MAGIC: GALILEO and SBAS Services in a Nutshell

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Abstract

GNSS Services and Applications are today in permanent evolution in all the market sectors. This evolution comprises:

- New constellations and systems, being GALILEO probably the most relevant example, but not the only one, as other regions of the world also dwell into developing their own elements (e.g. the Chinese Beidou system).
- Modernisation of existing systems, as is the case of GPS and GLONASS
- New Augmentation services, WAAS, EGNOS, MSAS, GRAS, GAGAN, and many initiatives from other regions of the world
- Safety of Life services based on the provision of integrity and reliability of the navigation solutions through SBAS and GBAS systems, for aeronautical or maritime applications
- New Professional applications, based on the unprecedented accuracies and integrity of the positioning and timing solutions of the new navigation systems with examples in science (geodesy, geophysics), Civil engineering (surveying, construction works), Transportation (fleet management, road tolling) and many others.
- New Mass-market applications based on cheap and simple GNSS receivers providing accurate (meter-level) solutions for daily personal navigation and information needs.

Being on top of this evolving market requires an active participation on the key elements that drive the GNSS development. Early access to the new GNSS signals and services and appropriate testing facilities are critical to be able to reach a good market position in time before the next evolution, and this is usually accessible only to the large system developers as the US, Europe or Japan. Jumping into this league of GNSS developers requires a large investment and a significant development of technology, which may not be at range for all regions of the world.

Bearing in mind this situation, MAGIC appears as a concept initiated by a small region within Europe with the purpose of fostering and supporting the development of advanced applications for the new services that can be enabled by the advent of SBAS systems and GALILEO.

MAGIC is a low cost platform based on the application of technology developed within the EGNOS project (the SBAS system in Europe), which encompasses the capacity of providing real time EGNOS and, in the near future, GALILEO-like integrity services. MAGIC is designed to be a testing platform for safety of life and liability critical applications, as well as a provider of operational services for the transport or professional sectors in its region of application.

This paper will present in detail the MAGIC concept, the status of development of the system within the Madrid region in Spain, the results of the first on-field demonstrations and the immediate plans for deployment and expansion into a complete SBAS+GALILEO regional augmentation system.

Keywords: GNSS Applications, SBAS, GALILEO.

1. Introduction

The world of GNSS is undergoing strongly currents of evolution in many different areas right in the moment in which it has nearly become a state of the art commodity affordable to anyone.

The economical and technological interests of the different regions in the world have led to the development of new GNSS constellations and systems.

The European GALILEO [1] initiative is probably the most ambitious under development, but it is not the only one as Japan, China or India are also struggling to set up their own systems.

While new systems appear, the two traditional GNSS systems, GPS and GLONASS, are not standing still. Both systems are following plans for modernisation, which should lead to significant improvements of the already successful GPS services, as well as bringing GLONASS back into the market place, which the Russian system was close to achieve back in the 90's [2] before being truncated by the backstroke of Russian economy.

Regional and local augmentations to GPS, more affordable and more controllable in terms of integrity and liability, are spreading throughout the world. WAAS, EGNOS, MSAS are already there, GRAS or GAGAN closely following.

Aside from the GNSS infrastructure and systems, the applications market is also spreading in many directions: Safety of Life services, professional applications, mass-market positioning solutions, etc.

Under such evolving scenario, it is quite difficult for service providers, manufacturers and even research institutions to keep updated on where the systems go and how applications and services can be developed to meet new user demands.

Early access to the new GNSS signals and services and appropriate testing facilities are critical to be able to reach a good market position in time before the next evolution.

Unfortunately for regions and industrial sectors worldwide, such access is often limited and inaccessible, either because of technological barriers or simply because of the costs and risks involved with the development of basic state of the art infrastructure.

Bearing in mind this situation, GMV, together with the local government of the Madrid region, started in 2005 a project called MAGIC [3], aimed to bring the more advanced GNSS infrastructure closer to the direct end user market.

