EU Space Programmes for Geomatics

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1. SUMMARY

The evolution of the European GNSS Agency (GSA) into the European Union Agency for the Space Programme (EUSPA) sets the start of a new era for EU Space. EUSPA will create even more opportunities for EU citizens and the economy, in particular by leveraging synergies between the space programme components on the downstream market, especially for GNSS and Earth observation, playing a key role in the development of downstream applications.

This article provides an overview about the EU Space Programmes Galileo, EGNOS and Copernicus, their synergies and applications for geomatics' users.

2. GALILEO

2.1. What is Galileo

Galileo is the European Global Navigation Satellite System (EGNSS) that provides satellite positioning services worldwide. The Galileo system was designed focusing on the civil citizens, making it independent from military entities and allowing the provision of a full range of services that ease the development of multiple applications at user level.

Galileo is currently providing three different services: Galileo Open Service (OS) and Galileo Search and Rescue (SAR), which are accessible to civil users, and the Galileo Public Regulated Service (PRS) which is delivered to governmental and authorized users.

2.2. Galileo Services

Galileo Open Service (OS)

Galileo OS is a free of charge positioning and timing service available worldwide. Galileo OS offers the **Galileo OS Ranging Service,** allowing users to estimate their distance to the satellite, the **Galileo OS UTC Time Determination Service**, providing with a direct and accurate access to Universal Time Coordinated (UTC) and the **Galileo OS Positioning Service** which allows Galileo receivers to estimate their position through combination of ranging and timing measurements.

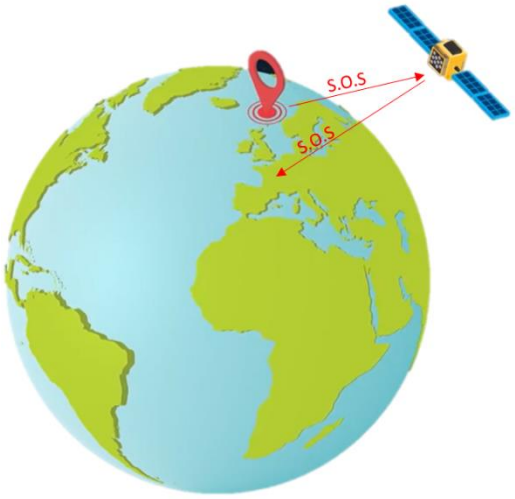


Figure 1: Galileo OS positioning and timing service

Galileo provides ranging signals in three different frequency bands, enabling single- and dual- frequency positioning for users equipped with suitable receivers. The receivers may be single frequency (SF) or double frequency (DF). SF receivers extract navigation information from any of the three frequencies (E1, E5a and E5b) while a DF receiver extracts information from a combination of E1 and E5a or E1 and E5b. A DF solution allows compensation of the ionospheric errors, thus provides better performance to the user. How the receiver understands the Galileo OS signals is explained in the Galileo OS Signal In Space Interface Control Document (OS SIS ICD).

Galileo Search and Rescue (SAR)

Galileo offers a significant contribution to the Search and Rescue service (SAR), an international life-saving service managed by COSPAS-SARSAT. Contribution from Galileo to SAR service is twofold. In the first place, Galileo satellites re-transmit distress alert signals from SAR beacons to the corresponding rescue centers in ground. This is crucial for a fast detection of distress beacons.

Figure 2: Galileo contribution to COSPAS-SARSAT

On the second place, with the **Galileo Return link service**, Galileo will also provide a return signal, letting people know that their signal has been received. This acknowledge message reduces the stress of people while they wait for the rescue team.

2.3. Future Galileo Services

Once fully deployed, Galileo will offer two new services: **Galileo Open Service Navigation Message Authentication (OSNMA)**, which will allow users to authenticate Galileo navigation messages and **Galileo High Accuracy Service (HAS)**, which will offer orbit and clock corrections to be processed by users' receivers and obtain decimeter accuracies.

- **Galileo OSNMA** provides receivers with the assurance that the received Galileo navigation message is coming from the system itself and has not been modified. OSNMA is authenticating data for geolocation information from the Open Service through the Navigation Message

(I/NAV) broadcast on the E1-B signal component. This is realized by transmitting authentication-specific data in previously reserved fields of the E1 I/NAV message. By using these previously reserved fields, OSNMA does not introduce any overlay to the system, thus the OS navigation performance remains untouched. Besides, those receivers already tracking OS signals will only need a firmware update to start authenticating the navigation data. Additional details about OSNMA service can be found in Galileo Open Service Navigation Message Authentication (OSNMA) Info Note.

