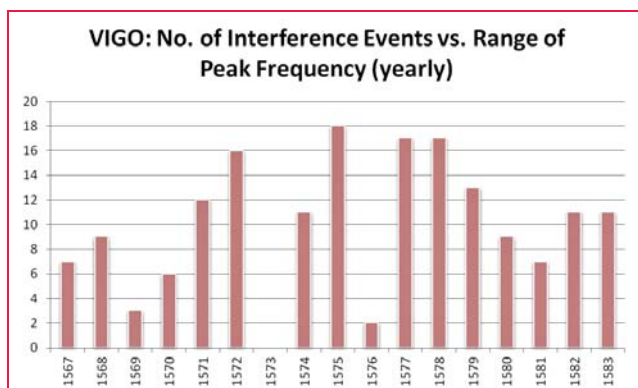


Figure 6: Vigo Airport. Number of interference events vs. Frequency (Year 2015)

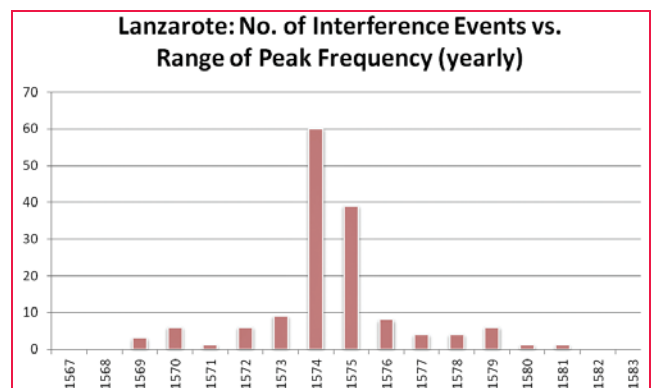


Figure 8: Lanzarote Airport. Number of interference events vs. Frequency (Year 2015)

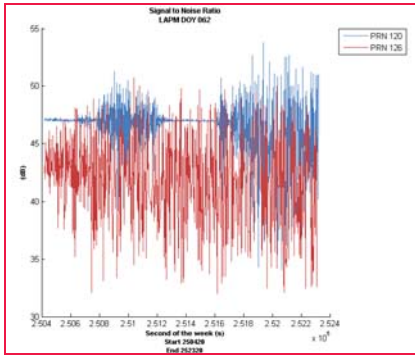


Figure 9: Scintillation in La Palma receiver. EGNOS GEO Satellites (Canary Islands)

## Affection to GNSS Performances

The second step after the detection and identification of the anomaly is to analyse whether the events have had impact on GNSS Performances (GPS and SBAS solution). Depending on the severity of the interference events, these are classified in three different types from the least to the most severe:

- Disruption of APV-I EGNOS capabilities. (Type 1).
- Denial of EGNOS service. (Type 2)
- Denial of GPS service. (Type 3)

The first type means that the EGNOS Protection Levels have been affected to the point of exceeding the APV-I alert limits (*All the interference events in this document have been compared against APV-I requirements (HAL=40 m and VAL=50m)*). The second type means that the track of GEO EGNOS satellites has been lost or the necessary number of satellites to compute EGNOS solution is not reached. Finally, the third type means that the receiver tracks less than four usable satellites necessary to compute GPS Solution and consequently the navigation and positioning capacity.

The total number of events affecting GNSS performances detected in the ten sites was 105 with a medium length of approximately 500 seconds each event. All these events affected to the APV-I EGNOS availability, 64 disabled the EGNOS capabilities and 20 of them completely denied the GPS navigation solution. In the next paragraphs, it will be described

Table 3: Interferences affecting GNSS performances during 2015 (This table includes all the interference events or GNSS signal degradation (C/N0) detected.)

Station (ICAO Code)	Number of events	Total duration (seconds)	Type 1	Type 2	Type 3
GCLA	1	538	1	1	0
GCRR	3	1709	3	0	0
LEAM	24	10994	24	9	5
LECL*	14	4569	14	7	2
LEGE	5	4554	5	5	2
LEJR	5	1934	5	4	1
LEMH	0	0	0	0	0
LESO	10	3238	10	4	0
LEVX	10	5045	10	7	1
LEXJ	10	2350	10	8	2
TOTAL	105	52379	105	64	20

\* This station was operative from March 2015 onwards

an example of interference detected by srx-10i/DINTEL and by the recurrent analysis of the signal to noise ratio.

One of the interference was detected in Almeria Airport (LEAM) on November 23<sup>rd</sup> 2015 from 18:42:19 to 18:49:13 UTC. It has to be remarked that in Almeria Airport there are published RNP APCH procedures down to LPV, LNAV and LNAV/VNAV minima to THR 25[10] & [11].

srx-10i/DINTEL detected this interference in two different frequencies that exceeded the limit of the ICAO Mask for the Continuous Wave Interference (-120.5 dBm). The frequencies, peaks values and bandwidth of each interference spectrum components are shown in Table 4.

The plot of the spectrum recorded and its comparison with the ICAO Mask is shown in the Figure 10.

Table 4: Interference Spectrum Components in Almeria Airport. November 23<sup>rd</sup> 2015

Frequency (MHz)	Peak Power (dBm)	Bandwidth (KHz)
1575.59	-96.4	60.75
1574.95	-113.8	44.49

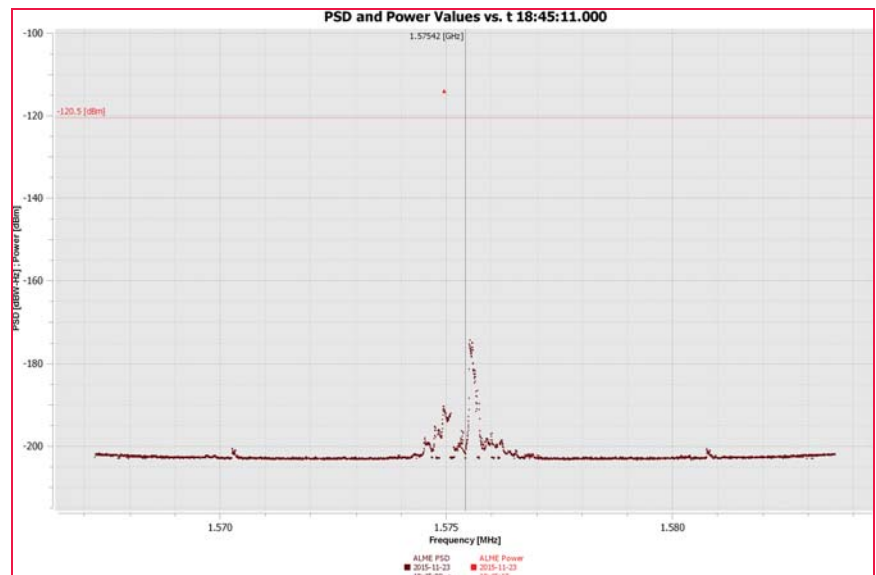


Figure 10: GPS L1 Spectrum. Almeria Airport. November 23<sup>rd</sup> 2015

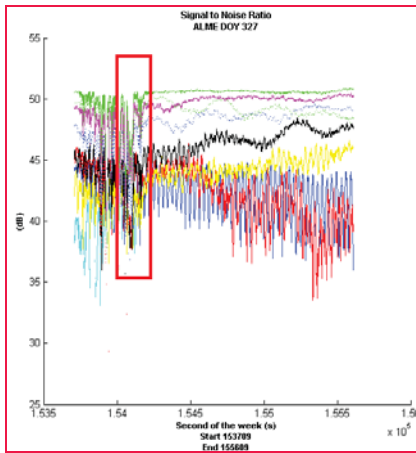


Figure 11: GPS Satellites Signal to Noise Ratio. Almería Airport. November 23<sup>rd</sup> 2015

In parallel, and making use of the GNSS raw data stored by the GNSS receiver, the C/N0 of each satellite was analyzed in order to confirm if this event had affected any GNSS observable or if there was another undetected degradation. The C/N0 of all the GPS Satellites in view is shown in Figure 11.

The maximum power measured was detected at 18:45:11 when it is observed that the receiver lost the track of all the GPS satellites. It was due to the drastic drop of the signal to noise ratio in all the satellites that GPS Solution was lost for a few seconds. At the same time, the receiver lost EGNOS capabilities which took some minutes to recover the track of EGNOS GEO corrections.

### Interference events and its impact in real operations

The previous sections were focused on the interference events registered using receivers located on the rooftop of the control towers, which can be considered at ground level. According to [6] this scenario is suitable for interference detection during take-offs and landings at airports; however there are other events that cannot be covered by this configuration.

One of these examples is the loss of GPS capabilities reported by several aircraft on December 2015 in TMA Galicia (north-west of Spain). In total,

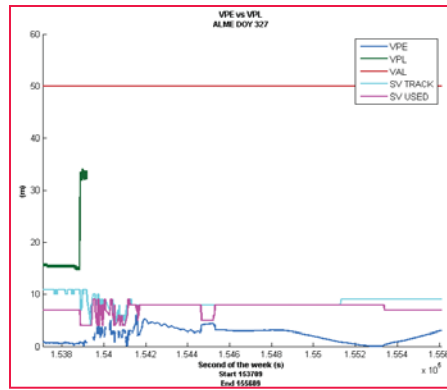


Figure 12: EGNOS Performances (Vertical Component). Almería Airport. November 23<sup>rd</sup> 2015

there were eight GPS loss of navigation events reported from 30<sup>th</sup> November 2015 to 14<sup>th</sup> December 2015. The altitudes of the flights were comprised between 5000 ft to 12000 ft. All these events were classified as jamming due to the fact of the unavailability of the GPS constellation instead of false positions which would mean spoofing.

