The ESA SISNeT Project: Current Status and Future Plans

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ABSTRACT

Likewise other Satellite Based Augmentation Systems (SBAS), EGNOS– the European SBAS – will broadcast augmentation signals for GPS through Geostationary Earth Orbit (GEO) satellites. GEO broadcasting is proved to be an efficient strategy for avionic applications and other modes of transport. For some applications, though, it may be of interest to complement GEO broadcasting through other transmission means. For instance, building obstacles in cities or rural canyons may difficult the GEO reception. In those situations, complementary real-time Internet-based broadcasting of the EGNOS signal is of major interest as a way to continue taking the most of the EGNOS potential, irrespectively of the user environment. This is a well known problem for which the ESA SISNeT technology has proved to be an excellent solution.

SISNeT is a service developed by the European Space Agency (ESA) (a work led by the authors of this paper) in 2001, which allows retrieving the EGNOS messages across the Internet in real-time, usually employing wireless networks like GSM or GPRS. In case of low visibility of the GEO satellites, users can continue taking the most of the EGNOS potential, via SISNeT.

In the early days of SISNeT, advanced simulation activities revealed that the combination of EGNOS and the almost unlimited capabilities of the Internet could open the door to a lot of innovative applications for Satellite Navigation. The evolution of SISNeT and related applications in 2001 – 2006 has demonstrated and justified what simulations were anticipating. To the authors and ESA satisfaction, SISNeT is today a consolidated technology, used widely in Europe and outside as the SBAS Internet service provision standard protocol. This has been achieved mainly thanks to:

- The internal ESA work on SISNeT.
- The launch of a number of ESA contracts with European industry, on SISNeT developments.
- The consideration of the SISNeT technology in numerous ESA and GJU projects.
- The consideration of the SISNeT technology in state-of-the-art commercial simulation tools.
- The interest of worldwide companies, organisations and universities on applying SISNeT to a large variety of applications, research and development projects.
- The implementation of SISNeT technology in commercial SBAS receivers.
- The excellent performances obtained with the pair EGNOS/SISNeT.
- The pragmatic conception of the SISNeT technology concept that allows an easy adaptation of general SBAS receivers to use SISNeT.

- The International recognition of the SISNeT concept with several International prestigious awards.

Several new application fields based on SISNeT have been identified, like educational applications, help to impaired people, support to tourism, quick initialisation of SBAS receivers, etc. The possibilities of SISNET have indeed revealed to be beyond ESA initial expectations.

This paper will present the most updated status of the SISNeT Project, introducing the new version 3.1 of the SISNeT platform (to be available in May / June 2006), which includes several new features, based on feedback from users and developed applications. The EGNOS Message Server (EMS), a non-real time complement to the SISNeT concept, will be shortly presented in this paper. In addition, the paper will include an outlook to the future of this ESA technology and its link with the EGNOS Data Access System (EDAS), which will allow the provision of EGNOS commercial services in 2006.

The Authors firmly believe that SISNeT, as a solid synergy between SBAS systems and the Internet will continue opening new doors to innovative developments and will become a mature technology as an integral part of the EGNOS system, through the EGNOS Data Access System concept.

1. INTRODUCTION

EGNOS, the European Geostationary Navigation Overlay Service [1-5], is the first step on the European contribution to the Global Navigation Satellite System (GNSS), and a fundamental stepping-stone towards GALILEO, Europe's own Global Navigation Satellite System. EGNOS is an augmentation system to the GPS and GLONASS Satellite Navigation systems, which provides and guarantees navigation signals for aeronautical, maritime and land mobile Trans-European network applications. In addition to EGNOS, there are two other Satellite-Based Augmentation Systems (SBAS) contributing to GNSS-1: the US Wide Area Augmentation System (WAAS) and the Japanese MTSAT Augmentation System (MSAS). Since February 2000, a pre-operational EGNOS signal is available through the so-called EGNOS System Test Bed (ESTB) [7-9]. The ESTB has proven to be an excellent vehicle to demonstrate the system operation to final users. Since year 2000, a number of demonstrations have been performed involving a large variety of user communities and, therefore, of user requirements. In particular, successful demonstrations were performed for land mobile, civil aviation, helicopters, trains, maritime and precision farming.

Similarly to other Satellite Based Augmentation Systems, EGNOS– the European SBAS – will broadcast augmentation signals to GPS through Geostationary (GEO) satellites. GEO broadcasting is proved to be an efficient strategy for avionic applications and other modes of transport. For some applications, though, it may be of interest to complement GEO broadcasting through other transmission means. For instance, building obstacles in cities or rural canyons may difficult the GEO reception. In those situations, complementary means of broadcasting (e.g. FM, Digital Audio Broadcasting – DAB – and the Internet) have a remarkable interest. In this context, the European Space Agency (ESA) launched an internal project to provide access to the ESTB messages in real time through the Internet. The product of this project has been a new technology, called SISNeT (Signal in Space through the

Internet [10 - 23]), whose interest has greatly grown since the initial SISNeT service was put in place by ESA in 2001.

This paper presents the current status of the ESA SISNeT project, describing several ESA contracts performed around SISNeT, successfully completed at the time of this writing, (March 2006).

The consideration of the SISNeT technology as an added value, in the frame of several ESA and GJU contracts, is also addressed in a separated Section of this paper. In addition, a non-real-time complement to SISNeT, called EMS (EGNOS Message Server) [46] is briefly introduced.

This paper also presents new version 3.1 of the SISNeT service, to be available in May / June 2006. The focus is finally oriented towards EDAS, the future evolution / generalisation of the SISNeT concept, which will allow SISNeT to become an integral part of EGNOS, and constitute a vehicle for the EGNOS commercial exploitation and multimodal service growth.

2. THE EGNOS SYSTEM

The European Tripartite Group[1], (ESA – EC – EUROCONTROL) has implemented, via the EGNOS project, the European contribution to the first generation of Global Navigation Satellite System (GNSS-1). The European Space Agency has been in charge of the system design, development and qualification of an Advanced Operational Capability (AOC) of the EGNOS system (also known as EGNOS V1).