- **Galileo HAS** provides free of charge high accuracy Precise Point Positioning (PPP) corrections through the Galileo signal (E6-B) and by terrestrial means (Internet). The corrections are composed by orbits, clocks, code and phase biases per each satellite. The HAS full service will include atmospheric corrections too. Additional details about HAS service description can be found in Galileo High Accuracy Service (HAS) Info Note.

2.4. Galileo in Geomatics

Geomatics professionals are already benefitting from using EGNSS in a multi-constellation and multi-frequency environment, providing higher availability, continuity and better results in harsh conditions. This is the result of new developments in receiver technologies, evolution in terms of price and usability and proliferation of augmentation services which are diverse, accurate and profitable.

The stringent accuracy demands across the various surveying applications such as land surveying (cadastral, construction and mine), mapping and marine surveying (marine cadastre, hydrographic and offshore surveys) benefit from the proliferation of high accuracy GNSS-based solutions. This is due to the number of differential correction networks/services and the increased affordability of high-accuracy receivers. The future Galileo HAS- which will target decimetre-level accuracy-will be a good candidate to cover accuracy demand on applications such as GIS and mapping.

2.5. Success stories

Below there is an example of projects where EGNSS, and in particular Galileo, is a key enabler to develop innovative applications:

SWEPOS, CORS network for satellite positioning in Sweden

- Introduciton of Galileo in its service in 2018
- With the introduction of Galileo,network users have observed higher availability and better performances, especially when using a high cut off angle or in harsh environments
- https://swepos.lantmateriet.se/default.aspx

DDK Positioning

- DDK Positioning uses the Iridium® satellite network to provide global precision positioning services that can augment GNSS constellations, including GPS and Galileo to significantly enhance their accuracy for critical industrial applications.
- https://www.ddkpositioning.com/

3. EGNOS

3.1. What is EGNOS

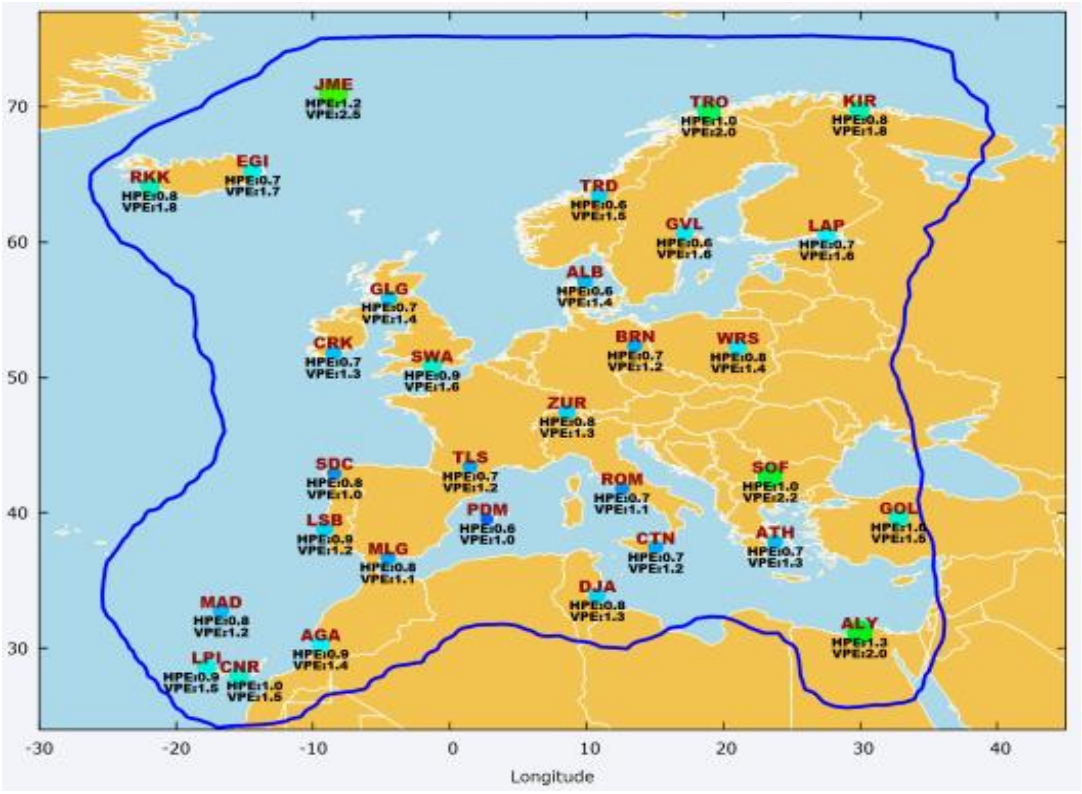
EGNOS (European Geostationary Navigation Overlay Service) is the European regional satellite-based augmentation system (SBAS) which provides corrections and integrity information to GPS signals. Although it was initially designed for aviation, it has proved to be useful in other markets such as geomatics, maritime and agriculture.