Following the notification of these events, ENAIRE GNSS department performed a study, in which, some ground receivers data were assessed. In this study, the GPS raw data was analyzed in order to confirm if any degradation was recorded at ground level. The GPS stations used to perform the study belong to the GNSS receiver's network, from IGN [12] and from GALNET [13].

Data from two hours before and two hours after each aircraft report were analyzed from the closest GNSS ground stations of the mentioned networks. The results did not show any degradation that confirmed affection at ground level. In addition, any GPS constellation issue was discarded since the geometry remained optimal during those days.

These kinds of events demonstrate that interference is an issue that can have hazardous effects at every flight level. For some PBN applications where only GNSS can support its implementation, this kind of interference could jeopardize the nominal operation and put at risk the safety operation, if no mitigations are considered.



Figure 13: TMA Galicia Interference events locations

### Conclusions and future steps

Interference events caused by jamming, whether if it is intentional or unintentional, has been demonstrated as an important threat which endanger GNSS signals. This degradation has an impact on the availability of maneuvers relying on GNSS that ENAIRE has published or it is aimed to publish in the near future.

This paper has shown the process performed by ENAIRE to detect GNSS interference. It represents only the first step in terms of detection given that further actions are being studied. Some of these activities comprise interference localization and inclusion of interference events in the ATC Interface, along with GNSS NOTAMS publication using the interference detectors network presented in this paper.

The number of interference events should be negligible due to the fact that mitigation activities are being developed to deal with this issue. This subject has been discussed in the ICAO Navigation Systems Panel (NSP) during the last years within a dedicated item in the agenda. This panel is involved in developing guidance on radiofrequency interference to GNSS and on potential mitigations [14]. Mitigations activities imply three different perspectives:

- Include standardized protection mechanisms against the threats from repeaters/pseudolites/jammers within commercial GNSS receivers.
- Taking advantage of conventional navigation aids and radar, or alternative position, navigation



- and timing systems (APNT).
- States should implement adequate policies and procedures to regulate and protect GNSS spectrum.

to reduce the impact of GNSS interference, as it is stated in the GNSS Manual [15] GNSS frequencies are protected for aviation use and coordinated actions and regulations should be considered at International or European level.

The regulation should be the primary way

Acronym	Expansion
ACC:	Air Control Center
AENA:	Aeropuertos Españoles
ANSP:	Air Navigation Service Provider
APCH:	Approach
APV:	Approach Procedure with Vertical guidance
ATC:	Air Traffic Control
C/N0:	Signal to Noise Ratio
EGNOS:	European Geostationary Navigation Overlay Service
ENAIRES:	Spanish Air Navigation Service Provider
ESA	European Space Agency
GALNET	Galician GNSS Network
GBAS:	Ground Based Augmentation System
GCLA:	ICAO code for La Palma Airport
GCRR:	ICAO code for Lanzarote Airport
GEO:	Geostationary
GIIST:	GNSS Intentional Interference and Spoofing Study Team
GNSS:	Global Navigation Satellite System
GPS:	Global Positioning System
HAL:	Horizontal Alert Limit
ICAO:	International Civil Aviation Organization
IGN:	Instituto Geográfico Nacional
LEAM:	ICAO code for Almería Airport
LECL:	ICAO code for Valencia TACC
LECM:	ICAO code for Madrid ACC
LEGE:	ICAO code for Girona Airport
LEJR:	ICAO code for Jerez Airport
LEMH:	ICAO code for Menorca Airport
LESO:	ICAO code for San Sebastián Airport
LEVX:	ICAO code for Vigo Airport
LEXJ:	ICAO code for Santander Airport
LNAV:	Lateral Navigation
LPV:	Localizer Performance with Vertical guidance
NOTAM	Notice To AirMen
PBN:	Performance Based Navigation
PSD:	Power Spectral Density
RAIM:	Receiver Autonomous Integrity Monitoring
RECNET:	ENAIRES Receiver Network
RNP:	Required Navigation Performance
RWY:	Runway
SBAS:	Satellite-Based Augmentation System
TACC:	Terminal Area Control Center
THR:	Threshold
TMA:	Terminal Management Area
UTC:	Coordinated Universal Time
VAL:	Vertical Alert Limit
VNAV:	Vertical Navigation
VPE:	Vertical Position Error
VPL:	Vertical Protection Level

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# Point clouds and orthomosaics from photographs

This paper presents the first examples where point clouds and orthomosaics, generated from close range photographs, can help civil engineers on their studies



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The three authors of this paper work at the Applied Geodetic Division of the National Laboratory for Civil Engineering (LNEC), in Lisbon, Portugal. LNEC is a state owned research and development institution founded in 1946. It works in the various domains of civil engineering (structures, hydraulic, geotechnics, environment, materials, among others), giving it a unique multidisciplinary perspective in this field. The main goals of the LNEC are to carry out innovative research and development and to contribute to the best practices in civil engineering.

The Applied Geodetic Division nowadays develops works in two domains: the geodetic surveying of large dams and other engineering structures for monitoring purposes, and the processing of digital images with applications in several domains, which includes the study of the evolution of pathologies in engineering works. Originally the processing of digital images made use mostly of the chromatic information included in the images (from satellite images to close range photographs). But recently it has evolved to extract information of the geometry of the objects by the generation of point clouds. This use of close range photographs (from distances of decimetres to a few meters),

which started in the summer of 2014, looks very promising and we, the authors, are identifying possible areas where the use of point clouds and orthomosaics that can be of interest to our colleagues of LNEC, civil engineers mostly.

This paper presents the first examples where point clouds and orthomosaics, generated from close range photographs, can help civil engineers on their studies. The photogrammetric products were all generated using the free open-source software Micmac (Multi-Image Correspondances, Méthodes Automatiques de Corrélation) from IGN (Institut National de l'Information Géographique et Forestière, France).

## First study case. The "introduction to point clouds"

Although many colleagues, civil engineers, know the concept of "point clouds" we felt that we should generate a small point cloud example, light to manipulate: we called it "introduction to point clouds". We were not innovative with the object chosen: we reproduced the example "Gravillon" of Micmac (Pierrot-Deseilligny, 2014): it creates a point cloud from a small pile of sand. Our example has a difference to

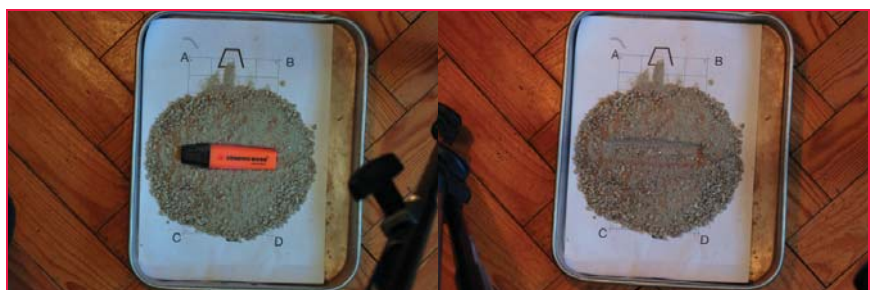


Figure 1: Photos of the pile of gravel "with" and "without" a highlighting pen on the top

“Gravillon” example: we embedded a highlighting pen on the top of the pile that was removed to study how differences between point clouds and orthomosaics can be detected. We created the first point cloud, the “with” point cloud, from a set of nine photos. Then, after, the pen was carefully removed and we took a second group of nine photos to generate the second point cloud: the “without” point cloud. In Figure 1 one can see two of the photos taken. Using these two clouds we could not only present the concept of point cloud but also we demonstrated that it was possible to detect differences between the clouds using (open-source) software.

The steps of the work, including the cloud comparison were:

### Preparation of the sample

Inside a small tray we placed a paper with some straight lines drawn. As we know their length we established our “Ground Control Points” (GCP) in the intersection of the lines. On it we put some small dimension size gravel borrowed by the Geotechnique Department of LNEC. On the top we embedded a pen.



Figure 2: The nine “with” photos (image created with Panellm). The tripod moved around the tray (step 45°) to take the “side” photos.

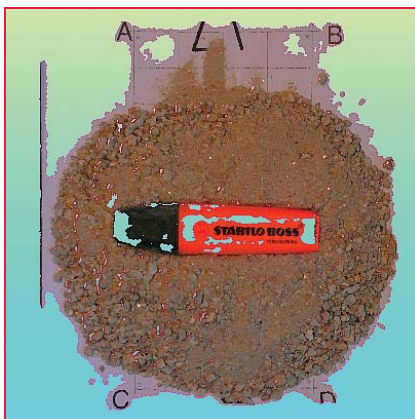


Figure 3: Point cloud “with” seen from above (1373494 vertices)

### Taking the photos

We used the digital camera Nikon D200, mounted on a tripod, with a lens with fixed focal length. The camera was set to manual mode (to keep focal length and aperture constants) and we took nine photos (Figure 2), JPG format, all about 1 meter of distance: one from the top, eight from the side. After this session we took other photos for calibration purposes.

### Building the “with” point cloud.

To build the cloud we followed the steps used in Micmac’s “Gravillon” example. These include (as presented by Pierrat-Deseilligny, 2011, and Samaan, 2013): i) common points search on pairs of photos; ii) computation of calibration parameters and geometric correction of the photos, determination of the position of the photos in a relative (not absolute) referential; iii) visualization of the positions and orientations of the camera in the relative referential establish previously (see Figure 6); iv) geo-reference of the data, to transform the relative orientation using the

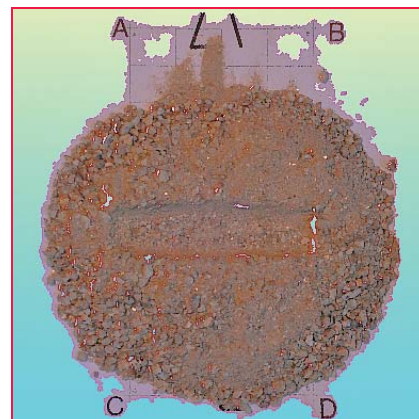


Figure 4: Point cloud “without” seen from above (1430990 vertices)

coordinates of three GCP well identified in the photos (points “A”, “B” and “C”, seen in Figure 1), either absolute coordinates in the 3D referential chosen and image coordinates in the photos; v) final computation of the external and internal orientations with data generated previously; vi) computation of the digital surface model, point cloud and ortomosaic (see Figures 3 and 5).

