The ESA EGNOS Project: The First Step of the European Contribution to the Global Navigation Satellite System (GNSS)

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Biographies

Félix Torán-Martí obtained his M. Sc. in Electrical Engineering from the University of Valencia (Spain), where he is currently pursuing his PhD Degree. In Sept. 2000 he joined ESA under the Spanish Young Graduate Program. Since 2002, he is working at ESA as System and Analysis Engineer for the EGNOS Project, with major contributions on simulation software development and on the ESA SISNeT Project. Mr. Torán has co-authored over 85 technical publications and holds one patent. He is member of ION and IEEE.

Dr. Javier Ventura-Traveset holds a M. Sc. in Telecommunication Eng. from the Polytechnic Univ. of Catalonia (Spain, 1988); a M. Sc. in Engineering by Princeton University (Princeton, NJ) in 1992; and a PhD in Electrical Eng. by the Polytechnic of Turin (Italy, 1996). Since March 1989, he is working at the European Space Agency (ESA) on mobile, fix, earth observation and satellite navigation programs; he is currently Principal System Engineer of the EGNOS Project. Dr. Ventura-Traveset holds 4 patents and co-authored over 150 technical papers. He is Member of ION and Senior Member of the IEEE.

Abstract

The European Tripartite Group (ETG)1, (ESA – EC – EUROCONTROL) is implementing, via the EGNOS project [1], the European contribution to the Global Navigation Satellite System (GNSS-1) which will provide and guarantee navigation signals for aeronautical, maritime and land mobile Trans-European network applications. On behalf of this Tripartite group, the European Space Agency is responsible for the system design, development and qualification of an Advanced Operational Capability (AOC) of the EGNOS system.

EGNOS will significantly improve the accuracy of GPS, typically from 10-15 meters to 1-to-3 meters. Moreover, EGNOS will offer a service guarantee by means of the Integrity signal and it will also provide additional ranging signals. It will operate on the GPS L1 frequency, and will thus be receivable with standard GPS front-ends. EGNOS is part of a mosaic of inter-regional satellite-based augmentation services (SBAS) that complement GPS and GLONASS. The other systems are the United States WAAS and the Japanese MSAS systems. Recently, India and China have launched similar initiatives, called GAGAN and SNAS, respectively. The EGNOS coverage area will be the ECAC (European Civil Aviation Conference) area but could be readily extended to include other regions within the Broadcast Area of the geostationary satellites, such as Africa, Central / South America, Eastern countries, and Russia. EGNOS will meet, in combination with GPS and GLONASS, many of the current positioning, velocity and timing requirements of the land, maritime and aeronautical modes of transport in the European Region. EGNOS is the first step of the European Satellite Navigation strategy and a major stepping stone towards GALILEO, future Europe's own global satellite navigation system

This paper describes the EGNOS System requirements and the overall System design. In addition, the EGNOS system test bed (ESTB) is also explained. The status of the EGNOS project, measured performances and future plans are also covered by this paper.

[1] A formal agreement based on article 228 of the EC treaty was concluded on 18.6.96 between the European Community, EUROCONTROL and ESA, for the development of the European Contribution to the first generation Global Navigation Satellite System (GNSS-1).

1. Introduction

The current capabilities of GPS and GLONASS, although very adequate for some user communities, present some shortfalls. The lack of civil international control presents a serious problem from the institutional point of view. In addition, there is a need for enhanced performance. In particular, civil aviation requirements for precision and non-precision approach phases of flight cannot be met by GPS or GLONASS only. Marine and land users may also require some sort of augmentation for improving GPS / GLONASS performances.

The first generation Global Navigation Satellite System, GNSS-1, as defined by the experts of the ICAO/GNSS Panel, includes the basic GPS and GLONASS constellations and any system augmentation needed to achieve the level of performance suitable for civil aviation applications.

EGNOS [1], which is a regional satellite based augmentation equivalent to the American *Wide Area Augmentation System* (WAAS) or the Japanese *Multi-transport Satellite based Augmentation System* (MSAS), is the first European implementation to GNSS. EGNOS will become operational end 2004. From 2008 onwards Europe should also have available the independent Galileo system. Galileo will be compatible and interoperable with GPS/GLONASS/EGNOS.

2. Description of the EGNOS Mission

2.1 General Objectives

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.