The purpose of EGNOS is to implement a system that fulfils a range of user service requirements by means of an overlay augmentation to GPS and GLONASS, based on the broadcasting through GEO satellites of GPS-like navigation signals containing integrity and differential correction information applicable to the navigation signals of the GPS satellites, the GLONASS satellites, EGNOS own GEO Overlay satellites and the signals of other GEO Overlay systems (provided they can be received by a GNSS-1 user located inside the defined EGNOS service area).

EGNOS will address the needs of all modes of transport, including Civil Aviation, Maritime and Land users. EGNOS [1-5] is a regional satellite based augmentation equivalent to (and interoperable with) the American *Wide Area Augmentation System* (WAAS) or the Japanese *Multi-transport Satellite based Augmentation System* (MSAS). In addition to interoperability, EGNOS has built-in expansion capability to enable extension of the services over regions within the Geostationary Broadcast Area of GEO satellites used, such as Africa, Eastern countries, and Russia. The combination of SBAS Interoperability and expansion concepts should allow providing a true global world-wide navigation seamless service.

From 2008 onwards, Europe should also have available the independent Galileo system. Galileo will be compatible and interoperable with GPS/GLONASS/EGNOS.

[1] A formal agreement based on article 228 of the EC treaty was signed between the European Community, EUROCONTROL and ESA, for the development of the European Contribution to the first generation Global Navigation Satellite System (GNSS-1).

In summer 2005, EGNOS has reached two major program milestones through the formal technical qualification process (known as ORR, Operational Readiness Review) and the start of its initial operations. This two events mark a success completion of more than 8 years of intensive work by ESA and European industry.

In parallel to the start of EGNOS operations, and similarly to the WAAS US Systems, the EGNOS system will be subjected to a modernisation program, the so called EGNOS V2 and EGNOS V3. These are to enlarge the service area, to provide additional services, to further improve performances and to follow SBAS standard evolutions, which should result as a consequence of GPS modernisation and the introduction of the European Galileo system.

In 2006, the deployed EGNOS infrastructure consists of four Mission Control Centres (MCC), six Navigation Land Earth Stations (NLES), and thirty-one Reference stations (called RIMS). The three EGNOS Geostationary satellites (Inmarsat 3 AOR-E, Inmarsat-3 IND-W and the ESA's ARTEMIS [6] satellite) have already started transmitting successfully EGNOS signals since December 2003, when first transmissions were made.

To complete the formal qualification process of the EGNOS V1 development programme, the Operational Readiness Review (ORR) was held in May/June 2005 with More than 60 peers, including ESA, Civil Aviation, GJU and EUROCONTROL reviewers supported. The Board was held on 16 June 2005 concluding that:

- EGNOS Technical qualification is successful, subject to the completion of some review actions and recommendations;
- EGNOS AOC requirements have been verified and are largely met;
- The system is ready to enter into Initial Operations as EGNOS V1.

The main objectives of the ORR were to confirm that the EGNOS system has been adequately qualified with respect to technical and safety requirements. A dedicated performance review panel concluded that all EGNOS system performances, when extrapolated to the operational conditions, are confirmed to be duly qualified.

This marks the success of more than 8 years of intensive work by ESA and European industry and enables to move into initial operations that started in July 2005 following the successful conclusion of negotiations between the ESSP and the European Space Agency.

The main objectives of these initial operations managed by ESA are to ramp-up and stabilise the technical operations of the EGNOS Ground Segment and of its Support Facilities, then to qualify these operations to arrive at the Operations Qualification Review (OQR) with an operationally qualified system able to support safety-of-life services (e.g. aviation). Each phase (ramp-up, stabilisation and qualification) is planned to last six months, thus planning for an OQR by end 2006.

After the OQR, the technical operations of the EGNOS system will then be directly controlled by the Galileo Concessionaire.

3. THE EGNOS SYSTEM TEST BED (ESTB)

The EGNOS System Test Bed (ESTB) [7 - 9] is a real-time prototype of EGNOS. It has provided the first continuous GPS augmentation service within Europe, and has constituted a great step forward for the European strategy to develop EGNOS, and GALILEO in the future. The ESTB objectives include:

- Support to EGNOS design. In particular, algorithm design benefits from the ESTB experience in design and usage.

- Demonstration of the system capabilities to users. The ESTB has constituted a strategic tool for the ETG, to promote the use of EGNOS and analyse its capabilities for different applications. In particular, ESTB availability has allowed (and still allows at the time of this writing) Civil Aviation authorities to adapt their infrastructure and operational procedures for future EGNOS use when Safety-of-Life service is declared operational. Three specific workshops sponsored by ESA, aiming at fostering the use of ESTB and analysing the needs of potential users, have been successfully organized since July 2000. A fourth workshop, focusing on EGNOS receivers and the transition from the ESTB to EGNOS took place at ESA Headquarters in Paris (France), in July 2003, with a major participation of worldwide receiver manufacturers.

- Analysis of future EGNOS upgrades.

- Acting as a backbone for continuous EGNOS experimentation and design improvement process.

The ESTB system architecture includes:

- A network of reference stations (RS), which are permanently collecting GPS / GEO / GLONASS data.

- A Central Processing Facility (CPF) generating the Wide Area Differential (WAD) user messages. This CPF is located in Honefoss (Norway).

- A second processing centre located in Toulouse (France), devoted to the generation of the GEO ranging data, which also acts as a node for the transmission of the user message.

- A real-time communications network based on frame-relay links.

Currently, the ESTB signal is transmitted via EGNOS, through the Inmarsat AOR-E GEO satellite.

Once the EGNOS Initial Operations reach the target stability (currently scheduled by mid 2006) and the necessary programmatic steps are completed, the EGNOS Open Service will be declared, and the ESTB will stop its operations (therefore, the EGNOS Open Service signal will be transmitted through AOR-E instead of the ESTB signal).