GMV is a Spanish company leader in the GNSS market in Europe from different perspectives:

- developer of infrastructure as a key participant of EGNOS and GALILEO development [4], [5]
- developer of technology and applications aimed to different sectors, as transport, emergency management, personal protection, etc [6]
- service and tool provider for GNSS-based road applications and fleet management, maritime applications, aeronautical services [7].

The company experience of the difficulties of being on the wave front of a rapidly evolving technology found the enthusiastic response of the Comunidad de Madrid, where a clear vision exists of the hurdles met by a region which tries to build its own technological GNSS sector without having direct access to the large infrastructure and technological facilities available for other larger companies or regions.

Sourcing from the know-how of a company in the heart of GALILEO and EGNOS development, MAGIC is a concept designed with the purpose of fostering and supporting the development of advanced applications for new services that can be enabled by the advent of modern SBAS systems and GALILEO. All this based on a low cost and easily accessible platform.

The MAGIC concept has been well received not only within the promoting institutions, but it has also awakened interest at international level. Currently MAGIC is selected as one of the Pilot Projects for the European Commission Initiative ERA-STAR, where several regions in Europe coordinate efforts to harmonise their research and development programmes within the aerospace domain.

In this paper we will briefly present the MAGIC concept, the status of development of the system within the Madrid region in Spain, the results of the first on-field demonstrations and the immediate plans for deployment and expansion into a complete SBAS+GALILEO regional augmentation system.

2. MAGIC

2.1 MAGIC Concept

MAGIC is developed with three main objectives in mind:

1. To provide a demonstrator / pre-operational system, aimed to distribute on a regional basis real-time, independent and highly configurable navigation information based on GPS data and EGNOS and GALILEO technology.
2. To serve as an enabler of GNSS applications and as a mechanism to allow for an early exploitation of GALILEO Signal in Space even before the GALILEO System is officially declared operational
3. To provide the means to perform demonstrations and awareness campaigns for a wide variety of fields in cooperation with different partners either on the service provision or in the industrial sectors.

MAGIC is conceived to provide a head-start competitive advantage in the development of GNSS applications and services that depend upon increased precision and integrity of the navigation solutions.

Those improved performances can be achieved independently from external systems and tailored to the specific requirements of each application. Applications developed based on MAGIC may open the technology and the market for the future exploitation of GALILEO, SBAS and other augmentation technologies in other countries.

2.2 MAGIC Design

The MAGIC scheme is based on the collection of measurements and data from existing reference stations combined with a few local receivers. In the concept being developed for Madrid, the source of data is coming from the EDAS (EGNOS Data server) [8] currently under development, plus additional local receivers.

The MAGIC Processing Centre computes ephemeris information and local or regional augmentations (e.g. wide area corrections), as well as confidence levels and all additional information required. This information is transmitted to the final user in formats and regimes compatible with those the user may find in the real systems, either GALILEO or SBAS-based systems [9].

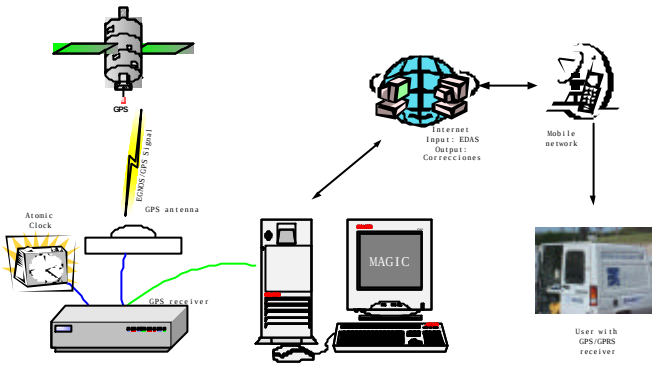

Figure 1. MAGIC Overview

The development of MAGIC comprises several steps:

1. The first step will be devoted to the integration of the local system with GPS to provide SBAS corrections and integrity information.
2. The second step will be the provision of GPS ephemeris and integrity based on the concepts planned for the future GALILEO services (starting with GALILEO Open service) system [10].
3. Finally MAGIC will extend its services towards GLONASS and the complete range of GALILEO Services in order to become a truly Multiconstellation and Multimodal Regional System.