### Building the point cloud “without”.

After taken the “with” photos we removed carefully the pen in order to keep the pile of gravel unchanged. We placed the tripod near the tray and took a new group of nine photos. We processed the information using the same software and following the same steps and we created the “without” cloud (see Figure 4).



Figure 5: Point cloud “with” seen from one side

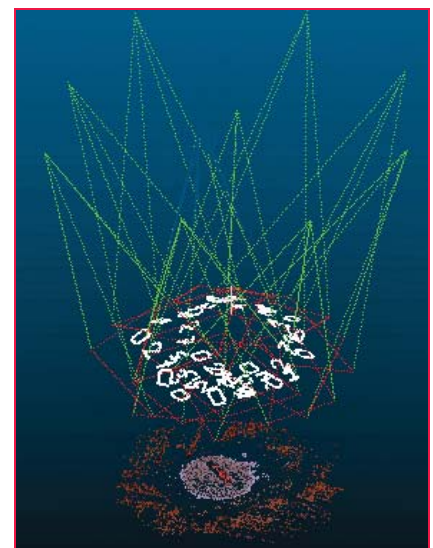


Figure 6: Relative positions of the photos (red rectangles) and the cameras (apex of the green pyramids)

To visualize the point clouds we used or Meshlab or CloudCompare (both open-source softwares). The background color (light cyan) seen in Figures 3 to 5 was chosen to make the “holes” (= areas without points) more visible. These holes appear because is difficult for the software to find homologous points in surfaces too homogeneous (like the paper, the pen or its cap).

### Comparing the clouds.

By comparing the clouds we expect that the depression, left by the pen when we took it out from the top of the pile, was visible (and could be somehow measured) by using software that compares the clouds. In this example is very obvious the change between the clouds. To perform the comparison we choose CloudCompare. As the clouds don't cover exactly the same areas (for instance, the areas without points near GCP “A” and “B” have different shapes) we select, in both clouds and using Meshlab, circular areas in the XY plane with the same centre and radius. All the points whose location didn't fulfil that condition were deleted. The new clouds were imported by CloudCompare and there we calculated the distance between

the clouds. Before this computation CloudCompare presents some data, as seen in Figure 7. The point cloud chosen as reference was the cloud “without”. The largest distance between the clouds is 0.0164 m (as seen in the form on the left side) and the majority of the points are at a distance lower than 0.002 m, according to the graph on the right and the colored distances at the centre.

Selecting only the distances larger than 0.002 m a new image is obtained (Figure 8) that covers a smaller area since it is limited to the area near the pen (the distances in the majority of the circle were smaller than 0.002 m and for that reason not represented when the new image was created). On the left side of the Figure 8 is presented the frequency chart of the image.

### Second study case. Natural rock joints

The Foundations and Underground Works Division (Concrete Dams Department) of LNEC carries out research studies that include the characterisation of the mechanical properties of rock masses and rocks. For

this, in its Rock Mechanics laboratory, it conducts tests to obtain values to the parameters that characterize the deformability and the strength of rock specimens and joints. The case presented in this paper is one specimen of a rock joint (see in Figure 9 the point cloud seen from above, and in Figure 9 the vertical photo of the specimen) that had undergone a shear test to evaluate the influence of the normal and shear loads on the variation of surface roughness (in the case of rock joints, the roughness has a large influence on the shear strength).

This specimen (a granite sample, 12×8 cm<sup>2</sup>) has been scanned with a three-dimensional scanner, as described by Resende and al. (2014), so we had 3D coordinates of its surface. The scan was made by the 3D needle-tip contact scanner Roland MDX-20 (Figure 11) which allows the three-dimensional scan of solids (Figure 12). It was adopted a horizontal resolution of 0.5 mm. The scanning of the surface of the

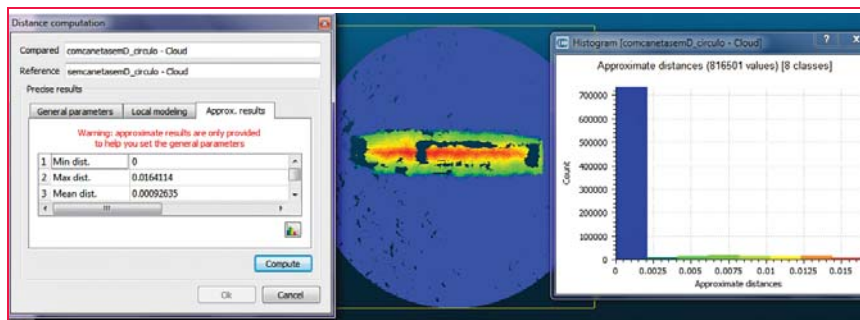


Figure 7: Software Cloudcompare: distance computation, graph with the distances colored according to their length and frequency chart of the distances

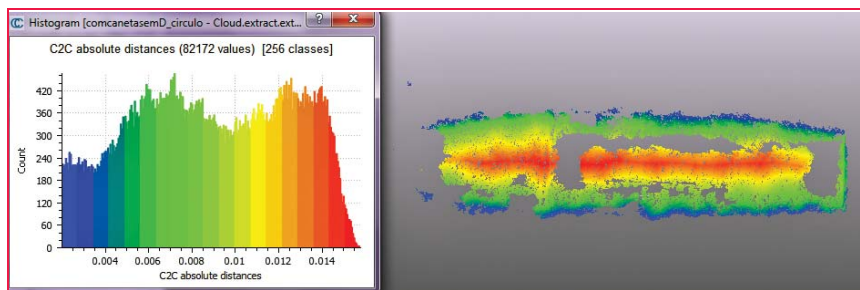


Figure 8: Software Cloudcompare: frequency chart of the distances and graph with the distances colored according to their length (distances larger than 2 mm)



Figure 9: Point cloud

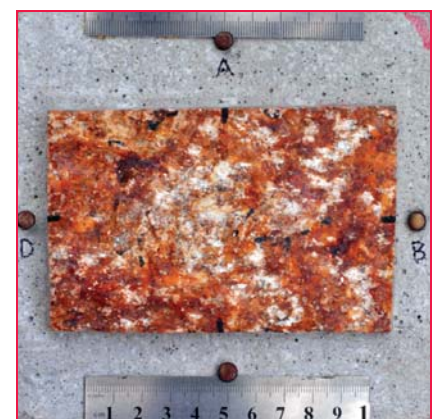


Figure 10: Vertical photo of the specimen

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## INTERGEO

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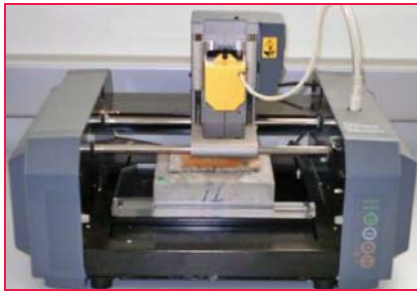


Figure 11: 3D scanner Roland MDX-20 during the measurements of a rock joint sample

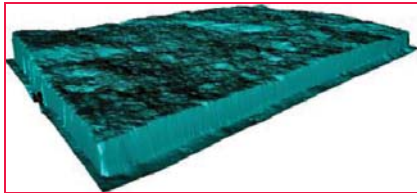


Figure 12: Digital image of a specimen rendered by the scanner control software

rock joint sample took eight hours.

We took nine photos of the specimen, following the methodology of the first case, with an innovation: the specimen was placed on a turning stand. This simple set decreased a lot the time that was spent on taking the photographs. With the nine photos it was created a point cloud and an orthomosaic. This one will allow studies never done before related with variations of the surface hue as a result of the shear test. As we didn't have GCP, we defined a local reference frame by choosing a point to be the origin of the frame, and two lines to establish, one, the orientation of the frame and, the other, the scale.

The surface of the specimen (the area with brown colors) was represented by 1647999 points with 3D coordinates. These can't be directly compared with the 3D coordinates of the 38290 3D points surveyed by the scanner. So the first stage was to align the point cloud with the scanned data, done by the software Cloudcompare, which employs the algorithm Iterative Closest Point to minimize the difference between two clouds of points. The second was to generate a height grid. The third was to import this data by QGIS and explore the raster tools. In Figure 13 is presented the rendering of the point cloud height grid, in Figure 14 the contour lines (from the point cloud overlaid on

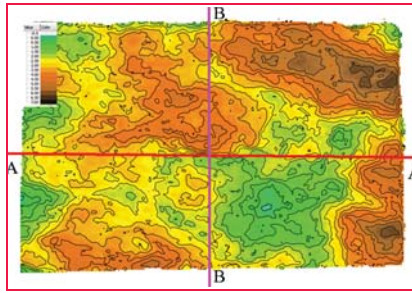


Figure 13: Rendering the point cloud height grid

those of the scanner) and, in Figure 15, two profiles lines, from the intersection of the vertical planes A and B (see their location in Figure 13) with the surface. Comparing the contour lines and the profiles small differences are noticeable.