The future of the ESTB is a support platform called SPEED (Support Platform for EGNOS Evolution and Development). This platform will be fed with EGNOS RIMS data from the EGNOS Data Access System (EDAS, later discussed in this paper), and will also accept extra RIMS directly connected to the platform for dedicated trials (via different interfaces, including FIBE, discussed later in this paper). SPEED will include a Central Processing

Facility and a light Central Control Facility, having the capability to modify / tune the algorithms, being able to perform tests of EGNOS evolutions requiring changes at MCC level. Broadcast will be possible both via GEO satellite and (preferably in many cases) via SISNeT.

4. THE SISNET TECHNOLOGY

Satellite broadcasting through GEO means is proved to be an efficient strategy for avionic applications and other modes of transport. For some applications, though, GEO broadcasting may provide some limitations. For instance, building obstacles in cities or rural canyons may difficult the GEO reception. Since the EGNOS message will still be very useful for those applications, a complementary transmission link may be considered to take the utmost advantage of the EGNOS potential.

For this reason, ESA launched specific contract activities (through the Advanced System Telecommunication Equipment program –ASTE–) to assess and demonstrate architectures where the ESTB signal is broadcast through non-GEO means (e.g. FM or GSM broadcasting).

In this context, ESA launched (in 2001) an internal project to provide access to the EGNOS test bed messages through the Internet. The product of this project is a new technology, called SISNeT (Signal in Space through the Internet) [10 – 23].

A first prototype of the SISNeT concept was set-up by the ESA GNSS-1 Project Office, in 2001. Since February 2002, the SISNeT service is accessible through the open Internet, via an authentication procedure. SISNeT accounts are free of charge, and can be requested by contacting the SISNeT team at SISNET@esa.int. Each account consists on a username, a password, the IP address of the SISNeT Data Server and the port to use. The SISNeT project is managed from the EGNOS Project Office (Toulouse, France), where the full platform design and development takes place. Maintenance of the SISNeT platform components is performed from the ESA ESTEC centre (Noordwijk, The Netherlands).

The SISNeT project can grant important advantages to the GPS land-user community. As this paper will bring to light, a user equipped with a GPS receiver and a GSM (or GPRS) modem can access the SISNeT services, thus being able to benefit from the EGNOS augmentation signals, even under situations of GEO blocking.

On the other hand, the Scientific and Engineering community may find major advantages in using SISNeT: the EGNOS signal can be received and processed without having to invest in an EGNOS receiver. Just a connection to the Internet is necessary. These benefits are also applicable to Educational environments (e.g. laboratory exercises based on the EGNOS signal do not imply acquiring receivers, only requiring computers connected to the Internet).

Another advantage is centred in the low bandwidth requirements of SISNeT: the transfer rate ranges from 300 bps to 700 bps, being 470 bps the average value. These characteristics make SISNeT very adequate to be used with GSM / GPRS wireless networks.

During SISNeT development, ESA has identified additional benefits that could be obtained from SISNeT, remarking the following:

- The indoor penetration of wireless networks as GSM or GPRS offers a lot of benefits for SBAS receiver initialisation. For vehicles, the SBAS receiver can be initialised in the garage, being ready to use (with EGNOS corrections) once reaching the street.

- In addition, when crossing long tunnels (or other segments with no GPS / GEO satellite visibility) SBAS/SISNeT receiver can start getting the necessary information before leaving the tunnel, since GSM / GPRS signals are normally accessible before reaching the exit. Considering the capability to retrieve previously broadcast messages via SISNeT, the SBAS system can be used just after leaving the tunnel in most of the cases, and the benefits of GEO ranging available without delay, just immediately after the EGNOS GEO(s) are again in visibility.

- Prior to reaching the urban environment (e.g. while a vehicle is in the garage or a person is inside a building), the GPS ephemeris information can be initialised from SISNeT, instead of waiting for the GPS message to be received (once on the urban scenario), reducing significantly the time to first fix.

At the time of this writing (March 2006), the new version 3.1 of the SISNeT platform is about to be released. New improvements have been added to this version, allowing optimising bandwidth usage. In addition, SBAS receiver time-to-first-fix parameter will be noticeable reduced (typically achieving less than 10 - 20 seconds when using a GPRS link). The new version 3.1 will offer access to the SIS broadcast of the three EGNOS GEO satellites (one of them, AOR-E, currently broadcasting the ESTB signal).

For extensive general and technical information about the SISNeT technology, the reader is addressed to references [10 - 35].

5. SISNET-BASED INDUSTRIAL ACTIVITIES

In the 2002 – 2004 timeframe, a number of ESA contracts with European Industry were launched, aiming at demonstrating the SISNeT potential. These contracts – which have been successfully completed, – are the following:

- **Development of a Handheld SISNeT receiver [24 - 26].** This device is based on a Pocket PC Personal Digital Assistant (PDA) device. It includes a GPS card, and the Internet is reached through a GSM / GPRS wireless modem. Specific software is embedded, combining GPS measurements with the EGNOS corrections got via SISNeT. As a result, position accuracy is considerably improved. Almost any commercial GIS software can be used with SISNeT positioning, thanks to a specific driver. It is worth to remark that the handheld SISNeT receiver makes use of a low-cost GPS card. Therefore, the necessary access to the GPS pseudo-ranges is not allowed. To solve this, the developed software applies the EGNOS corrections in the position domain (see [26] for details). However, to do that, the GPS ephemeris information is necessary. Fortunately, SISNeT solves the problem by making ephemeris information available. In addition to this problem, the GPS receiver applies the GPS ionospheric model when computing position, so this correction must be removed before applying the EGNOS ionospheric corrections. SISNeT helps solving the problem, by making the GPS ionospheric model parameters available. As shown in [26], experimentation with the SISNeT handheld receiver took place in Finland, obtaining accuracies of 1 – 2 meters in the horizontal components, and 2 – 3 meters in the vertical component. The developed device has been integrated into a Siemens SX45 mobile phone (see Figure 1) and has been re-used as a key component in other SISNeT-related ESA activities.