2.2 Aeronautical Applications

The performance objectives for aeronautical applications are usually characterised by four main parameters: accuracy, integrity, availability and continuity of service. The values for these parameters are highly dependent on the phases of flight. For typical phases of flight, typical requirements are those included in Table 1. Neither GPS nor GLONASS can meet the above integrity, availability and continuity of service objectives without a system augmentation, although their performance in terms of accuracy alone could meet the requirements of en-route, terminal area navigation and non-precision approaches.

These requirements are expressed by the International Civil Aviation Organisation (ICAO) under the form of SARPS (Standards and Recommended Practices.)

2.3 Maritime Applications

The performance objectives for maritime applications are generally broken down into ocean, coastal, in-land waters and harbour navigation. Minimum performance requirements for these four generic cases have been quantified by the European Maritime Radionavigation Forum (See Table 2):

Table 1: Aviation GNSS Signal-in-space performance requirements

<table>
<tr><th>Typical operation(s)</th><th>Accuracy lateral /vertical 95%</th><th>Alert limit lateral /vertical</th><th>Integrity</th><th>Time to alert</th><th>Continuity</th><th>Availability</th><th>Associated RNP type(s)</th></tr>
<tr><td>En-route</td><td>2.0 NM / N/A</td><td>4 NM / N/A</td><td rowspan="4">10^{-7}/h</td><td>5 min.</td><td rowspan="4">$1\text{-}10^{-4}$/h to $1\text{-}10^{-8}$/h</td><td>0.99 to 0.99999</td><td>20 to 10</td></tr>
<tr><td>En-route</td><td>0.4 NM / N/A</td><td>2 NM / N/A</td><td rowspan="2">15 s</td><td rowspan="2">0.999 to 0.99999</td><td>5 to 2</td></tr>
<tr><td>En-route, Terminal</td><td>0.4 NM / N/A</td><td>1 NM / N/A</td><td>1</td></tr>
<tr><td>Initial approach, NPA, Departure</td><td>220 m / N/A</td><td>0.3 NM / N/A</td><td rowspan="2">10 s</td><td rowspan="4">0.99 to 0.99999</td><td>0.5 to 0.3</td></tr>
<tr><td>APV-I</td><td>220 m / 20 m</td><td>0.3 NM / 50 m</td><td rowspan="3">2×10^{-7} per approach</td><td rowspan="3">$1\text{-}8 \times 10^{-6}$ in any 15 s</td><td>0.3/125</td></tr>
<tr><td>APV-II</td><td>16 m / 8 m</td><td>40 m / 20 m</td><td rowspan="2">6 s</td><td>0.03/50</td></tr>
<tr><td>Category I</td><td>16.0 m / 4-6 m</td><td>40 m / 10-15 m</td><td>0.02/40</td></tr>
</table>

Table 2: Maritime GNSS typical performances

<table>
<tr><td rowspan="3"></td><th colspan="4">GNSS System level parameters</th></tr>
<tr><th>Predictable Accuracy</th><th colspan="3">Integrity</th></tr>
<tr><th>Horizontal (metres)</th><th>Alert limit (metres)</th><th>Time to alarm[2] (Seconds)</th><th>Integrity risk</th></tr>
<tr><td>Ocean</td><td>10</td><td>25</td><td>10</td><td>10-5/ 3 hours</td></tr>
<tr><td>Coastal</td><td>10</td><td>25</td><td>10</td><td>10-5/ 3 hours</td></tr>
<tr><td>Port approach and restricted waters</td><td>10</td><td>25</td><td>10</td><td>10-5/ 3 hours</td></tr>
<tr><td>Port</td><td>1</td><td>2.5</td><td>10</td><td>10-5/ 3 hours</td></tr>
<tr><td>Inland waterways</td><td>10</td><td>25</td><td>10</td><td>10-5/ 3 hours</td></tr>
</table>

2.4 Land Applications

There are a large number of applications under development world-wide related to the use of satellite navigation and land mobile applications. These include: vehicle positioning, fleet management, position tracking, emergency services, theft protection, passenger information, road tolling, etc.

Depending on the application, the accuracy required for the various systems ranges from hundreds of meters to a few meters, requiring the use of differential corrections. Integrity is also required for some of these applications.

2.5 Other applications

Another important benefit of satellite navigation is the provision of a global time reference. EGNOS will provide a stable time reference within few ns of the Universal UTC time.

Related applications include, time synchronisation of cellular phone networks, VSAT synchronisation, electric power synchronisation networks, Internet nodes synchronisation, etc.

In addition, the combination of satellite navigation and mobile services will provide a wide-range of new services.