EGNOS provides three services offering different performances adapted to satisfy each user´s requirements. Geomatics activities can benefit from both the EGNOS Open Service (OS) and EGNOS Data Access Service (EDAS) while the EGNOS Safety of Life Service provides integrity and it is tailored to safety-critical transport applications.

3.2. EGNOS Services

The EGNOS Open Service is accessible free-of-charge in Europe to any user equipped with an appropriate GPS/SBAS compatible receiver for which no specific receiver certification is required. Neither a base station nor internet connection is needed, just access to the EGNOS Signal in Space.

The next picture shows an example of the values of the EGNOS Open Service accuracy in Europe, measured at Ranging Integrity Monitoring Stations (RIMS) during 6 months. HPE refers to the Horizontal Position Error and, as it can be seen, it is common to reach sub-metric accuracies (expressed as 95% percentile) when using EGNOS.



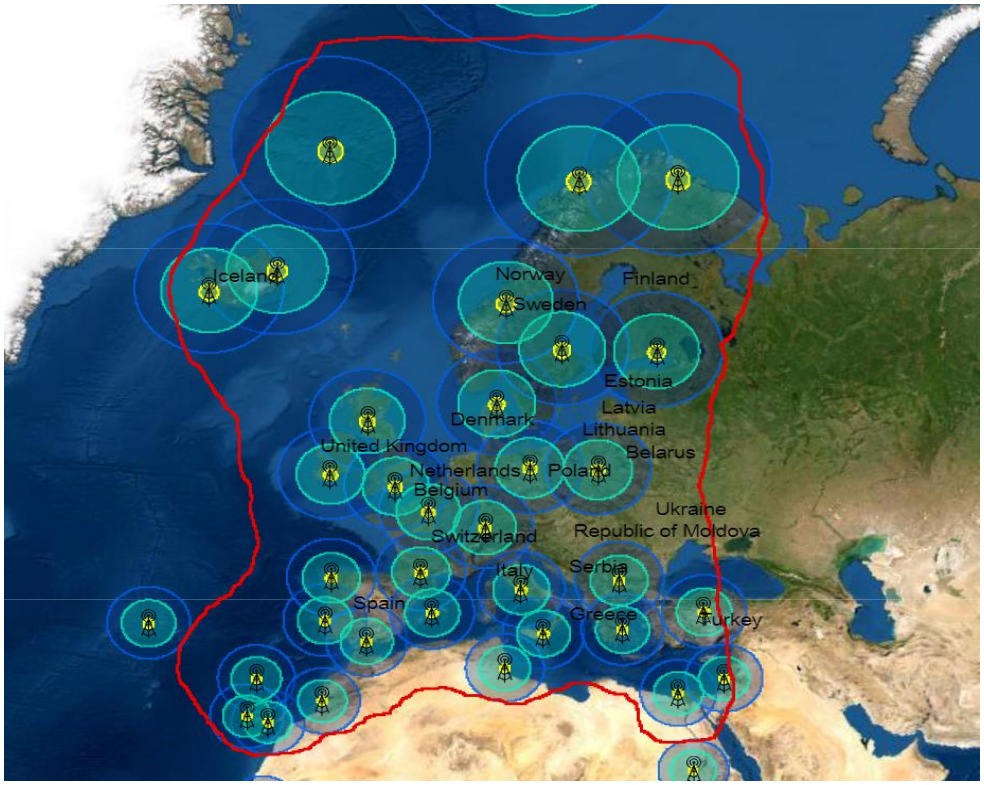
Source: [EGNOS Open Service (OS) Service Definition Document]

- The other EGNOS Service which may be used by geomatics applications is the EGNOS Data Access Service (EDAS), addressed to users that require enhanced performance for commercial and professional use. It offers access to EGNOS data through the Internet improving accuracy, reliability and availability of GNSS information.