Figure 1 - SISNeT handheld receiver embedded into a mobile phone

Figure 2 –SISNeT handheld receiver based on a NetPad device, for experimentation in urban buses in Toulouse (France).

- **SISNeT technology applied to urban buses fleet management systems [27]**. A one-box handheld SISNeT receiver was developed, based on a Psion NetPad device, equipped with the Windows CE .net operating system (see Figure 2). A mechanical adaptation was made to integrate a GPS receiver chipset. The link to the Internet is achieved through an integrated GSM / GPRS modem. Almost any commercial GIS software can be used with SISNeT positioning, thanks to a specific driver. The receiver was integrated in a real urban bus Toulouse (France), performing the usual trajectory. The selected bus line included open-sky, residential and downtown areas, allowing testing the robustness offered by SISNeT against different degrees of visibility. Results were quite promising, revealing that SISNeT could be a complement (or even a replacement) of the DGPS systems presently employed, which involve a high infrastructure cost.

Figure 3 – The TORMES Navigator for the Blind

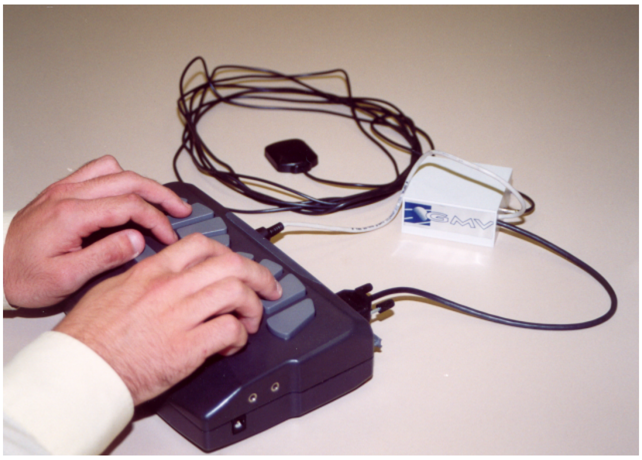

Figure 4 – The Sonobraille platform

- **Application of the SISNeT technology to help blind pedestrians navigate in cities [30,31]**. This activity consisted on assessing the feasibility of applying the SISNeT concept to improve the performance of a navigation device for the blind. The selected device, called TORMES (Figure 3), was developed by the Spanish company GMV Sistemas and ONCE (the Spanish organisation for the blind) before the start of the activity. TORMES is a personal navigator for the blind, based on a device called Sonobraille (Figure 4), which includes a Braille keyboard, a voice synthesizer, and a cartography database. The TORMES device is based on the use of a GPS receiver, hence suffering the typical problems of signal blocking in urban areas. Thanks to the re-use of the SISNeT handheld receiver (based on a PDA), it has been possible to test the impact of injecting the EGNOS corrections, got from SISNeT, in the TORMES device. Tests have been performed in peripheral, central and downtown areas of Valladolid (Spain). Results have been quite promising, revealing a significant improvement in terms of correctly matched streets, and offering a level of accuracy that could allow locating objects even at the street level.

Table 1 *–Impact of the number of accessible GEO satellites in positioning availability (absolute improvement in availability percentage.)*

SVs	Impact of 1GEO	Impact of 2GEOs	Impact of 3GEOs
4	29%	29%	36%
5	24%	24%	36%
6	15%	16%	27%
7	14%	15%	22%
8	28%	32%	36%
9	36%	57%	65%
10	19%	54%	73%

- **Development of a professional SISNeT receiver, and test in the context of an urban buses fleet management system.** An integrated professional device – called ShPIDER, see Figure 5 – including a GPS receiver and a GPRS modem has been developed. Its navigation algorithms allow significantly improving positioning accuracy and availability. Figure 6 shows results from a static test, where the accuracy improvement is visible. Furthermore, advanced availability improvement techniques have been applied, obtaining very promising results. The receiver has been tested in the context of bus fleet management systems in Valladolid (Spain), and also in the frame of the ESA EGNOS TRAN project, in Rome. For further details, the reading of [28,29] is strongly recommended. In the frame of this activity, a simulation study (based on the GMV Polaris simulation tool [35]) has been performed, assessing the impact of the number of accessible EGNOS GEO satellites in availability of positioning. Table 1 shows the main outcomes of this study, showing the percentage of improvement obtained when having access to one, two and three GEO satellites, respectively. In addition, the ShPIDER receiver has allowed testing the impact of EGNOS-SISNeT versus GPS-only, under low visibility conditions. This has been done via static tests in urban scenarios. Some representative results are shown in Figures 7 and 8. As it can be noticed, the impact of SISNeT is significant, and furthermore, it becomes more important when the visibility conditions degrade. As an example, for a mask angle of 40 degrees (low visibility conditions) an improvement of about 40% in accuracy is obtained thanks to SISNeT in the vertical component.