3. MAGIC DEVELOPMENT STATUS

MAGIC has been divided into several activities to complete its development, as it can be seen in the Figure 2.

The main objectives and the current development status of each one of the two lines of work: feasibility studies and concept demonstration will be detailed in the following subsections:

3.1 Feasibility Studies

The objective of this group of tasks is to perform an analysis in three directions. First, it is aimed to assess the feasibility of

MAGIC concept to provide the corrections and integrity information to GPS signal, based on the processing of data provided by a receivers network. This was the first task carried out within the project, and the achieved results confirm the feasibility of MAGIC.

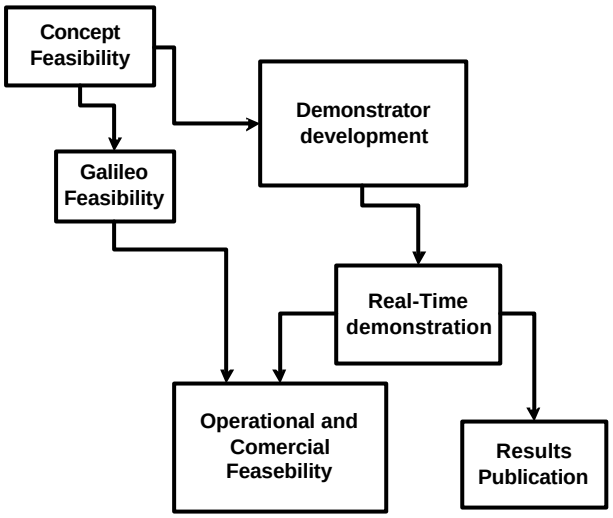

Figure 2. MAGIC Study Logic

The second task within this group is devoted to the study of the integration of GALILEO constellation into the MAGIC concept. By this, we mean the study of the feasibility of the inclusion of GALILEO constellation in the list of satellites to provide corrections and integrity for, and at the same time, the analysis of the integration of MAGIC as a provider of External Regional Integrity Services for GALILEO. This analysis is currently on going.

The last task is devoted to the operational feasibility and intended target sectors and customers for exploitation of the concept benefits.

3.2 Concept Demonstration

The objective of this group of tasks is to demonstrate the validity of MAGIC concept.

The first step, considered as the most important within the MAGIC project, consists in the elaboration of a demonstrator, able to provide almost all MAGIC capabilities. The demonstrator development includes two main tasks that can be summarized as follows:

- Complete software life-cycle for the real time monitoring and control component of MAGIC. This includes the requirements specification, architectural and detailed design, coding, unitary tests, integration and validation tests. For the validation test, the validation environment used for the EGNOS Central Processing Facility (CPF) Processing Set [11] have been used to test MAGIC capabilities in a comparable manner to those of the EGNOS element already qualified and in operation in Europe.
- Adaptation and integration of the processing functions in the new hardware and operating system platform. There processing functions are based on state of the art EGNOS technology,

All these tasks have been already carried out, with successful results, perfectly compatible with validation results obtained with the Operational EGNOS CPF Processing Set.

Figure 3. MAGIC Reference Station installation

Furthermore, some other necessary tasks, not strictly limited to the software life-cycle, have also been carried out. These are:

- Assessment and selection of the hardware and operative system platform,
- Installation and exact location of a MAGIC Reference Station in GMV premises (Figure 3).

3.3 Next steps planned

The next steps planned in the MAGIC development are structured in two areas:

- Integration with real-time networks of receivers for demonstration and pre-operational services in the Madrid region
- Further developments towards the integration of GALILEO within MAGIC

The first area includes as main steps the realisation of a number of demonstrations based on recorded data for several applications and the integration with the EGNOS Data Access Server (EDAS).

In particular it is planned that MAGIC should be able to interface with EDAS for real time demonstrations in Madrid Region during early 2007.