2.6 Performance Objectives of the EGNOS System

Of the three user communities, civil aviation requirements are the most stringent (in terms of integrity and continuity) and hence the EGNOS performance objectives are driven by the needs of civil aviation, covering then, the needs of land and maritime user communities.

The coverage area serviced by EGNOS will be the European Civil Aviation Conference (ECAC) service area comprising the Flight Instrument Regions (FIR) under the responsibility of ECAC member states (most of European countries, Turkey, the north sea and the eastern part of the Atlantic ocean). ECAC is defined in Fig. 1.

The EGNOS AOC performance objectives are to provide a primary means service of navigation for all phases of flight from en-route through precision approach within the ECAC area. In addition, EGNOS has potentially the capability to offer also services over the full Geostationary broadcast area.

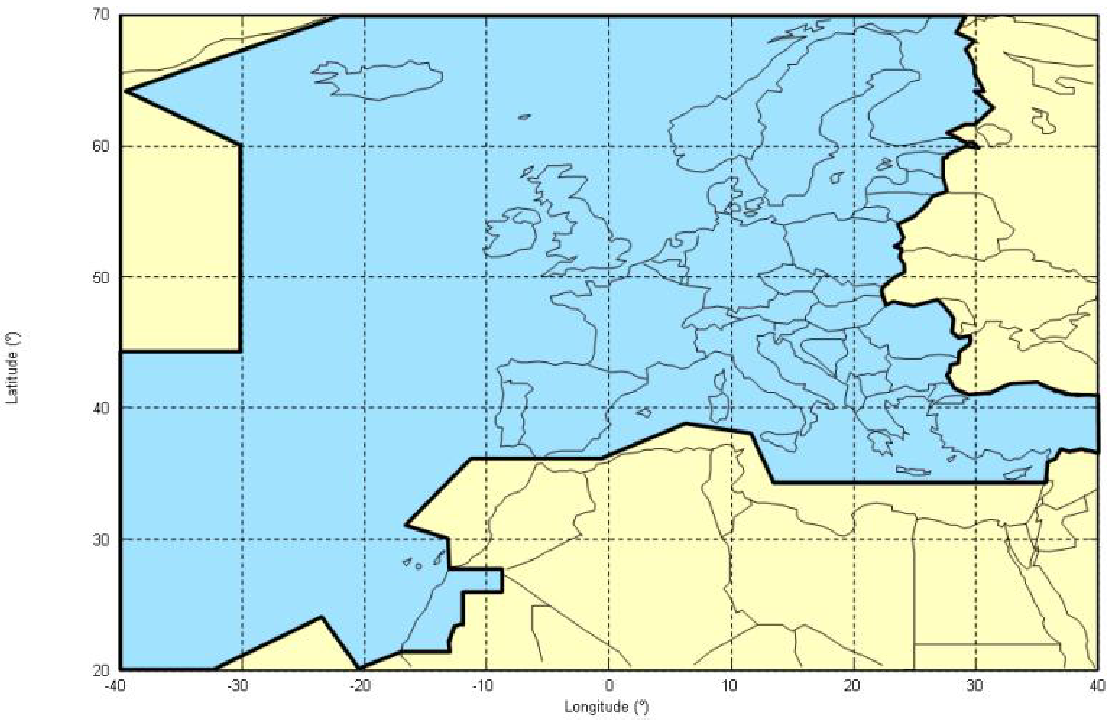

Figure 1 – European Civil Aviation Conference (ECAC) approximate area coverage

3. Description of the Main EGNOS Functionalities

The EGNOS system will provide the following functions:

- **GEO Ranging (R-GEO):** Transmission of GPS-like signals from 3 GEO satellites (INMARSAT-3 AOR-E, INMARSAT-3 IOR-W and the ESA ARTEMIS satellite – see Fig. 2--) for the AOC phase. This will augment the number of navigation satellites available to the users.

- **GNSS Integrity Channel (GIC):** Broadcasting of integrity information. This will increase the availability of GPS / GLONASS / EGNOS safe navigation service up to the level required for civil aviation non-precision.
- **Wide Area Differential (WAD):** Broadcasting of differential corrections. This will increase the GPS / GLONASS / EGNOS navigation service performance, mainly its accuracy, up to the level required for precision approaches down to CAT-I landing .

Figure 2 – Artist's impression of ESA's Artemis satellite (J. Huart)

4. EGNOS Architecture and System description

The EGNOS Reference architecture is depicted in Fig. 3. It is composed of four segments: ground segment, space segment, user segment and support facilities.