Figure 5: The ShPIDER receiver

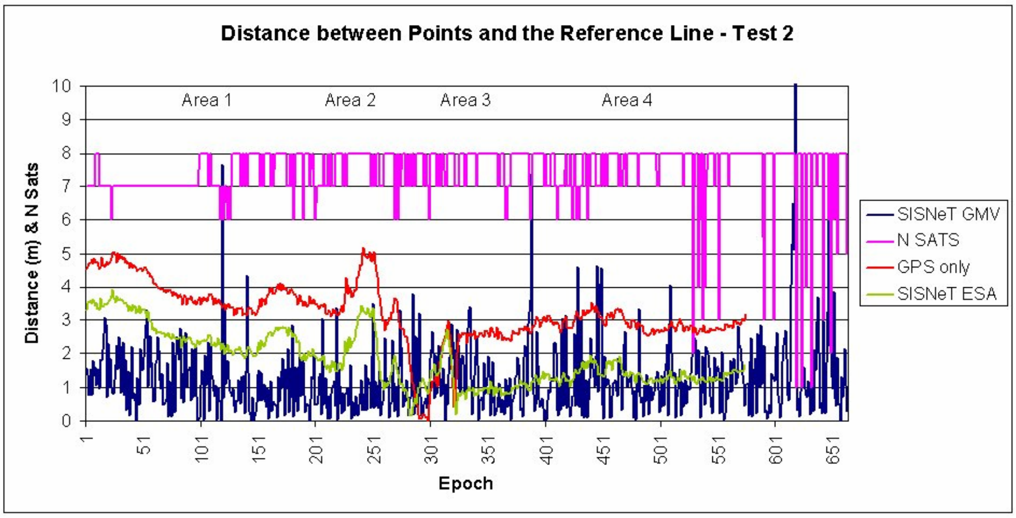

Figure 6 –Static test results using GMV's ShPIDER receiver. The red curve corresponds to GPS-only, the green curve corresponds to the PDA based SISNeT receiver, and the blue curve is obtained using ShPIDER. Note that no smoothing has been applied to the ShPIDER results.

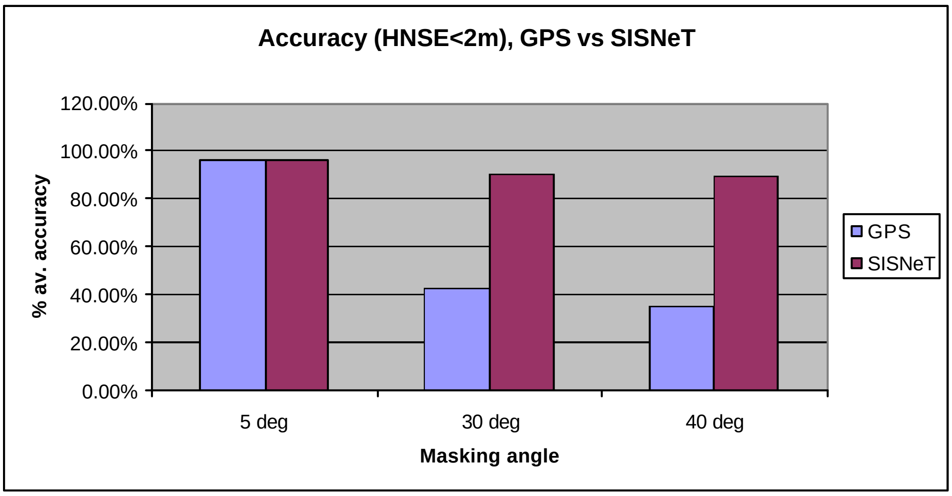

Figure 7- GPS-only versus SISNeT comparative bar plot based on real experimentation (availabilities for 2m horizontal accuracy)

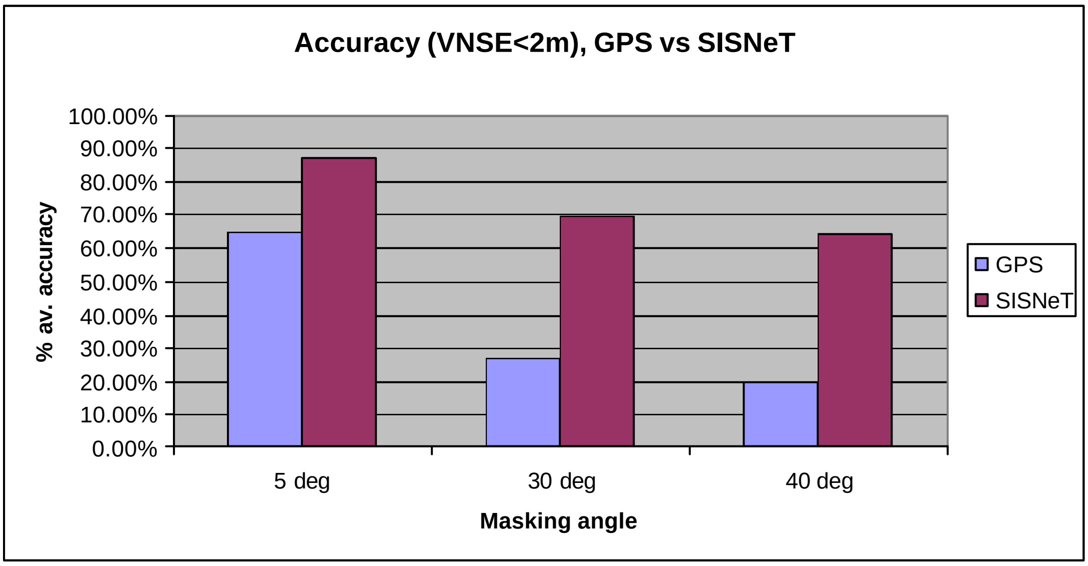

Figure 8- GPS-only versus SISNeT comparative bar plot based on real experimentation (availabilities for 2m vertical accuracy)

- **Improvement of the SISNeT network in terms of performance, security and confidentiality.** A consultancy study has been performed, obtaining specific indications on how to expand the SISNeT network to cope with tenths of millions of users, and offer high levels of confidentiality and security.

The success obtained through the contracts explained above, together with the big effort put by ESA and the Galileo Joint Undertaking (GJU) in the dissemination of results, has motivated the integration of the SISNeT technology in several other ESA and GJU projects. Some of those projects are the following:

- **FIBE (Fully Internet Based ESTB)**. The SISNeT Data Server includes a direct link with the ESTB Central Processing Facility (CPF) on one side, and an Internet link with users on the other side. This project aims at fully Internet enabling the ESTB. To do that, the Internet should replace the current Frame Relay links between the ESTB RIMS and the ESTB CPF. This could dramatically reduce the costs of communications and make the addition of RIMS an easy task, with a very special interest in the frame of ESTB expansion activities, and in the future SPEED concept. In a first phase, the state of the art network communication technologies have been studied, finding that ADSL could be an excellent candidate to be used in the FIBE context. In 2004, preliminary feasibility tests (performed by SGI, GMV group, Spain) have provided an initial confirmation of the ADSL feasibility for FIBE. Based on the obtained results, in 2005 ESA has proceeded with the substitution of some ESTB – RIMS links by the Internet, which have been transparent to the ESTB operation, and at the same time have reduced the network costs dramatically.