### Third study case. The model of a breakwater

Breakwaters in seaside areas are good examples of structures that can be monitored using the products derived from photographs taken by cameras mounted on unmanned aerial vehicles (UAV). The authors have presented in FIG Congress of 2014 an evaluation of the surface model of the breakwater of Ericeira (Henriques et al, 2014). The good results, especially if one takes into account the windy conditions during the flight, give us a good motivation to test the use of photogrammetry indoors, to help the studies of physical models of breakwaters belonging to the Harbours and Maritime Structures Division of the Department of Hydraulics and Environment.

Some of the studies of this division are on the structural behaviour of coastal protection structures, like breakwaters, under the action of waves. In tanks, different types of waves are reproduced, being that their height and period are set to reproduce the natural conditions of the sea that hits the structures. During the tests, that are several days

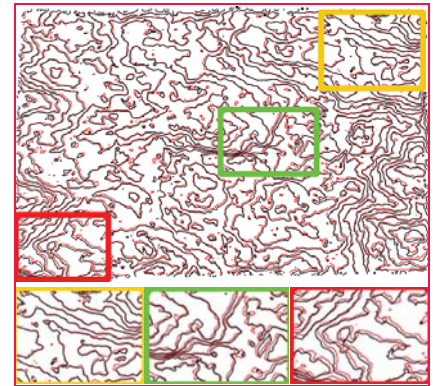


Figure 14: Contour lines: point cloud in black; scanner coordinates in red. Zooms of the three areas

or weeks long, there is a succession of periods of generation of waves followed by periods of pause, used to get information about the structure, namely the changes that affect its surface.

The aim of our study is to get answers to three questions: i) point clouds and orthomosaics can give accurate information on the behaviour of the models? ii) the generation of these products is time consuming? iii) how to get vertical pictures when the model is surrounded by water? At this moment we can answer to the first question with a "yes". Concerning the other two we know for sure that is impossible, without the development of software, to perform a full automatic processing of photos because is necessary to get the coordinates of GCP on the photos, a phase that now demands the direct intervention of the user. Concerning vertical photos, we tested the use of an unmanned aerial vehicle (a small four rotors helicopter) that included a low quality camera. Despite its low quality, the photos were good enough to realize

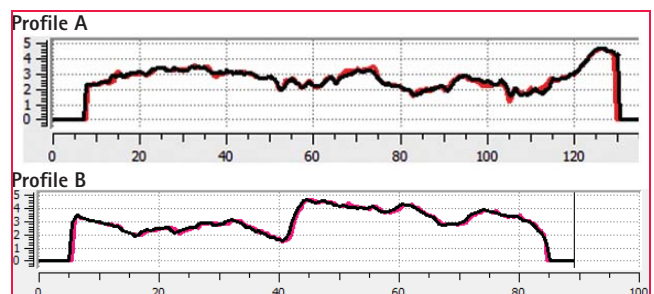


Figure 15: Profiles of the specimen: point cloud in black; scanner coordinates in red/pink. Unit: millimetres



Figure 16: Model of a breakwater



Figure 17: Blocks of concrete



Figure 18: Ortho BD

that helicopters is not the solution because the rotation of the propellers generated wind that produced agitation on the water surface and that affected the vision of blocks located under water. The solution must be different.

To get data to answer to the first question we chose a model of a rubble mound breakwater (2 m long, 1.3 m width and 0.3 m height, see Figures 16 and 17). The surface was covered with cubic blocks of concrete, painted in different colours, reused from other breakwaters models. The eight lower rows of blocks were covered with water. The photographs were shot vertically. The camera was at 3m high, fixed to a horizontal rod that was attached to a column. This column was supported on a structure with four wheels. The set moved on a platform that belongs to the model. The camera, the Nikon D200, was programmed to take

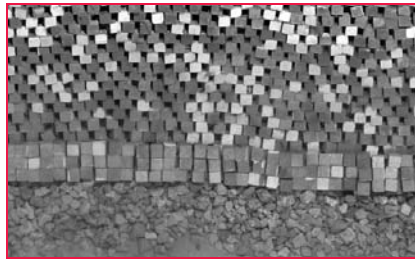


Figure 19: Average of the bands of the ortho AD

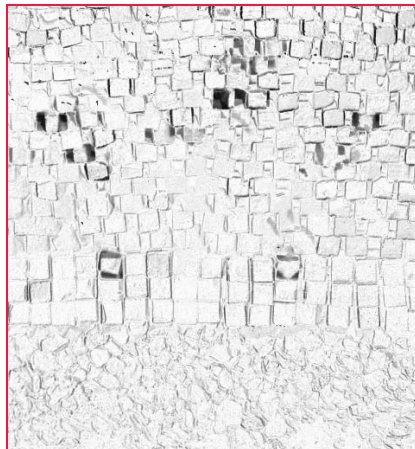


Figure 20: Image "negative of the modulus of the differences between the averages AD and BD"

photographs automatically every 10 seconds during 10 minutes. In each position two photos were taken. After the first survey we moved some blocks manually and we made a second photo survey.

By applying Micmac we produced two orthomosaics (Figure 18), with a pixel size 0.32 mm in average, and two point clouds: a "before displacements", BD, and an "after displacements", AD. The orthos (raster images) were processed by QGIS. We used the "Raster Calculator" to: i) average the three RGB bands to generate two single band raster images (BD and AD, Figure 19); ii) to calculate the difference between these images; iii) to calculate the "square root of the square of the difference" (mathematical operation used when the function "modulus" is not available), operations that highlight the differences (see in Figure 20 the negative of the image created). The areas with differences are presented with darker grey. A more detailed description of the work can be found in Henriques et al., 2016.



Figure 21: Drone octocopter SKY II. The support of the camera is under the drone, between the landing gears



Figure 22: One remote controller

#### Fourth study case. Visual inspection of wall of a dam

Some signals of deterioration and cracking of dams can only be identified by visual inspections. For this reason, these are irreplaceable in the control of the safety of dams. Concerning the exterior walls, and sometimes also the crest, as there is no direct access to most of these areas, cameras and/or binoculars are used to perform the inspection work, which is usually done from the banks of the river. In our test we used photos taken by a digital camera carried by an unmanned aerial vehicle (UAV) helicopter of a small area on the downstream face and of the spillway on the crest of Bouçã dam (Figures 24 and 25).

The photo survey was done by a digital camera Sony Nex-7, mounted under an eight-rotor mini helicopter (Figure 21, photo taken before the camera was mounted). The flight was remotely controlled by a pilot on the ground and there was a second technician who controlled the camera (its orientation and when to trigger). Each one had a

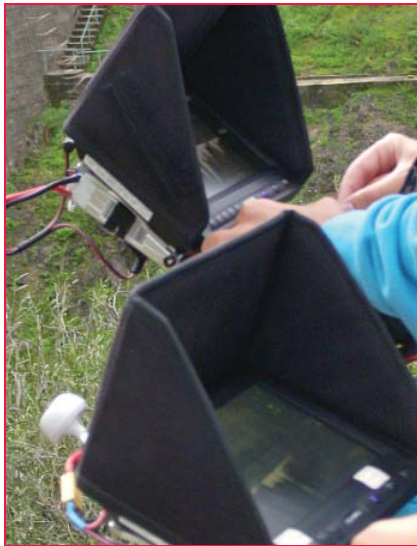


Figure 23: Remotely commanding the drone and the camera



Figure 24: Horizontal photograph of the downstream wall of Bouça dam

remote control (Figures 22 and 23) that communicated with the drone. There were made three flights. Table 1 has a resume of the info of each flight. The first flight had to be interrupted due to a short shower, during which the heli was on land, protected from the rain.

The dam has three major horizontal cracks, which are under surveillance since they were noticed. Two appear during the first filling, by 1956, the third in January of 2007. Due to the colour of the deposits of carbonates under the cracks, one can easily see their location.



Figure 25: Inclined photograph of the spillway on the crest of Bouça dam



Figure 26: Point cloud of a section of the spillway

The change of the focal length allowed, without changing much the distance drone-wall, to have a group of images more global, better to produce an orthomosaic of the dam. On Figures 27 and 28 one can see the differences between the photographs taken with the focal length of 50 mm (flight A) and a focal length of 16 mm (flight B).



Figure 27: Flight A. Central crack photographed with a focal length of 50 mm



Figure 28: Flight B. Central crack photographed with a focal length of 16 mm

The first step of software Micmac is to detect common points in each pair of photos. In Figure 29 is presented the location of common points as detected by the software: one can see that it was difficult for the software to identify points in the white areas and in the wet areas.

An orthomosaic is created by gathering selected areas of images, photos that were corrected from distortions of the camera

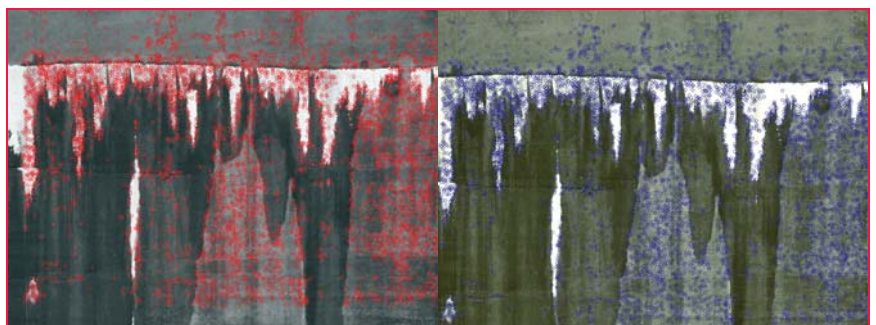


Figure 29: Common points in a pair of photographs

Table 1: Some data about the flights

Flight	Area	Distance to the dam	Flight length	N.º photos	Nº blurry photos	Focal length	Size pixel
A	cracks	4m-9m	4min 45s	99	9	50 mm	1.3 mm
B	cracks	8m-12m	2min 52s	83	7	16 mm	5.0 mm
C	spillway	2m-4m	53s	26	1	16 mm	5.6 mm





Figure 30: A section of orthomosaic generated with photos of flight B



Figure 31: Information generated by Micmac: areas covered with the same photo



Figure 32: Relating the areas with the photos

and from the geometry of acquisition. In Figure 30 is presented a section of the orthomosaic generated by Micmac with the photos of flight B and, in Figure 31, information that helps to understand how the orthomosaic is built: an area with the same colour means that in that area of the orthomosaic it was used the same image (see Figure 32). In Figure 30 one can notice the frontiers between some areas; changing the value of a parameter of Micmac the final image could become more homogeneous.