EDAS is a service being developed by the Galileo Joint Undertaking under technical supervision of the EGNOS Project Office of the European Space Agency. This service will provide real-time EGNOS products for service providers under Service Level Agreements. In particular EDAS will provide high quality GPS and GLONASS real time data from a network of 34 stations around the world (about 80% of them are located in Europe).

MAGIC will include a real-time interface with EDAS, so MAGIC can be used with EDAS with the proper Service Level Agreement. This will enhance the MAGIC services for local European regions, as Madrid, and can also support the use of MAGIC for other regions where EGNOS receivers are located.

The second area of work includes the upgrade of MAGIC to provide multiconstellation / multistandard capabilities. This is aligned in three main development areas:

1. Implementation of GALILEO Global Integrity concepts applied to GPS satellites in order to allow for the early testing and validation of GALILEO applications using the added value of GALILEO's Global integrity
2. Inclusion of GLONASS data processing both for the SBAS-mode and the GALILEO Global integrity mode
3. Inclusion of GALILEO data processing, as soon as GALILEO data is available (e.g. through GALILEO System Test Bed satellites, as GIOVE-A or GIOVE-B, or as soon as GALILEO IOV satellites are in operation).

4. Fostering GNSS Technology development with MAGIC

The MAGIC concept is being developed for the region of Madrid in Spain with the support of the Comunidad Autónoma de Madrid. The concept finds its application on the needs of a large Capital city and its surroundings, where accurate and reliable positioning is a day to day need for a variety of applications on environments as public and goods transport, security, law enforcement, civil engineering works, etc…, just to quote some examples.

These needs and objectives are general needs for regions all over the world and the MAGIC concept has the advantage of its complete adaptability to provide an attractive and affordable service to any region interested in having access to the benefits of an accurate, reliable and fully controlled satellite navigation augmentation system.

The potential of MAGIC as an enabler for research and development activities and technology development for other companies and regions, is one of the strongest points of this concept.

The MAGIC basic infrastructure is being developed through a specific R&D project co-financed by GMV and the Comunidad de Madrid. This development started already in the second half of 2005 and follows the plan outlined in the previous section.

The articulation of MAGIC allows naturally for the participation of companies from other regions in different potential aspects of the system which are outlined in the following diagram.

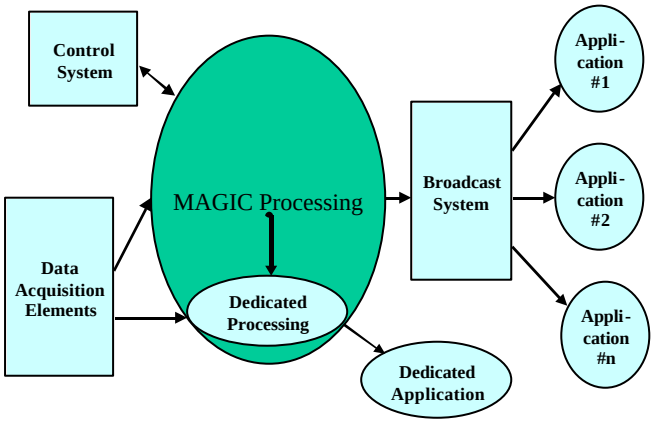

Figure 4. Cooperation Schemes with MAGIC

The picture shows in green the basic MAGIC Processing Centre developed by GMV, while in light blue are elements that can be developed by partner companies either independently or in cooperation.

The elements which are naturally open for cooperation are listed in the following subsections.

4.1 Provision of data acquisition elements

MAGIC requires the set up of a number of stations capable of acquiring GNSS data and providing these data in real or near real time to the Processing Centre.

The Processing Centre is being developed by GMV based on an open interface with the input data segment, which can be shaped to the specific characteristics of the available data.

The contribution to MAGIC in this area can take several forms:

- Provision of access to an already operated network of GNSS stations
- Development of communications infrastructure
- Development of interface components allowing the translation of specific receiver formats into the MAGIC open interface format
- Development of specific data pre-processing for advanced applications

4.2 Development of Control System elements

MAGIC is designed to be a nearly automatic system once in operation, but it requires to be operated at least for the configuration and start up of the system as well as for regular monitorisation of the system status.