The *EGNOS Ground Segment* consists of GNSS (GPS, GLONASS, GEO) *Ranging and Integrity monitoring Stations* (called RIMS) which are connected to a set of redundant control and processing facilities called *Mission Control Centre* (MCC). The system will deploy 34 RIMS located in mainly in Europe and 4 MCCs located in Torrejon (E), Gatwick (UK), Langen (D) and Ciampino (I). The MCC determines the integrity, pseudo-range differential corrections for each monitored satellite, ionospheric delays and generates GEO satellite ephemeris. This information is sent in a message to the *Navigation Land Earth Station* (NLES), to be up-linked along with the GEO Ranging Signal to GEO satellites. These GEO satellites downlink this data on the GPS Link 1 (L1) frequency with a modulation and coding scheme similar to the GPS one. All ground Segment components are interconnected by the *EGNOS Wide Area Communications Network* (EWAN). The system will deploy 2 NLES (one primary and one back-up) per GEO navigation transponder and an NLES for Test and Validation purposes, located in Torrejon (E), Fucino (I), Aussaguel (F), Raisting (D), Goonhilly (UK), and Sintra (P) respectively (Fig. 4 shows planned sites for the different EGNOS G/S elements)

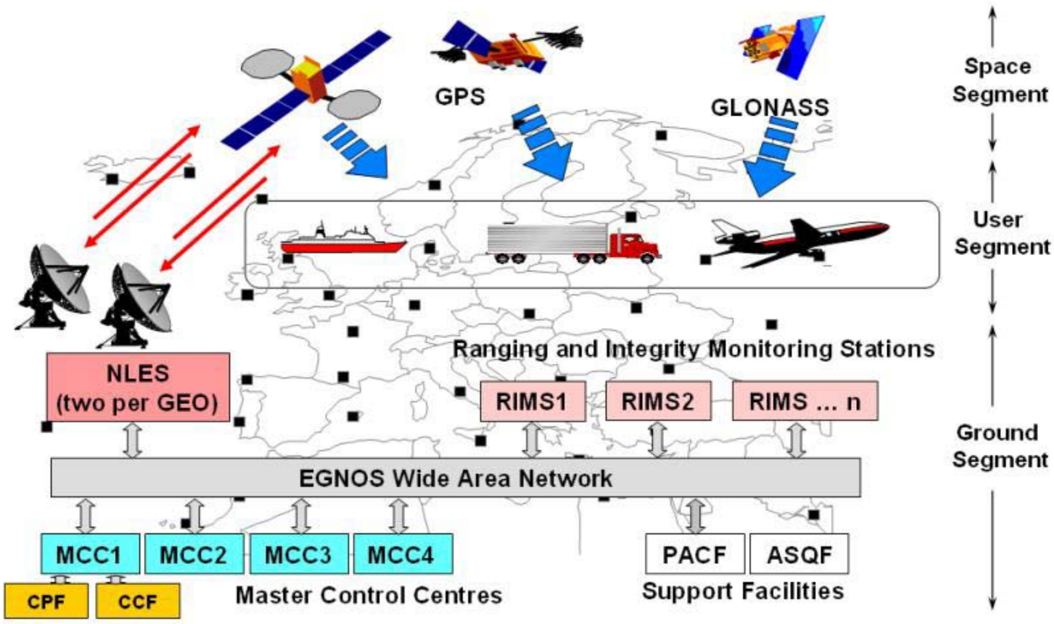

Figure 3 – The EGNOS system architecture

The *EGNOS Space Segment* is composed of three Geostationary transponders. The EGNOS AOC system is based on INMARSAT-3 AOR-E and IOR-W, and the ESA ARTEMIS [2] navigation transponders (See Fig. 5)

The *EGNOS User Segment* consists of an EGNOS Standard receiver, to verify the Signal-In-Space (SIS) performance, and a set of prototype User equipment for civil aviation, land and maritime applications. Those prototype equipment will be used to validate and eventually certify EGNOS for the different applications being considered.

Finally, the *EGNOS support facilities* include the *Development Verification Platform* (DVP), the *Application Specific Qualification Facility (*ASQF) located in Torrejon (Spain) and the *Performance Assessment and Checkout Facility* (PACF) located in Toulouse (France). Those are facilities needed to support System Development, Operations and Qualification.