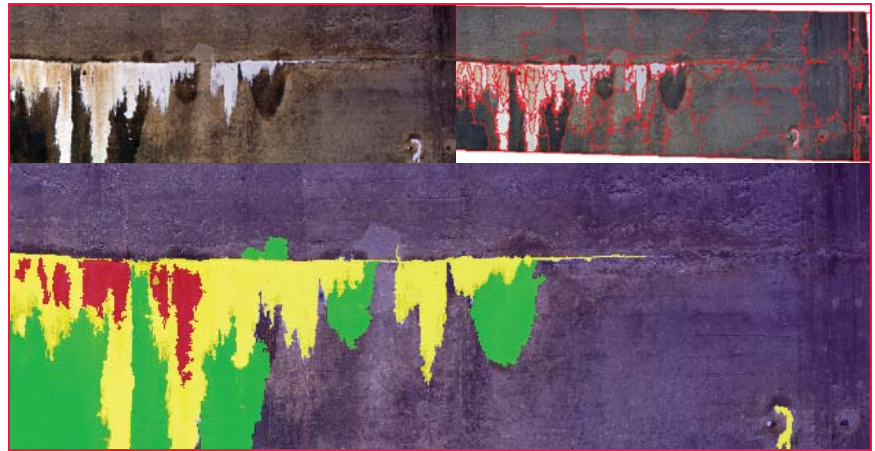


Figure 33: Object-based image classification: original image; segmentation; classification

The main purpose of the flights was to collect data to support aided visual inspections. To evidence anomalies on the surface, digital image classification techniques were used to show the areas that shared the same characteristics. It was applied the technique known as “object-based image classification” to classify the anomalies represented in the orthomosaics and used the software *eCognition* from Trimble. The steps of classification were: i) segmentation: neighbour pixels were aggregated forming objects based on colour and shape (parameters defined by the user); ii) selection of variables and respective thresholds that provide an efficient identification of the features that are going to be classified; iii) automatic classification of the image.

The result of the classification is presented in Figure 33. One can see that three themes were chosen: i) white areas: deposits of calcium carbonate below the cracks where the water has leaked/is leaking; ii) red areas: areas where the calcium presents a redish colour; iii) wet concrete.

During the segmentation process, large and compact objects were formed respecting the radiometric borders visible in the image. Instead of performing the analysis of each individual pixel, the classification was applied over the objects. The objects representing areas with carbonates were identified through radiometric variables. The

classification of the wet areas, besides the radiometry, also considered the proximity between the objects to be classified and those previously classified as carbonates. One can notice that some of the areas of the concrete that are darker were not classified as wet because its colour is not dark enough.

## Conclusions

Point clouds and orthomosaics generated from photographs taken at short distances, less than 10 meters, can be helpful tools to experts like civil engineers that must make small scale studies. The examples presented were the first attempts and more studies on the accuracy must be performed. As a complement to the point clouds and orthomosaics, digital image processing techniques were verified to be great, providing useful information for Civil Engineering applications. In the presented examples, contributions to the identification of pathologies, detection of changes caused by natural elements and displacement evaluation were given.

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## SAP Enterprise Asset Management Data for Integrity Engineers

AssetWise APM helps integrity and reliability engineers working with SAP Enterprise Asset Management (EAM) to develop programs that support risk-based inspections (RBI) processes. With a view to the SAP Portal in real-time, inspectors and maintenance technicians are empowered with the information they need, when they need it in the field. With access to SAP EAM asset and work history, users can navigate assets geospatially and get immediate feedback when condition readings are out of allowable tolerances. The asset health dashboard consolidates and analyzes all condition data from inspections and real-time monitoring devices, which facilitates more timely and accurate decisions on corrective actions.

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## Intermap Chooses Global Mapper

Blue Marble Geographics has announced that Intermap Technologies has signed an Enterprise License Agreement (ELA) providing unrestricted access to Global Mapper and the Global Mapper LiDAR Module throughout the company's data management and processing operations. [www.bluemarblegeo.com](http://www.bluemarblegeo.com)

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## UN-GGIM: Europe announces creation of GRF-Europe

Europe is contributing to the UN's Global Geodetic Reference Frame (GGRF) by developing a platform for exchanging information and expertise. The creation of a new UN-GGIM: Europe working group, GRF-Europe will connect a range of stakeholders and act as an intergovernmental link whilst also promoting the sharing of open geodetic data and common standards as well as fostering capacity building where needed. In doing so, it will provide a link between the geospatial community, including EUREF the International Association of Geodesy Reference Frame Sub-Commission for Europe, scientists and policy makers.

“The UN General Assembly urges the sharing of geospatial data to benefit people and the planet,” explains GRF-Europe Working Group Leader, Markku Poutanen from Finland.

The GGRF aims to change from the current system, where contributions to the development of the global geodetic reference frame are undertaken on a ‘best efforts’ basis, to one where they are made through a multilateral collaboration under a UN mandate. [www.un-ggim-europe.org](http://www.un-ggim-europe.org)

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## Hydrographic Production Database (HPD)<sup>TM</sup> 3.2

Teledyne CARIS<sup>TM</sup> have announced the release of Hydrographic Production Database (HPD)<sup>TM</sup> 3.2. As part of the CARIS Ping-to-Chart<sup>TM</sup> solution, HPD offers an integrated suite of products for managing data in a seamless database, providing simultaneous data compilation by multiple users.

This release offers exciting features which will allow HPD users to implement new workflows, create new products, and obtain even more value from their database. [www.caris.com](http://www.caris.com)

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## USGS and ISRO cooperation

The U.S. Geological Survey and the Indian Space Research Organization (ISRO) have finalized an agreement for new levels of cooperation in the exchange and use of Earth observation data. The memorandum of understanding was recently signed by Dr. Suzette Kimball, USGS Director, and Dr. V. K. Dadhwal, previous Director of the National Remote Sensing Centre (NRSC), ISRO.

The agreement will allow USGS to receive data of full U.S. coverage (including Alaska & Hawaii) from two of the sensors onboard ISRO's Resourcesat-2 satellite. These data include the Advanced Wide-Field Sensor (AWiFS) with a ground sample distance of 56 meters and the Linear Imaging Self-Scanning Sensor III (LISS-III) with a ground sample distance of 23.5 meters. <https://www.usgs.gov>

### TomTom Inaugurates its Hub in Pune

TomTom (TOM2) has inaugurated its first global state-of-the-art Innovation Hub in Pune. With this facility, it aims to develop a deeper culture of innovation in the company with a free-flow of information and ideas across the globe, allowing experimentation and cross-boundary co-operation to drive change throughout the organization. <http://corporate.tomtom.com>

### Qualcomm and Baidu announce commercialization of IZat

Qualcomm Technologies, Inc. (QTI), is working closely with Baidu in the implementation of the Qualcomm® IZat™ Integrated Hardware Location Platform, which will be available in the latest generation of Qualcomm® Snapdragon™ chipsets across all tiers. The IZat Location Platform uses a combination of signals from various location sources, including GNSS and sensors. This integration at a hardware level is designed to result in accurate

location information, fast time-to-first-fix, improved robustness and seamless transition for both outdoor and indoor environments, and lower power for users of location-based applications and services across smartphones. [www.qualcomm.com](http://www.qualcomm.com)

### Verizon buys Fleetmatics

Verizon will buy Fleetmatics for \$2.4 billion. Fleetmatics specializes in software that allows fleet managers to keep track of location, fuel usage, mileage and more. While there's no word what Fleetmatics' assets will be used for, it's likely that the company will utilize its new acquisition to help bolster its connected-car offerings. [www.cnet.com](http://www.cnet.com)

### Small Vessel Tracking Contract

exactEarth Ltd. has announced that it has been selected by the Fisheries Commission (West Africa Regional Fisheries Programme), an agency of the Ministry of Fisheries and Aquaculture Development (MOFAD) of the

Government of Ghana, for the provision of Satellite AIS data services as well as a small vessel tracking solution. Along with a comprehensive Satellite AIS data feed, exactEarth will provide MOFAD with 450 Class B AIS transceivers to be installed on inshore fishing vessels which will be tracked via satellite utilising exactEarth's exactTrax™ small vessel tracking technology. [exactearth.com](http://exactearth.com).

### Pakistan's first indigenous digital mapping solution launched

TPL Trakker Ltd, a tracking solutions provider, launched country's first indigenously developed digital mapping solution. With close to a million housing addresses, TPL Maps claims to have approximately 1,000 3D building models and 300,000 kilometers of road network mapped across the country. Created using state-of-the-art technology, the TPL Maps app provides real-time intelligent routing, live traffic updates, turn-by-turn navigation options and smart search, among other features. <http://tribune.com.pk>

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## Improving Satellite Navigation in the Far North

The Norwegian research ship Gunnerus, part of the Norwegian University of Science and Technology, is seeking to emulate the technology used by Europe's Geostationary Navigation Overlay System, or EGNOS. EGNOS is currently in use in Europe and contains about 40 ground monitoring stations that measure GPS signals, creating a more precise map for users to interact with when they are on the go.