The adaptation to specific user needs in terms of system control and monitorisation is an open area of development for potential partners, where the contribution can be found also in different forms:

- Development of dedicated control systems able to interface with MAGIC for configuration, start up and monitoring.
- Development of infrastructure and telecommunications for remote commanding and control of MAGIC.
- Development of data analysis and monitorisation tools
- Provision of Operation Infrastructure and Services.

4.3 Development of a Broadcast System

The current concept of MAGIC is based on using the SISNeT technology [12] for GSM broadcasting of differential GNSS corrections to the end users. This service is already in place by ESA for EGNOS corrections.

This alternative is not necessarily the only feasible one and other means can be envisaged or developed for specific applications. Examples of other dissemination means for which prototypes and some demonstrations have been developed in the past are RTCM differential corrections format [13], and DAB or RDS broadcasting.

Depending on the infrastructure existing on the different regions and the final intended usage, there is a wide field of technological development around MAGIC in order to provide and guarantee the data broadcast, with activities such as:

- Provision of the broadcasting equipment (SISNeT servers, RTMC radio transmitters, etc)
- Development of new technologies for broadcast of differential GNSS data
- Development of the necessary interfaces and infrastructure between MAGIC and the broadcasting elements.
- Operation Services

4.4 Development of Advanced Applications

The potential for the development of innovative GNSS applications is probably one of the most attractive assets of MAGIC.

Building from the added values of precision and integrity that the MAGIC Processing Centre can provide, there is a wide field of applications that can be developed. Current GPS-based services can be provided with increased value and also new ideas can be developed and tested.

Two main types of applications can be built: applications based directly on the outputs provided by MAGIC processing (SBAS-like GNSS corrections) or applications based on different products, which require to interact with both the application and the processing.

4.4.1 Development of End-user GNSS Applications from MAGIC products

This mechanism is simple and straight forward, being particularly suited to integrate development projects which may be already on-course on the regions within the MAGIC pilot project.

As the interface between the MAGIC Processing Centre and the End-user Application is based on an open standard interface, this mechanism is also well suited to protect the Intellectual Property Rights developed by the participating partners, as there is no need to interchange proprietary information to set up the complete service.

Through the integration of the developed applications with MAGIC, there will be a new field for validation, demonstration and eventually commercial operation of those applications, which otherwise may just remain on the drawing board with little perspective of further development.

A close cooperation would be beneficial between the application developers and the MAGIC development team, to extract the best potential of the integration process. However, it is also perfectly feasible to work on an independent basis, giving maximum flexibility for the development of proprietary technology on a given region.

4.4.2 Development of Dedicated Applications requiring upgrades on the MAGIC Processing Centre

During the processing of GNSS data to obtain the SBAS-like corrections, there are different levels of intermediate data in the MAGIC Processing Centre that are not regularly output. Examples of these intermediate data are:

- Pre-processed raw measurements like cycle-slip free phase data, carrier-smoothed pseudoranges, iono-free ranges.
- Intermediate processed data as satellite and receiver L1-L2 differential hardware biases, vertical tropospheric estimations, long term predicted orbits, global ionospheric information, etc.
- Complete set of differential corrections at 1 Hz rate

Potential new applications may be developed starting from such intermediate processed data or even based on other type of data that could be suitable as an add-on to the MAGIC Processing Centre.

In this scheme, a very close cooperation between GMV and the application developer will be essential to ensure a swift integration of these innovative ideas within the basic processing structure of MAGIC. Technology development, transfer and sharing, will be a natural by-product of such cooperation schemes.

5. Conclusion

This paper has presented the potential of the MAGIC concept to support the development of GNSS technology, applications and services.

The MAGIC demonstrator is a reality that will start operations in the last part of 2006 in the Madrid Region in Spain, and is open for other regions of the world, with a full potential for cooperation with companies of different sectors around the GNSS business area.

Based on low cost solutions and well-proven technology, MAGIC is a sensible choice to support GNSS policies, to provide early pre-operational services and to set up basic GNSS infrastructure for research and development activities.

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