In particular, EDAS provides ground-based access to EGNOS data through a collection of services. The most common services in geomatics are:

✓ EDAS **SISNeT**: Access to messages from EGNOS GEO satellites transmitted through the Internet using the SISNeT protocol. A device with internet connection is required, including a software tool implementing SISNeT protocol.

✓ EDAS-based **NTRIP**: DGNSS and RTK corrections provided through Internet in the surroundings of the EGNOS RIMS. A DGNSS and/or RTK receiver compatible with the NTRIP protocol is required. The available positioning solutions based on EDAS in the area can be seen in the **EDAS RTK and DGNSS coverage map**:



Source: [EDAS DGNSS Coverage Map]

3.3. EGNOS Visibility Maps

EGNOS is available over all Europe, but the terrain orography and artificial obstacles such as high buildings could affect the visibility of EGNOS geostationary satellites broadcasting the GPS corrections. In order to support the users to identify EGNOS "shadow areas", the EGNOS Visibility Maps allow visualizing natural and urban areas where there is no visibility of one or both EGNOS operational geostationary satellites.

Source: [EGNOS Visibility Maps (left on country side, right on urban environment)]

3.4. EGNOS in Geomatics

GNSS is a key enabler for geomatics applications which involve the geo-data collection means and techniques used in land surveying (including cadastral, construction, mining or infrastructure monitoring), photogrammetry, remote sensing, marine surveying and other emerging applications, such as those based on drones or mobile mapping.

EGNOS in particular may support geospatial data acquisition in those scenarios in open space, with sub metric accuracy requirements and without internet access. That is the case of the following applications in geomatics:

- Management of natural areas: Forests and parks, camping areas, wind farms.
- Management of utility networks: Water, electricity, telecommunications.
- Inventory and control of assets in open areas: Urban furniture, traffic signs.
- Taking of samples in field campaigns: Environmental law enforcement agents, biologists, archaeologists.
- Determination of perimeters and areas: Municipality borders, urban planning, green cadastre, construction, dumping sites.

To sum up, the main advantages of EGNOS in geomatics are:

- EGNOS is a free-of-charge service
- EGNOS provides stable and continuous corrections in real time
- EGNOS signal is provided by satellite:
    - Wide coverage over Europe
    - No SIM card, no base station, no radio link, etc.
    - Real time solution
- Almost all professional mapping and surveying devices are EGNOS-enabled. Users just have to activate it in an easy and friendly way.

3.5. Success stories

There are many success stories which evidence the benefits of EGNOS. Some examples are detailed below.

Maritime surveys in the Hydrographic Office of the Polish Navy

- Maintenance of the national hydrographic database, production and updating of navigational charts and promulgation of navigational warnings.

Anaptixi

- EGNOS supports to carry out geomatics projects such as the LUCAS Survey (state and changes in the type and use of land) for collection, processing and management of spatial information

Eustream

- EGNOS helps to inspect gas transmission pipelines and achieve the required precision in sites with no GPRS coverage.

Europe´s Protected Areas

- EGNOS may support Europe´s Protected Areas to preserve their ecosystems and management of their infrastructures.

Cycling Portugal

- EGNOS collects position coordinates for each of the signs or panels deployed along the routes in order to record more accurate track logs.

Source: EGNOS User Support Website

4. COPERNICUS

4.1. What is Copernicus

Copernicus, previously known as Global Monitoring for Environment and Security (GMES), is the European Union's Earth observation programme coordinated and managed by the European Commission in partnership with the European Space Agency (ESA), the EU Member States and EU agencies.

One of the main goals of EUSPA is to foster the use of EU space technologies. In particular, for Copernicus, EUSPA will focus on increasing the downstream market uptake of Copernicus, leveraging the synergies with the European Navigation Satellite Systems (EGNSS), Galileo and EGNOS.