The ionosphere is particularly active in polar areas, creating a more difficult environment to get a satellite signal. The researchers hope to gain more knowledge as to how the ionosphere more specifically affects satellites, and how to move around these obstacles to create satellite augmentation in this area.

The Norwegian vessel is testing potential improvements to the Satellite-Based Augmentation System, or SBAS, for these northern regions. This project would utilize ground monitoring stations in Russia and combine them with the northernmost ground monitoring stations for EGNOS. The research crew hopes that their new information will help expand GPS in the Polar Regions to overlap with Europe, Russia, and the United States. [www.gislounge.com/](http://www.gislounge.com/)

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## Uttar Pradesh Police, India selects Hexagon

Uttar Pradesh Police, the largest police force in India, has selected an integrated suite of public safety software from Hexagon Safety & Infrastructure to enhance call handling, officer dispatching and agency-wide reporting in India's most populous state. Hexagon's industry-leading Intergraph Computer-Aided Dispatch (I/CAD) will form the basis for the largest police emergency response system in India, and possibly the largest in the world, serving 220 million people.

Uttar Pradesh Police will be the first Indian state police force to implement an integrated emergency operation center (EOC) at its capital city of Lucknow. The

software will deliver map-based views of calls, events and units in the field to 246 call takers and 114 dispatchers. [www.hexagonsafetyinfrastructure.com](http://www.hexagonsafetyinfrastructure.com)

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## Ingrid Daubechies receives Simons grant

Ingrid Daubechies, a prominent mathematician whose pioneering work on wavelets is the foundation for various consumer products and GNSS applications, has received a \$1.5 million grant from the Simons Foundation. Daubechies is the James B. Duke Professor of Mathematics and Electrical and Computer Engineering at Duke University in Durham, North Carolina.

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## Status updates to GPS-Aided Collision Avoidance System

The Federal Railroad Administration (FRA) last week released a status update that calls for railroads to roll out Positive Train Control (PTC) technologies, which incorporates GNSS technology, as soon as possible. The update also underscores the Obama administration's calls to provide more funding to assist commuter railroads in implementing PTC.

PTC uses GNSS, but mostly GPS, to prevent train-to-train collisions, high-speed derailments, and the unauthorized movement of trains into work zones. The FRA's status update includes railroad-by-railroad quarterly data as of June 30, 2016. The report also includes on-track segments completed, employees trained, radio towers installed, route miles in PTC operation, and other key implementation data.

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## Russia develops Hi-Tech jammer to block enemy electronics

An integrated jamming system to screen strategic facilities from cruise missiles, smart bombs and drones using GPS, GLONASS, Galileo and Beidou GNSS for homing has entered service with the Russian armed forces. Russian Airborne Troops to Include Drone, Electronic Warfare Units by 2017 Dubbed as POLE-21, the system consists of jamming modules installed on mobile phone towers and working as a single whole to cover

entire areas and making them impregnable to satellite navigation systems. Besides being powered by a tower's circuit, the Pole-21 modules also use their GSM antennas as a backup channel for signal control and transmission. All the four GNSS whose signals are effectively deflected by Pole-21 work within the 1176.45 and 1575.42 MHz range. Even a 20 watt transmitter is enough for Pole-21 to jam all signals in this range within a radius of 80 kilometers. Pole-21 has one downside though. While generating radio interference against the enemy using the GPS satellite navigation systems, it does the same to domestic users of GPS and its Russian analogue – GLONASS. <https://sputniknews.com>

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## Unmanned Harvester using Glonass

Russia is set to develop unmanned agricultural machinery running on the Russian Glonass navigation system by 2018. The technology will be developed by the Ruselectronics holding, represented by the Progress Microelectronic Research Institute (JSC Progress MRI) design center, for the Rostselmash agricultural equipment company. "After the completion of development work in two years' time, we will be able to provide unmanned machinery [for the agricultural sector] – an operator may be present, but rather for control in case of unforeseen situations. There seem to be no particular dangers in an open field," according to first deputy CEO for development and researches at JSC Progress Igor Korneyev. <https://sputniknews.com>

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## Galileo satellites to start broadcasting navigation messages

According to two Notice Advisories to Galileo Users (NAGUs), the two Galileo satellites launched into elliptical orbits in August 2014, GSAT0201 using PRN code E18 and GSAT0202 using PRN code E14, will start transmitting navigation messages for test purposes. The Signal Health Status (SHS) flags will be set to "Test" and the Data Validity Status (DVS) flags will be set to WWG (working without guarantee). The satellites will not be included in the broadcast almanacs.

Users are requested to provide feedback on usage of GSAT0201 and GSAT0202 by contacting the help desk on the European GNSS Service Centre web portal.

### Space weather forecasts to eliminate GPS mistakes

Researchers from RMIT are borrowing the Bureau of Meteorology's supercomputer capacity at NCI to crunch through calculations they hope will predict how 'disturbances' in the earth's atmosphere could be putting GPS off track. Brett Carter, a research fellow in space weather and physics, is leading a team studying how the layer of charged particles surrounding the earth, known as the 'ionosphere', affects GPS readings - and how this knowledge could make the technology more accurate.

"Any disturbance that start at sun and arrive at the Earth through the solar wind and the magnetosphere affects the plasma in the upper atmosphere," Carter said.

"Because it's a medium of charged particles, when you pass radio waves through it, radio waves are affected by electrons inside the plasma."

These pockets of different atmospheric density slow down radio waves as they pass through between orbiting satellites and GPS-enabled devices on the ground. These disturbances – also known as GPS interpolation events or plasma bubbles – happen almost every day somewhere around the world. In areas close to the equator, from June to September, there is around a 50 percent chance of a disturbance happening on any given day. This can alter GPS location calculations which are based on the assumption that all radio waves are travelling at the same speed, he said.

The researchers will attempt to generate forecasts based on data gathered from GPS ground stations, along with the US COSMIC-2 low Earth orbit satellite constellation, which is set to launch over the next 12 months. [www.itnews.com.au](http://www.itnews.com.au)

### Breaking barriers for people living with vision loss

Researchers at McGill University have developed an innovative technology so Canadians living with vision loss can better navigate the world around them. After successfully testing its Autour application in Montréal, and with funding from the Canadian Internet Registration Authority's Community Investment Program, the McGill team has launched an expanded version of the app to include cities across Canada.

The app overlays GPS, Google Maps, public transit and other data to provide audible instructions and descriptions to help guide users' movements. Usability is a key factor making Autour the app of choice for the blind and visually impaired community. The expanded Autour features a new tutorial to give users a clear understanding of how the app works. The tutorial can even be used indoors, and in other environments where GPS may not be available. <https://cira.ca/>

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## Operational trials of DAA and BVLOS display software

Kongsberg Geospatial and the Federal Aviation Administration's (FAAs) ASSURE UAS Center of Excellence, lead by Mississippi State University has announced that the Alaska Center for Unmanned Aircraft Systems Integration (ACUASI) at the University of Alaska Fairbanks, and the University of North Dakota Center for Unmanned Aircraft Systems Research, Education and Training will both be adopting and integrating the Kongsberg Geospatial IRIS UAS display application into their flight operations as part of Detect And Avoid (DAA) and beyond visual line-of-sight (BVLOS) operations.

The Alliance for System Safety of UAS Through Research Excellence, or ASSURE, team is comprised of 22 universities and over 100 industry partners, providing the FAA with access to a team of scientists in the UAS community and coordination of activities to achieve common UAS research goals. [www.kongsberggeospatial.com](http://www.kongsberggeospatial.com).

## Propeller Aero launches AeroPoints

Australian technology company Propeller Aero has launched AeroPoints: smart ground control points that make it easy for anyone to capture survey-accurate mapping using drones. Its patent-pending technology provides a simple solution to one of the major roadblocks to widespread commercial drone adoption: accuracy. It's another step forward for Propeller Aero on its mission to transform the way different industries can use drones and other camera devices. [propelleraero.com/aeropoints](http://propelleraero.com/aeropoints)

## GPS drone weedkiller technology from CIC

CIC Holdings PLC, Sri Lanka, for the first time in the world has developed a technology to scan weeds in large paddy fields using battery powered drones (planes) and spray chemicals to them using the drone. The company's research and development team has used studies and research for the past 8 years to introduce this novel technology. Samantha Ranatunge, MD, CIC Holdings said that

they had invested around US 6,000 for this home grown research. "CIC has been pioneering in agriculture and research and this is a result of that effort that this 'Precision Agriculture Practices' (Smart farming) are being implemented," he said.

He said that through aerial photography obtained from the drone surveillance they can identify weeds and create a GPS map and then program the drone to spray chemicals to that particular area via GPS. [www.dailynews.lk](http://www.dailynews.lk)

## Drone to monitor illegal quarrying

In the first initiative of its kind, the Uttarakhand government in India has decided to use a drone to check illegal quarrying on the Gaula riverbed. The unmanned aerial vehicle, which will take flight from Haldwani, has been procured by the state's forest department. Its primary purpose is to check areas like swamps and forested areas that are not easily accessible to regular staffers. Conservator (western division) Parag Madhukar Dhakate said they have long felt the need for a drone because many places in the state are inaccessible by foot due to the treacherous terrain. "But, at present, we will focus only on illegal quarrying activities on the Gaula riverbed," he added. [www.hindustantimes.com](http://www.hindustantimes.com)

## Feds turn to space experts NASA for small-drone traffic plan

As the unmanned aircraft industry continues to evolve, the United States is depending on its space agency to help manage small drone traffic close to the Earth. NASA is currently entering the second phase of a four-step plan to draw up rules of the skies for drones that weigh 55 pounds or less and fly no higher than 500 feet. The project is meant to develop performance standards for drones that would be used for commercial purposes by companies such as Amazon and Google.