- **EGNOS Navigation Terminals (Eurotelematik, Germany)**. In a first phase, this project has developed two land mobile terminals and one maritime terminal as prototypes, based on specific EGNOS receivers. In addition, three prototype applications were implemented and demonstrated. In a second project phase the industrialisation of the equipment and the applications has been carried out. The added value of feeding SISNeT information (converted to RTCM format) into those receivers has been assessed, obtaining promising results (detailed information can be found in [32]). The applications demonstrated in the second phase exploit the advanced features of the EGNOS signal and thus benefit significantly from the improved availability of EGNOS data using SISNeT as a backup distribution channel. The applications covered in the project are: public services, transportation of goods, forestry applications, road tolling, steering aid for dredging and vessel monitoring. For further information about EGNOS Navigation Terminals, the reading of [33] is strongly recommended.

- **ADVANTIS**. This GJU project, developed by a consortium led by GMV (Spain), aims at providing integrity for liability-critical applications. In other words, ADVANTIS focuses on applications where liability regime has a legal or commercial nature. Integrity information is necessary for a satisfactory development of such applications. The single user-equipment / multiple services will be the main philosophy to be followed in this project. ADVANTIS user equipment will be able to access SISNeT and take benefits from the potential offered by this technology. In the frame of ADvantis, Septentrio has included SISNeT capabilities in their PolaRx2 receiver, being the first commercial receiver implementing SISNeT [48].

- **ARMAS**. The ARMAS project has been developed under ESA contract, by several European companies, and its main objective has been to assess the feasibility of an Intelligent Car Navigation System, based in GNSS and Cellular Network technologies, in order to improve Safety, make dynamic traffic management a realistic proposition and provide a competitive solution for Road Tolling based in Satellite Positioning. The use of SISNeT has been considered in the frame of ARMAS, through the use of the ShPIDER receiver (Figure 5).

- **MOMO**. Since September 2005, GMV Sistemas and ONCE are working, under ESA contract, in developing a preliminary demonstrator of a navigation tool for blind pedestrians integrated on a mobile phone. The so-called MOMO [34] project aims at demonstrating that a mobile phone could be a useful tool for the navigation of blind pedestrians in cities, thanks to the added value of the ESA EGNOS system and the ESA SISNeT technology. This demonstrator has all the elements of the final system (e.g. voice synthesis and mapping capabilities in the mobile phone), with the exception of taking out the GNSS module, implemented as a PDA, which is linked to the mobile phone via Bluetooth. Since mobile phones computing capacities are low, the complexity of the navigation algorithms is concentrated in a remote application server, which is accessed via the Internet. That server can be easily updated in the future with new LBS services, for instance, the computation of multimodal routes (involving subways, bus transport, etc.). The demonstration campaign of this device is expected to start by mid April 2006. The project is expected to be completed by mid May 2006. ONCE (the Spanish Organisation for the Blind) is actively participating in this project representing the final user community needs. It is the opinion of the Authors that MOMO will open the door towards converting the developed demonstrator into a fully integrated commercial mobile phone solution in a very near future.

In addition to all the above projects considering SISNeT, it is worth to mention that state-of-the-art simulation tools include SISNeT simulation capabilities. A good example is the GMV POLARIS software [35], a professional tool including specific models to simulate SISNeT.

6. SISNET SHORT-TERM EVOLUTION PLANS

ESA has recently completed the development of the new version 3.1 of the SISNeT platform. At the time of this writing (March 2006), ESA is completing the internal testing of the SISNeT version 3.1 components. ESA plans were to make available this new version of SISNeT by April 2006.

However, several SISNeT users requested ESA to delay the upgrade until May / June 2006, due to scheduled demonstration campaigns involving SISNeT receivers exclusively compatible with current version 2.1. For this reason, the availability of SISNeT version 3.1 is expected by May / June 2006.

New version 3.1 introduces one aspect that makes it not backwards compatible with current version 2.1: the use of separators (CR and LF). This was introduced responding to requests of SISNeT users, and in order to avoid any problem of backwards compatibility, a new version 3.0 of SISNeT was made available and announced to all SISNeT users. This version 3.0 has not become official, but has made sure that the transition to version 3.1 is smooth, providing users enough time (more than one year) to prepare their applications to switch to the new version 3.1 of SISNeT.

The migration to the new version 3.1 of SISNeT will be preceded by the publication of the new version 3.1 of the SISNeT User Interface Document (UID), which will be made available for free download at the ESA SISNeT website [22] two weeks in advance to the start of SISNeT version 3.1 operation.

The main enhancements introduced in the new version of SISNeT are the following:

- **SISNeT will be accessible via telnet** (principal obstacle in previous versions was the absence of CRLF separators).

- **Capability to retrieve already broadcast SBAS messages.** This allows significantly reducing the Time To First Fix (TTFF) of SBAS receivers, down to 30 seconds or less in many cases (depending on the performance of the Internet link in use).

- **Availability of additional SBAS broadcast streams**. Currently, SISNeT makes available the ESTB broadcast (obtained from the Inmarsat AOR-E GEO satellite). The EGNOS messages obtained directly from the ESTB CPF are also available through an additional port, using the SISNeT Data Server version 3.0 (this service, as explained above, is intended for testing purposes only). The new version 3.1 of SISNeT will make available three ports, providing access to the AOR-E, IND-W and Artemis GEO satellites [6], respectively.
- **New mechanism for the test of new SISNeT messages.** The new version of SISNeT will include a new special command, allowing distributing new messages (generated in external servers) to SISNeT users, for testing purposes. If, after testing, a new message is considered valuable, it would be considered as a candidate for coming

evolutions of the SISNeT DS2DC protocol (to be, hence, documented in a later release of the UID). The availability of this testing mechanism is selective, and indeed, this feature will not be available in the public ESA SISNeT service. It will only be enabled in the frame of ESA cooperation with activities considering SISNeT, under previous agreement, installing the data server in different locations, and for limited periods of time. Users interested in exploiting this mechanism to study new potential commands are kindly invited to contact the ESA SISNeT team at SISNET@esa.int.