The main objective of Copernicus is to achieve a global, continuous, autonomous, high quality and large amount of reliable and up to date information on the status of our planet. Copernicus observes

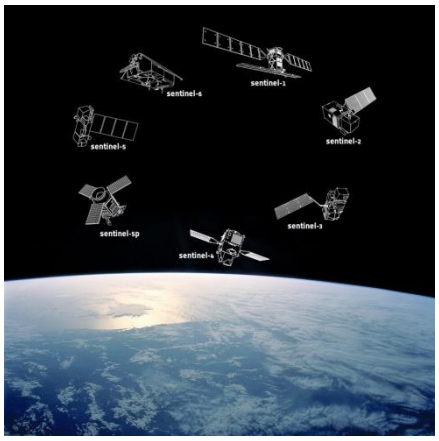
the environment, collects, stores, analyses data and provides products to enable effective decision-making. The data are analysed in a way that generate indicators useful for researchers and end users providing information on past, present and future trends. Therefore, Copernicus contributes to improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security.

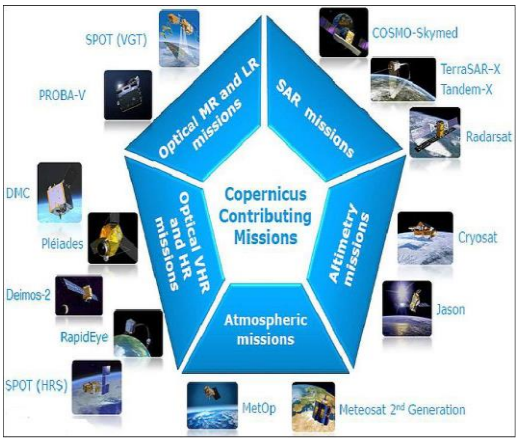
The vast majority of data delivered by Copernicus is made available and accessible to any citizen, and any organisation around the world on a free, full, and open basis, delivering 20 terabytes per day of data and information.

4.2. Components of Copernicus

The implementation of the programme is under the responsibility of the European Commission for its three components: Space, Services and In-situ.

- **Space Component** is composed for two satellite missions:
  - Sentinel constellation: the six Sentinels satellites are the core or Space component, and are being developed for the specific needs of the Copernicus programme
  - Contribution Missions: missions from other spaces agencies to complement Sentinel mission and other requirements





Source: ESA

- The six Copernicus **Services** (Land Monitoring, Marine Environment Monitoring, Atmosphere Monitoring, Emergency Management, Services for Security applications and Climate Change) produce value-added products based on the space data served by the Sentinels and the Contributing Missions.

Source: Copernicus Services

- In Situ Component, used mainly for calibration and validation of Copernicus data, can be divided into:
    - Observations: environmental measurements from measuring stations, weather balloons, sensors aboard airplanes, ships, floats, moorings, radars
    - Reference data: topographic maps (natural land surface and man-made features), hydrography, transport networks and land cover, digital elevation models, aerial imagery, etc.

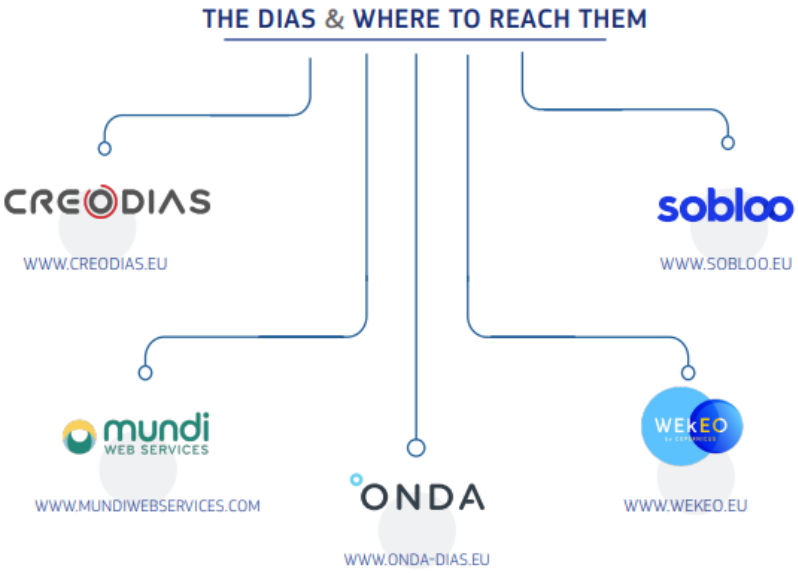


Source: Copernicus In SItu

4.3. Access to data

There are different points to access Copernicus data.