The EGNOS AOC Pre-Operational Implementation involves the detailed design, development, deployment and verification of three elements defined hereafter as:

- EGNOS System Test Bed (ESTB);
- EGNOS Advanced Operational Capability (AOC) System
- AOC Complementary Activities

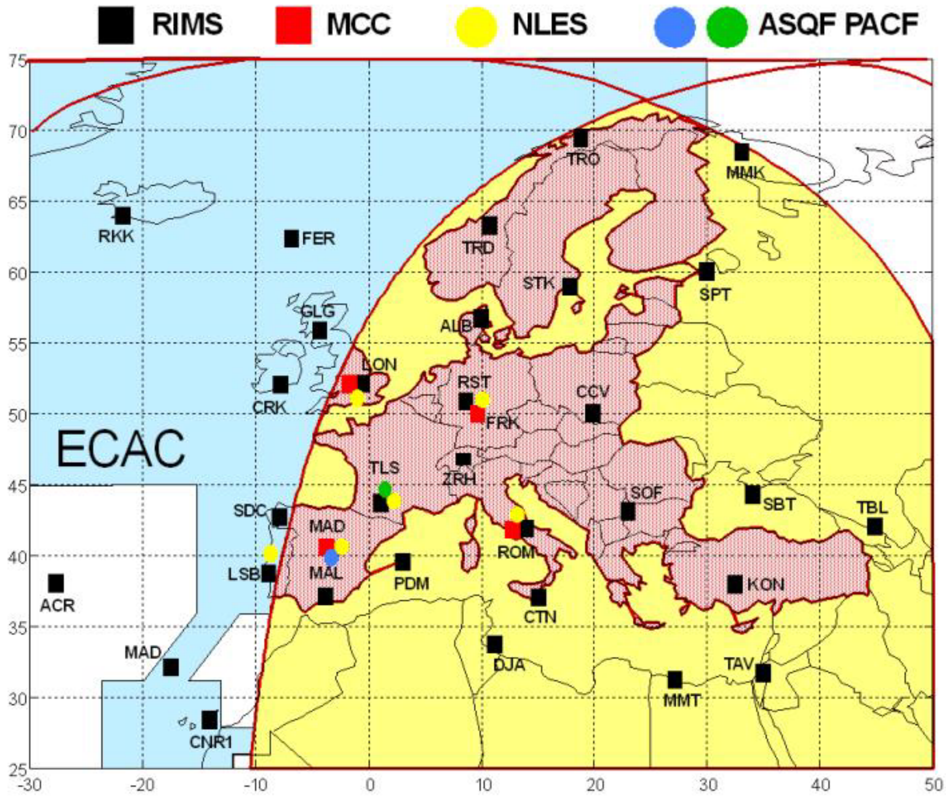

Figure 4 – EGNOS deployment map

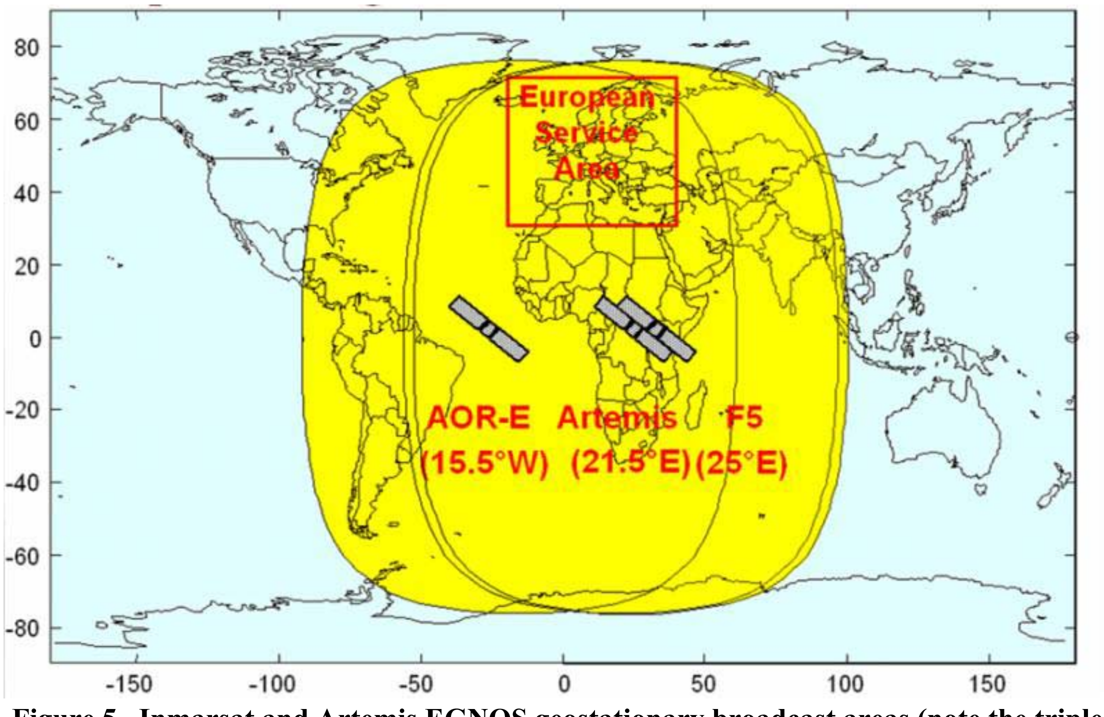

Figure 5– Inmarsat and Artemis EGNOS geostationary broadcast areas (note the triple coverage over Mediterranean region and Africa)

5. The EGNOS System Test Bed (ESTB)

The ESTB (EGNOS System Test Bed) is a real-time prototype of EGNOS (European Geostationary Navigation Overlay Service). It provides the first continuous GPS augmentation service within Europe. The ESTB [3] has been developed under European Space Agency (ESA) contract by an industrial consortium, involving key European Satellite Navigation industries such as Alcatel Space Industries, Astrium, GMV, Racal, Seatex and DLR. In order to optimise the overall ESTB effort, existing assets have been taken into account to build up the ESTB. These include the SATREF™ system from NMA (Norwegian Mapping Authority) and the EURIDIS ranging system from CNES. Early 2001, the ESTB has been fully connected with the Italian Mediterranean Test Bed (MTB) being provided by ENAV (–Italian Civil Aviation Authority--).

The ESTB, operational since February 2000, constitutes a great step forward for the European strategy to develop the future European Satellite Navigation Systems: EGNOS and GALILEO. The ESTB has been developed with a set of objectives including:

- The support to EGNOS design: In particular, algorithm design benefits from the ESTB experience in design and usage.
- The demonstration of the capabilities of the system to users: The ESTB constitutes a strategic tool for the European Tripartite Group (ETG). The ETG is promoting the use of EGNOS and analysing its capabilities for different applications. In particular, ESTB availability allows Civil Aviation authorities to adapt their infrastructure and operational procedures for future EGNOS use, when it becomes operational. Several ESA workshops have taken place to the date, aiming at fostering the use of the ESTB and analysing the needs of potential users, with a very large number of participants, and covering a variety of different users and countries world-wide.