Once version 3.1 of the SISNeT platform becomes the official one, ESA will continue working on next versions of the service. An important source of ideas about potential new SISNeT services exists, coming from inside ESA and also from SISNeT users. The above mentioned mechanism for testing new SISNeT messages is expected to be exploited as much as possible with the aim of assessing those ideas and keep SISNeT growing in the medium / long term.

7. THE ESA EMS SERVICE: A NON-REAL-TIME COMPLEMENT TO SISNET

In October 2003, ESA launched the EMS (EGNOS Message Server), a 24h/24h archive of the EGNOS message broadcast through the IOR-W Geostationary satellite (PRN 126), publicly accessible via FTP.

EMS stores the EGNOS messages in text files, each one containing one hour of transmissions. The following organisation is applied:

- Files corresponding to each day-of-year are put together into daily directories;
- Daily directories corresponding to each year are put together into yearly directories;
- Yearly directories are contained into top-level directories, each one corresponding to the transmission of a specific GEO satellite.

Since December 2004, EMS archives the SBAS messages broadcast by GEO PRNs 120, 124, and 126 (i.e. the messages corresponding to the three EGNOS GEO satellites: AOR-E, IOR-W and ARTEMIS).

The EMS server can be accessed at ftp://ems.estec.esa.int

All the details about the EMS file format and organisation can be found in the EMS User Interface Document [46], available at the EMS official website (http://www.esa.int/navigation/ems). More generally, ESA has created a dedicated EGNOS website for professionals [47], which covers the EMS, SISNeT, the ESTB, and other technical aspects of EGNOS.

The EMS service is demonstrating a significant potential in the independent monitoring of the EGNOS performances and the validation of SBAS receivers.

8. SISNET AND EMS BASED ESA SOFTWARE TOOLS SUPPORTING GNSS EDUCATION

In support to GNSS Education, ESA developed in 2005 the SISNeTlab tool. This software, which is available free of charge since April 2005, is a user-friendly EMS-based tool, allowing users quickly and easily assessing the performance of various SBAS systems. It gives the user a wide variety of functionalities and the graphs produced can help in comparing and better understanding the various SBAS systems.

Figure 9 puts the SISNeTlab tool in context. SISNeTlab downloads the data corresponding to the requested period from EMS, and performs various analyses on the information broadcast in the SBAS messages, presenting results in a graphical and easy to understand manner. This makes SISNeTlab a tool especially useful for the Educational community. Students can quickly learn about SBAS systems and understand the information broadcast by those.

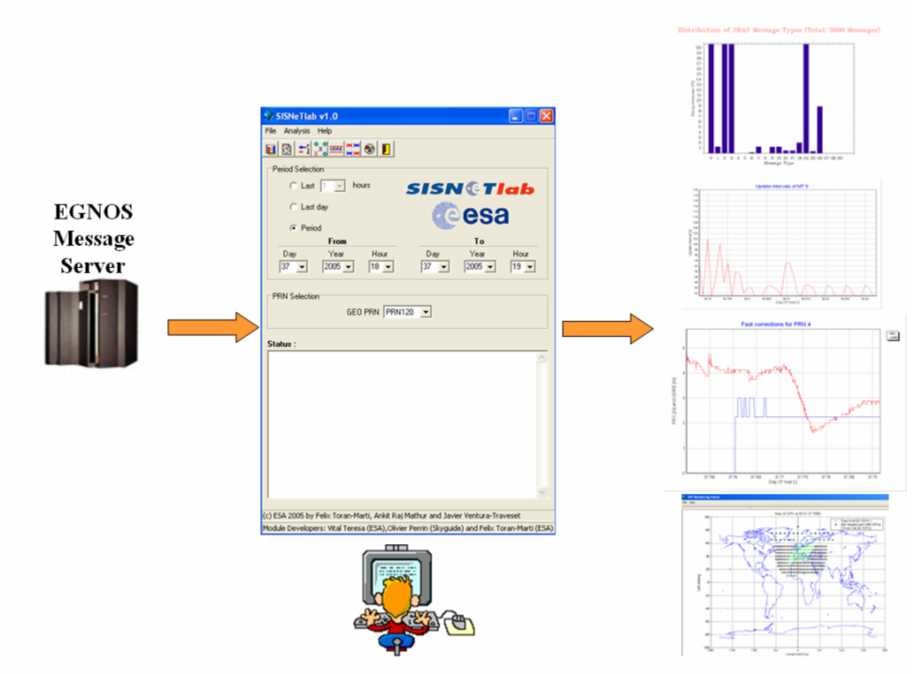

Figure 9 – The SISNeTlab tool in context.

For any given SBAS Geostationary satellite, and for a selected period of time, the current version 1.0 of SISNeTlab offers various analysis capabilities. These include:

- Distribution of messages
- Update intervals of each message type
- Number of messages lost, if any
- Different analyses at Ionospheric Grid Points
- UDRE and Fast corrections evolution over time
- Satellite monitoring status.

ESA has recently completed development of new version 2.0 of the SISNeTlab tool, and it is now starting the corresponding beta-testing campaign. ESA plans to make new version 2.0 of SISNeTlab available by mid 2006.

For further information on the ESA SISNeTlab software, the reader is addressed to [49] and [50].

Since SISNeTlab is an EMS-based tool, it is intended for offline application; in other words, this tool allows analysing a period of previously broadcast SBAS messages. In order to complement SISNeTlab with real-time SBAS message analysis capabilities, ESA has developed the new version 3.1 of the SISNeT User Application Software (UAS).