- DIAS ("Data and Information Access Services") are five new access points available to users. All DIAS platforms provide access to Copernicus Sentinel data, as well as to the information products from the six operational services of Copernicus, together with cloud-based tools (open source and/or on a pay-per-use basis)



Source: Copernicus Access Data

- Other Points of Access:
    - Services catalogue
    - Access Hubs
    - Access Points
    - Apps (EO Browser, …)

4.4. Applications of Copernicus: synergies with EGNSS

The wide availability of EO data has led to increased opportunities in different markets. The opportunities could be divided in different Copernicus sectors and can be explored in the Copernicus_market_report_2019 .

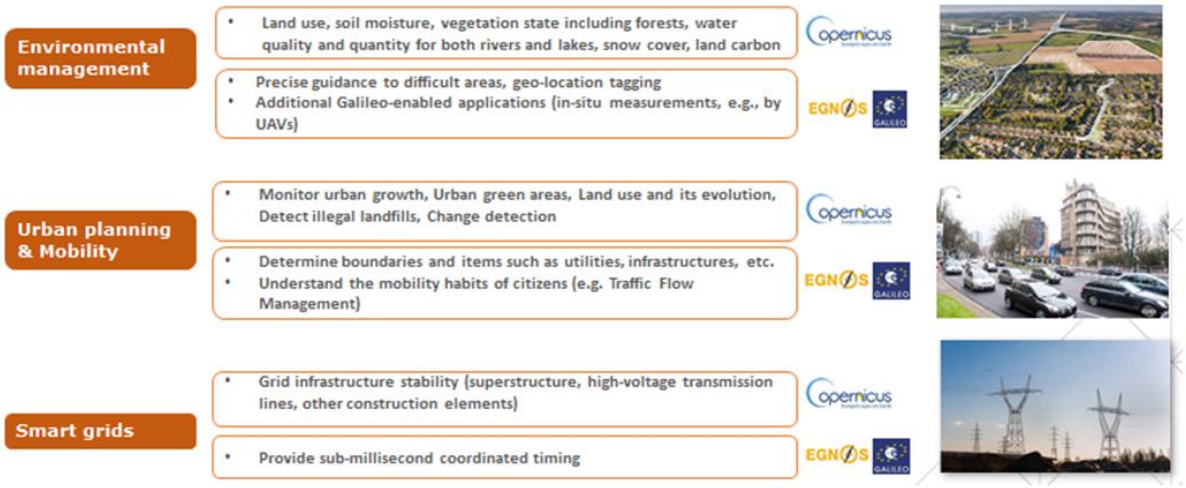
The main Copernicus applications in mapping and surveying activities are:

- Environmental management (tree inventories…)
- Urban (urban heat islands, heritage, air quality monitoring, thermal auditing, …)
- Smart grids
- Surveying (land, marine, hydrographic..)
- Construction and infrastructures
- Exploration and seismic surveying
- etc

Although there are applications that uses Copernicus or EGNSS individually, there are already a number of applications that already use both, integrated as a whole, adding value to users.

On the one hand, Copernicus often needs its data georeferenced by GNSS, and on the other hand, typical GNSS applications can be complemented with imagery and maps to provide context information.

In particular, below it is presented some graphic examples that show how Copernicus and EGNSS contribute to mapping and surveying applications:



4.5. Success stories of Copernicus and EGNSS

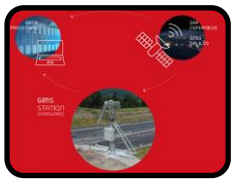
There are already some examples that show the benefits of the combined use of Copernicus and EGNSS. They are detailed below:

- Success stories that uses Galileo and Copernicus

Ixoriguè: the solution for livestock management integrating Galileo and Copernicus.

Development, design and manufacture of air blast sprayers and trailed mist blowers.

Improving livestock performance and increasing precision achieved in difficult mountainous environments



Geodetic Integrated Monitoring System (Horizon 2020)

Low-cost system based on EGNSS, Copernicus SAR and in-situ sensors, for monitoring ground deformations with a focus on landslides and subsidence.