The agency is hoping to present its research to the Federal Aviation Administration before 2020, John Cavolowsky, according to director of NASA's Airspace Operations

and Safety Program. NASA is entering the next phase of a plan to draw up rules of the road for small drones that fly under 500 feet. The NASA project is meant to develop performance standards for drones that would be used for commercial purposes. [www.dailymail.co.uk](http://www.dailymail.co.uk)

## Report on how to legally operate drones under new FAA regulation

To coincide with the new Small UAS Rule, aka Part 107, Commercial UAV News has announced the release of a free online report that helps define what it means to legally fly drones under the new FAA regulation that went into effect recently. The ruling represents a critical moment that will forever change the commercial drone industry, and the report is an accessible article that outlines the essential guidelines for non-hobbyist small unmanned aircraft (UAS) operators looking to understand the impact of Part 107 and the stipulations for flying commercial UAVs under the new legislation. The report helps to clarify what is required, spells out operations that are enabled and restricted, outlines what the process entails, and reveals what Part 107 covers. It also clarifies what Part 107 means for those previously cleared by the FAA to legally operate commercial drones under Section 333 Exemptions.

## CNN To Gather News Using Drones

Two full-time drone operators will help the network integrate the unmanned aircraft systems into its ongoing news coverage. CNN will now use unmanned aerial drones to help it gather news in a wide range of situations as part of the company's newly created CNN Aerial Imagery and Reporting (AIR) unit. The news broadcasting company unveiled the CNN AIR efforts in an Aug. 18 announcement that also revealed that the company has hired two full-time drone operators to fly the devices. CNN has been working with the Federal Aviation Administration since 2015 on research to safely use drones for newsgathering, according to the company. [www.techweekeurope.co.uk](http://www.techweekeurope.co.uk)

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## Iran unveils VTOL drone for aerial photography

Iran's Defense Ministry has unveiled 'Roham' - a homegrown Unmanned Aerial Vehicle (UAV) with vertical take-off and landing (VTOL) capabilities used for aerial photography. Roham has been developed for taking aerial photographs over difficult terrains, where landing and take-off is impossible for other types of aircraft. The drone, manufactured jointly by the Defense Ministry and local academic and research centers, can receive photogrammetry (mapping from aerial photographs) data, fly and hover over sea or mountainous and forested areas, land on and take off from any location, monitor a specific target at low altitudes and patrol an area at a high speed. [www.tasnimnews.com](http://www.tasnimnews.com)

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## Iran, Russia to cooperate in building remote-sensing satellite

According to Mahmoud Vaezi, minister of IT, Iran has said that an agreement

has been hit with Russia where it will cooperate with Iran in developing Iran's National Remote-Sensing Satellite.

He said that among his visit's achievement was an initial agreement with Russian to work with Iranian industries to build the remote-sensing satellite, under the title of National Remote-Sensing Satellite; "as the project is very critical, we predict building of the satellite to last two years," said Mr. Vaezi. <http://en.mehrnews.com>

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## Pix4D Elevates Agriculture Software to Desktop & Cloud Solution

Today Pix4D announces its first hybrid processing solution. Users of Sequoia with a license of Pix4Dmapper Ag will be able to process both locally in Pix4Dmapper Ag and on the Pix4Dcloud. Together with this announcement, Pix4D also introduces very flexible monthly (149 USD) and yearly (1490 USD) plans for its Pix4Dmapper Ag solutions.

This new strategy comes from seeing the need in the agriculture industry for more flexible processing options to facilitate competitive operations. With the hybrid approach, users are able to choose where to process: whether they prefer to process data right after landing and are in an area with bad connectivity, or want to upload to the cloud and not involve processing hardware. Because the powerful Pix4D engine powers both options, the results will be equally geometric and radiometrically accurate, regardless of where they were processed.

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## Jamaica introduces drones to farmers

The Ministry of Industry, Commerce, Agriculture and Fisheries, is collaborating with local company D&C Drones to revolutionise the agriculture sector through the introduction of drone technology. Recently, the Ministry took the technology to farmers in Lowe River, Trelawny, to demonstrate its use and applicability. <http://jis.gov.jm> 



[www.ip-solutions.jp](http://www.ip-solutions.jp)

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[ion.org/gnss](http://ion.org/gnss)

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## Sensoror supplies IMUs for NASA Raven and Near Earth Orbit Scout

Sensoror AS first began supplying its standard Inertial Measurement Unit (IMU) and Gyroscope Modules for Low Earth Orbit (LEO) space applications in 2012, beginning with the launch of the NASA sponsored AeroCube-4 satellite.

Recently Sensoror is a supplier for NASA's current and future Low and Near Earth Orbit space applications. Sensoror's STIM300 and STIM210 inertial products are now a standard part in many spacecraft's similar to the AeroCube-4. Current NASA projects using STIM inertial systems include the Raven technology demonstration and Near Earth Asteroid (NEA) Scout. Raven, which launches to the International Space Station in 2016, will test key elements of an autonomous relative navigation system. Its technologies may one day help future robotic spacecraft autonomously and seamlessly rendezvous with other objects in motion, such as a satellite in need of fuel, or a tumbling asteroid. The NEA Scout is a robotic reconnaissance mission that will be deployed to fly by and return data from an asteroid representative of NEAs.

NASA, in conjunction with the Aerospace Corp, spearheaded the use of STIM products in space, and many other commercial launch and satellite companies have since followed NASA's lead.

The STIM Gyroscope Modules are often used in combination with GPS or a Star Tracker and Kalman Filter to orient and stabilize the satellite, as well as to provide feedback on satellite motion induced by its reaction wheels. In some applications, the gyroscopes are used to stabilize satellite-to-satellite communications.

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## NovAtel releases 2 triple-frequency marine GNSS antennas

NovAtel Inc. has introduced the GPS-713-GGG-N and GPS-713-GGGL-N ATEX-qualified triple-frequency GNSS antennas with an Inmarsat rejection filter.

Based on the company's pinwheel technology, the antennas offer multi-constellation reception of L1, L2 and L5 GPS; L1, L2 and L3 GLONASS; B1 and B2 BeiDou; as well as E1 and E5 a/b Galileo frequencies.

The GPS-713-GGGL-N also supports L-Band from 1525 to 1560 megahertz. The same antenna can be used for GPS-only, dual or triple constellation applications, resulting in increased flexibility and reduced equipment costs, the company said in a news release.

The phase center of the antennas remain constant as the azimuth and elevation angle of the satellites change. Signal reception is unaffected by the rotation of the antenna or satellite elevation, according to NovAtel. With the phase center in the same location for the GNSS signals, and with minimal phase center variation between antennas, the antenna is suitable for baselines of any length.

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## Septentrio PolaRx5 GNSS

Septentrio has announced that the expansion of the PolaRx5 GNSS receiver family with the introduction of its newest ionospheric scintillation monitoring product. The PolaRx5S is powered by Septentrio's AsteRx4 next-generation multi-frequency engine. It offers 544 hardware channels and supports all major satellite signals including GPS, GLONASS, Galileo and BeiDou for all-in-view ionospheric monitoring. The increased number of pierce points provided by the highest possible satellites creates a more comprehensive opportunity for mapping anomalies. [www.septentrio.com](http://www.septentrio.com)

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## Harxon antenna aimed at marine positioning

Harxon has released a utility beacon antenna — HX-CS7615A — to professionally solve marine satellite positioning challenges. The HX-CS7615A supports GPS L1/L2, GLONASS L1/L2 BDS B1/B2/B3 and beacon frequencies (282.6 to 326 KHz), which greatly overcomes the defects of long-distance transmission limits. In addition, combining

wide frequencies in one antenna makes the new device more cost effective.

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## Fugro, US Army Corps of Engineers ink mapping deal

The agreement is a five-year indefinite delivery indefinite quantity (IDIQ) contract with a ceiling value of \$12.5 million. It marks Fugro's third consecutive mapping contract with the Corps, making this a partnership that has spanned more than 30 years. Mapping completed under this contract will support the Corps' Center of Expertise for Photogrammetric Mapping in their endeavours to provide full service, rapid response photogrammetric mapping. Task orders from the contract will span the range of geospatial services that Fugro offers, including photogrammetry, LIDAR elevation mapping, oblique imagery solutions, remote sensing, topographic and planimetric mapping, land use/land cover analysis and disaster response services. [www.marinelink.com](http://www.marinelink.com)

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## Spectracom Introduces GSG-6 Series GNSS Simulators

Spectracom has introduced two timing-related products, the GSG 6-Series GPS/GNSS simulator for testing receivers' timing capabilities and the SecureSync Timing Reference with enhanced Loran (eLoran) backup capability for GNSS.

The company's off-the-shelf GSG 6 units support dual-frequency (L1/L2) GPS receivers and military secure SAASM modules with pseudo P(Y) code as well as the new GPS civil signals, L2C and L5; legacy GNSS L1 (GLONASS, BeiDou, and Galileo) signals and other new GNSS signals: GLONASS L2, Galileo E5, BeiDou B2; and Indian Regional Navigation Satellite System (IRNSS) L5.

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## Hemisphere GNSS Launches OEM Boards

Hemisphere GNSS has introduced two new OEM boards, the Eclipse P326 and P327, designed for machine control, land or marine survey, and agriculture applications. The boards support GPS, GLONASS, BeiDou, Galileo, and



Japan's QZSS. The boards are the first within the Eclipse product line to have refreshed low-power capability, reduced size, cost, and weight, the company said. P326 and P327 offer centimeter-level accuracy in single or multi-frequencies, using signals from multiple GNSS constellations and Atlas-capable modes.

Because of its small size (41 x 71 millimeters), P326 is a drop-in upgrade for Hemisphere's existing products. The P327 module, larger at 41 x 72 millimeters, is a drop-in upgrade for standard 20-pin modules manufactured by other companies.