The UAS is an ESA internal tool existing since the early days of SISNeT. Indeed, it has been the first implementation of the SISNeT UAS concept ever made, and provided a preliminary demonstration of the SISNeT concept feasibility. In its first versions, the UAS included the capability to analyse, in real-time, a few of the SBAS messages types broadcast by the ESTB, these messages being obtained via SISNeT in real-time. The current version 3.1 is prepared to analyse all the SBAS messages currently broadcast by EGNOS, and even some others not yet broadcast (e.g. message types 27 and 28). This new version is optimised to take benefit from the new features introduced in new version 3.1 of the SISNeT platform.

ESA makes intensive use of this tool in the frame of performance monitoring activities, complementing other important tools like the ESA EGNOS real-time performance monitoring website, available at http://www.esa.int/navigation/egnos-perfo

ESA considers the UAS 3.1 software as a relevant tool in support to GNSS Education (complementing SISNeTlab). The UAS is considered relevant in several other domains; for instance, it may constitute a valuable resource for receiver manufacturers, as support to the test of SBAS receivers. For those reasons, ESA has decided to make the UAS available for free download. Availability for download is planned by mid 2006.

9. AN OUTLOOK TO THE FUTURE: THE EGNOS DATA ACCESS SYSTEM

As this paper has put in relief, since 2002, ESA is investing a significant effort in the field of dissemination of the EGNOS messages through non-GEO means, with an especial emphasis in transmission via the Internet, but also considering other means like DAB (Digital Audio Broadcast) or RDS (Radio Data Service).

ESA is aware that the EGNOS commercial exploitation will be significantly based on dissemination of multimodal services through non-GEO means [36]. Moreover, ESA is also aware that the introduction of EGNOS in some user communities may require some format adaptations. For instance, some user communities are based on receiver equipment following a standard which is different than the one employed by EGNOS (RTCA DO229). For instance, in the case of maritime users receiving DGPS corrections via the RTCM SC104 specification, the modification of user equipment to use EGNOS is not a cost effective solution in many cases. These format problems can be successfully solved by:

- Having access to the EGNOS products in real-time and within guaranteed performance boundaries;

- Converting those products to the desired format.[2]
- Broadcasting resulting information through non-GEO means.

In view of the above facts, an interface providing access to the EGNOS products becomes necessary. That interface should:

- Provide access to the EGNOS products (principally RIMS data and SBAS messages) in real-time.
- Provide that information within guaranteed performance boundaries (delay, data integrity, security, etc.)
- Be an integral part of the EGNOS system.

ESA has responded to the above needs by conceiving the EDAS (EGNOS Data Access System). This project –under procurement by the GJU at the time of this writing (March 2006) – will allow added-value service providers to obtain the EGNOS products in real time and within guaranteed performance boundaries, then providing multimodal services to end users through non-GEO means. In other words, the EDAS will constitute the vehicle for the EGNOS commercial exploitation by the EGNOS Economic Operator. Figure 10 shows the potential revenue flow, where added value service providers pay the EGNOS Economic Operator for the EGNOS products, and end-users pay the Service Providers for the supply of EGNOS-based multimodal services.

Figure 10 – Commercial exploitation of the EGNOS system through EDAS: potential revenue flow

Some examples of potential EDAS based applications are listed here below:

- Provision of SISNeT services;
- Provision of the EGNOS information in RTCM format [32];
- EGNOS pseudolites [45];
- Provision of EGNOS services through RDS [40];
- Provision of EGNOS services through DAB;
- Provision of WARTK-based [41-44], corrections;
- Accurate ionospheric delay/TEC maps;
- Provision of RIMS data;
- Provision of performance data (e.g. XPL availability maps, GIVE maps, etc.)
- Provision of EGNOS message files (following the EMS format [46]);
- Provision of ready-to-use information via SISNeT: fast corrections, ionospheric corrections based on the user position, etc… these values being directly provided on demand.

[2] Note that the second step (conversion to the desired format) may be located at the receiver side, i.e. after broadcast through non-GEO means.

- Provision of GPS (and then GEO and GLONASS) IGS-based services (e.g. by post-processing the EGNOS RIMS data and EGNOS messages.)

As mentioned in the above list, the future of SISNeT as a professional service is based on the use of the EDAS (note that currently the main source of information comes from SBAS receivers in a base station).

10. SUMMARY AND CONCLUSIONS

This paper has presented the ESA SISNeT technology status and future plans.

After some background on the EGNOS project and the EGNOS System Test Bed, the SISNeT project has been introduced and described in general terms.

After that, several industrial activities considering the SISNeT technology have been briefly introduced, including development of several receivers and their application in various fields like bus fleet management, liability critical applications, automatic road tolling, public services, forestry applications, transportation of goods and helping blind pedestrians navigate. Some relevant experimental results from those activities have been also presented. All those activities have demonstrated further the potential of the ESA SISNeT technology, and have opened the door to new challenges in numerous fields.

In addition, the consideration of SISNeT in state-of-the-art simulation tools (like GMV POLARIS software [35]) has been highlighted. It has been also remarked the integration of SISNeT capabilities in commercial receivers, like Septentrio PolaRx2 [48].

SISNeT has become a *de facto* standard for SBAS dissemination over the Internet at international level. Worth to remark that, in the frame of ESA International cooperation, other countries like China or Russia have expressed their interest in using the ESA SISNeT technology for dissemination of SBAS data.

This paper ends with an outlook to the future, presenting EDAS, the future professional evolution of SISNeT, which will provide the basic products of EGNOS, allowing service providers to exploit this information, supplying a large mosaic of multi-modal services through non-GEO means. EDAS will constitute the vehicle for EGNOS based multimodal service growth and EGNOS commercial exploitation.

The successful results derived from ESA contracts on the SISNeT technology demonstrate the potential of this ESA technology. Moreover, the consideration of this technology today in multiple contracts provides confidence on the future of SISNeT. The Authors firmly believe that SISNeT will continue opening doors to innovative applications, and will become a mature technology, becoming integral part of EGNOS through EDAS and derived services.

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