Deformation monitoring at mm level, in a daily-based acquisition rate

Real-time alerts in case of sudden movements

Source: [European GNSS Service Centre]

- Success stories that uses EGNOS and Copernicus

EGNOS contributes to the improvement of air quality and urban mobility in cities

University of Cartagena (UPCT) are developing a system architecture for the compilation of environmental data using low-cost mobile sensor devices equipped in public transport vehicles. The data collected provides real-time information on traffic density, weather, meteorological and pollution status

Soil zoning using Copernicus and EGNOS

CYCYTEX has developed a methodology for the zonal characterization of soils based on the combined use of Copernicus and EGNOS, through the correlation of both in situ measurements (done using an EGNOS enabled equipment) and the Sentinels satellite images (Copernicus Programme)

EGNOS in sinergy with Copernicus helps improving drainage systems and variable rate fertilization

The University of Lleida / is applying a technology that measures soil ECa using a device that georeference the measurements using EGNOS, together with Sentinel-2 images to identify drainage problems in some parts of the field, and therefore to understand the causes of crop development and yield variability

Source: EGNOS User Support Website

5. CONCLUSIONS

- **European Space Programmes** (Galileo, EGNOS and Copernicus) provide **FREE** and valuable information to any users that can be optimally used in applications that benefit decision making processes, contributing to sustainable development.
- **EGNSS** contribution is widely recognized in mapping and surveying context providing **accuracy and georeferenced data**. Fields of applications are cadastral and constructions, infrastructure monitoring, mine surveying, mapping & GIS, environmental management, urban planning, etc.
- **EUSPA** is the user-oriented operational agency of the EU Space program, contributing to sustainable growth, security and safety of the European Union. Therefore, one of the main roles will be to provide more opportunities for entrepreneurs to develop their activities based on **synergies between Copernicus and EGNSS** (Galileo and EGNOS).
- The European Space Programmes, EGNSS and Copernicus, are **complementary** and provide **added value** for users. The combined use enhances the ability to use satellite technologies and contributes to the benefits obtained. In fact, GNSS is the most efficient and widespread technology for geo-referencing and precisely time-stamping all EO measurements.
- The **knowledge, awareness and contribution** of different actors is essential for a good development of applications, including municipal authorities, policy makers, farmers, surveyors, universities and R&D centres, private/public companies, etc.

6. REFERENCES

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7. BIOGRAPHICAL NOTES and CONTACTS

Eduard Escalona Zorita, **from EU Agency for the Space Programme (EUSPA),** PhD, is Space Downstream Market Officer at EUSPA since 2019 contributing to the downstream market development of Galileo, EGNOS and Copernicus. Dr. Escalona obtained his MSc and PhD degrees in telecommunications engineering from the Polytechnical University of Catalonia (UPC). He is co-author of over 70 scientific articles in topics related to Future Internet architectures and services.

Ana Senado García, from Galileo Service Centre, is Telecommunications Engineer from the University of Alcalá (Spain) with about 8 years of experience in the positioning technology sector (GNSS), in particular, EGNOS and Galileo. Currently, her main activities are related to Galileo service provision, Galileo system evolutions and improvement of Galileo services to users. She has worked in transport sector, specifically aviation and maritime. She is currently working on the promotion and adoption of Galileo services (Open Service and Search and Rescue Service) as well as preparing for the provision of future services (Galileo High Accuracy Service and Open Service Navigation Message Authentication service).

Maria Ruiz Molina, from EGNOS Service Provider holds a Master´s degree in Telecommunications Engineering by the Technical University of Madrid (Spain). She has been working for more than ten years in R&D European programmes, initially in the aviation sector, contributing to SESAR programme and afterwards in GNSS. Since 2017 she has been working at the EGNOS Service Provider in aviation domain and currently in agriculture and geomatics.

Teresa Martinez Reche, from EGNOS Service Provider is Degree in Physics by University of Granada (Spain) with postgraduates studies in Earth Observation (EO). Teresa has worked as Technical Manager in Remote Sensing and Cartography projects. Currently she is working for the EGNOS Service Provider, in the frame of the EGNOS Service Adoption contract for the European Agency for the Space Programme (EUSPA) ,focused in Agriculture and Geomatics market segments .The main activities are to promote the adoption of EGNOS and assist its users in the use of EGNOS, as well as to promote synergies between EGNOS and Copernicus among potential interested users

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