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### UK Firm develops GPS-free positioning system

Defense contractors Polaris Consulting have developed a software system to use visual and radar data to compute a vessel's position in littoral waters – independent of GPS.

The research was funded by the UK Ministry of Defence's Centre for Defence Enterprise for use in autonomous applications, allowing self-navigating vehicles to get a fix on their location in coastal areas where an adversary is jamming GPS signals ("GPS denied environments").

The common option for automated, GPS-free navigation is the inertial guidance system, long used in aerospace and defense applications. However, an inertial system's estimate is based on dead reckoning from one initial position, and it degrades over time until the next fix. It must be very sensitive in order to deliver an accurate estimated position, and the equipment is expensive.

Instead, Polaris' software uses an algorithm for integrating input from optical and radar sources, analogous to a mariner's triangulations in terrestrial navigation. It calculates a position based on what each input "sees" and then adjusts how much it trusts the data based on current conditions. If it's foggy, the algorithm treats the camera-based position as less accurate. [www.maritime-executive.com](http://www.maritime-executive.com)

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### INS/GNSS Inertial Navigation System for Maritime Applications

With iMAR Navigation's iNAT-RQT-4003, an RLG-based highly accurate INS/GNSS system is launched which is not affected by any ITAR regulations and which is handled under standard dual-use export control only. The system is designed for navigation and guidance applications as well as for most accurate surveying applications with interface capabilities to external sensors like USBL or DVL.

The iNAT-RQT ('iNAT' stands for 'iMAR Navigation & Timing') is the successor of the iNAV-RQH system, which has now been on the market for more than 15 years. The new version has lower power consumption, smaller size, less weight and extended interface capabilities including Ethernet (UDP, TCP/IP), UART RS422/RS232, CAN, ARINC429, ARINC825, HDLC and USB. The system supports GPS, GLONASS, Beidou, GALILEO and TerraStar, provides RTK and optionally SAASM capability and contains 32GB of internal memory for online data storage. The system is qualified to MIL-STD-810G, MIL-STD-416F, MIL-STD-704F and DO-160G.

The iNAT-RQT-4003 has gyro-compassing capability and is used for AUV navigation as well as for surface-vessel navigation, surveying and motion control.

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### Trimble acquires AXIO-NET

Trimble has announced the acquisition of AXIO-NET GmbH from Airbus Defence and Space. Based in Hannover, Germany, AXIO-NET is a prominent provider of GNSS corrections and professional data services serving Germany, the United Kingdom and Benelux. [www.trimble.com](http://www.trimble.com)

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### IndoorAtlas Awarded 2.2 Million Grant from the European Commission

IndoorAtlas Ltd has received €2.2 million from the European Commission Horizon 2020 grants program. Horizon 2020 is the biggest EU Research and Innovation program, with nearly €80

billion in funding available. Grant recipients, including IndoorAtlas, were selected based on technological breakthroughs with the potential to drive economic growth by taking great ideas from the lab to the market.

IndoorAtlas' researchers originally discovered that each modern building has a unique magnetic fingerprint. They went on to develop software that enables the magnetic sensor within any smartphone to accurately pinpoint and track a person's location indoors. Developers can now integrate indoor location-based services into their mobile applications. [www.indooratlas.com](http://www.indooratlas.com).

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### EANA S.E. Becomes Argentina's Air Navigation Service Provider

Empresa Argentina de Navegación Aérea S.E. (EANA), a Ministry of Transport company, has taken over full management of Argentina's air traffic services. The company says it plans to invest US\$121M in infrastructure and technology.

"We are very excited to take this definitive step as part of EANA's development by fully taking over the ANS. We are firmly committed to service quality and we shall make our contribution to the overall efficiency of the air transport system. That includes our own efficiency and that of our customers", said Agustín Rodríguez Grellet, General Manager of EANA S.E. "We want to proudly play a key part in the deep changes ahead and put EANA on a par with the world leaders in the industry" [www.airportsinternational.com](http://www.airportsinternational.com)

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### SXPad 800H released by Geneq

Geneq Inc. has released the SXPad 800H, which the company describes as a feature-packed, rugged handheld GPS data collector at an affordable price. It is specifically designed for mobile GIS users in applications ranging from water, electric and gas utilities, transportation, mining, agriculture and forestry. The high-performance 800-MHz device is designed to give users all the power

needed to work with maps and large data sets in the field. It is designed for rugged outdoor use, the company says, with a waterproof seal (IP65) and ability to survive a 5-foot (1.5-meter) drop to concrete. Its 3.7-inch color touchscreen (full VGA) is sharp and is sunlight readable.

### senseFly & Air Navigation Pro to reduce the risk of mid-air collision

senseFly, has teamed up with the popular aviation navigation app, Air Navigation Pro, to launch Safer Together. This joint initiative has been designed to address one of the biggest issues facing the General Aviation (GA) and unmanned aircraft communities: the risk of mid-air collision.

Safer Together will make the skies a safer place by providing GA pilots and drone operators with awareness of each other's airborne activities, giving them the knowledge they need to take any actions necessary to avoid mid-air incidents around 200 – 400 feet (60 – 120 m) above ground level, where most light-weight drones currently fly. This initiative is fully in-line with senseFly's recent involvement in Global UTM (UAS Traffic Management) and JARUS discussions.

### Intuicom offering enhanced connectivity solution for GNSS

Intuicom Incorporated has released the Intuicom 4G LTE RTK Bridge-X Communication Hub. Increasing the communication capabilities of the standard-setting RTK Bridge product line, the 4G LTE RTK Bridge-X lets users leverage the faster upload/download speeds, the expanded coverage and enhanced connectivity offered by 4G LTE providers including Verizon, AT&T and T-Mobile. The 4G LTE RTK Bridge-X supports all leading precision guidance systems and GNSS manufacturers. It allows users to access configure and manage their device from their smart phone, tablet or laptop without being connected by a physical cable. ▽

## MARK YOUR CALENDAR

### September 2016

#### INSPIRE 2016

20 - 30 September  
Barcelona, Spain  
[http://inspire.ec.europa.eu/events/conferences/inspire\\_2016/page/home](http://inspire.ec.europa.eu/events/conferences/inspire_2016/page/home)

#### EUROGEO 2016

29 - 30 September  
University of Malaga, Spain  
[www.eurogeography.eu/conference-2016-malaga/](http://www.eurogeography.eu/conference-2016-malaga/)

### October 2016

#### INTERGEO 2016

11 - 13 October  
Hamburg, Germany  
[www.intergeo.de](http://www.intergeo.de)

#### 37th Asian Conference on Remote Sensing (ACRS)

17 - 21 October  
Colombo, Sri Lanka  
[www.acrs2016.org](http://www.acrs2016.org)

#### INGEO 2017

18 - 20 October  
Lisbon, Portugal  
[ingeo2017.inec.pt](http://ingeo2017.inec.pt)

#### 3D Athens Conference

18-21 October  
Athens, Greece  
<http://3dathens2016.gr/site/>

#### 3rd Commercial UAV Show

19-20 October  
ExCel, London, UK  
<http://www.terrapinn.com/exhibition/the-commercial-uav-show/>

#### Commercial UAV Expo 2016

31 October - 2 November  
Las Vegas, USA  
[www.expouav.com](http://www.expouav.com)

#### Bentley YII Conference

October 31 - November 3  
London, UK  
[www.bentley.com](http://www.bentley.com)

### November 2016

#### ICG-11: International Committee on GNSS

6 - 11 November  
Sochi, Russia  
<http://www.unoosa.org/oosa/en/ourwork/icg/icg.html>

#### Trimble Dimension 2016

7-9 November  
Las Vegas, USA  
<http://www.trimbledimensions.com/>

#### INC 2016: RIN International Navigation Conference

8 - 10 November  
Glasgow, Scotland  
<http://www.rin.org.uk/Events/4131/INC16>

#### 36th INCA International Congress

9 -11 November  
Santiniketan, West Bengal, India  
<http://incaindia.org>

#### FROM IMAGERY TO MAP: Digital Photogrammetric Technologies

13 - 17 of November  
Agra, India  
<http://conf.racurs.ru/conf2016/eng/>

#### 13th International Conference on LBS

14-16 November  
Vienna, Austria  
<http://lbs2016.org>

#### International technical symposium on navigation and timing

15-16 Nov  
Toulouse, France  
<http://itsnt.recherche.enac.fr/index.php>

#### GSDI 2015 World Conference

28 November - 2 December  
Taipei, Taiwan  
<http://gsdiassociation.org/index.php/homepage/gsd-15-world-conference.html>

### December 2016

#### ISGNSS 2016

5 - 7 Dec  
Tainan, Taiwan  
<http://isgnss2016.ncku.edu.tw/>

#### IGNSS 2016

6 - 8 December  
UNSW Australia  
[ignss2016.unsw.edu.au](http://ignss2016.unsw.edu.au)

#### United Nations/Nepal Workshop on the Applications of GNSS

12 - 16 December  
Kathmandu, Nepal  
<http://www.unoosa.org/pdf/icg/2016/nepal-workshop/InfoNote.pdf>

#### Navitec 2016

14 - 16 December  
Noordwijk, Netherlands  
<http://navitec.esa.int>

### February 2017

#### 17th annual International LiDAR Mapping Forum (ILMF)

13-15 February  
Denver, Colorado, USA  
[www.lidarmap.org](http://www.lidarmap.org)

### March 2017

#### 2017 GIS/CAMA Technologies Conference,

6 - 9, March  
Chattanooga, Tennessee  
[www.urisa.org](http://www.urisa.org)

### April 2017

#### GISTAM 2017

27 - 28 April  
Porto, Portugal  
<http://gistam.org/>

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