- The analysis of future EGNOS upgrades.

The ESTB architecture is presented in Fig. 6. The ESTB is made up of a space segment, comprising one transponder on board the Inmarsat-III IOR-E satellite, a ground segment comprising a number of reference stations spread over Europe and beyond, a processing centre and the Inmarsat uplink stations. Communication lines interconnect all stations.

During the ESTB development, contributions of various providers have been integrated with the existing assets:

- A network of 10 RIMS, which are permanently collecting GPS/GEO/GLONASS data;
- Central Processing Facility (CPF), generating the WAD (Wide Area Differential) user messages. The CPF is located in Hønefoss (Norway), and hosted in SATREF™ platform;
- One Navigation Land Earth Station (NLES) located in Fucino (Italy), allowing the access to the INMARSAT III IOR-E satellite. Until mid-2003, the ESTB transmitted also through the INMARSAT-III AOR-E satellite, via an NLES located in Aussagel (France), as depicted in Fig. 6.
- Three EURIDIS RIMS for the purpose of the GEO Ranging function. These RIMS are located on an intercontinental basis in order to provide a wide observation base for the GEO. They are also collecting GPS/GEO data;
- A processing centre located at Toulouse (France), devoted to the generation of the GEO ranging data, and which also acts as a node for the transmission of the user message;
- A real-time communications network, allowing the transfer of the RIMS data to the CPF, and of the navigation messages from Honefoss to the NLES.

By using GPS and ESTB Signal-In-Space, users within Europe can nowadays determine their position with sub-meter errors both in the horizontal and vertical components, 95 percent of the time. This is illustrated in Figure 7, which is based on real-data collected from the ESTB. The area within which the test signal can be exploited is determined primarily by the location of the reference stations. The ESTB APV-2 service area is depicted in Figure 8 (this Figure is also based in real data collected from the system).

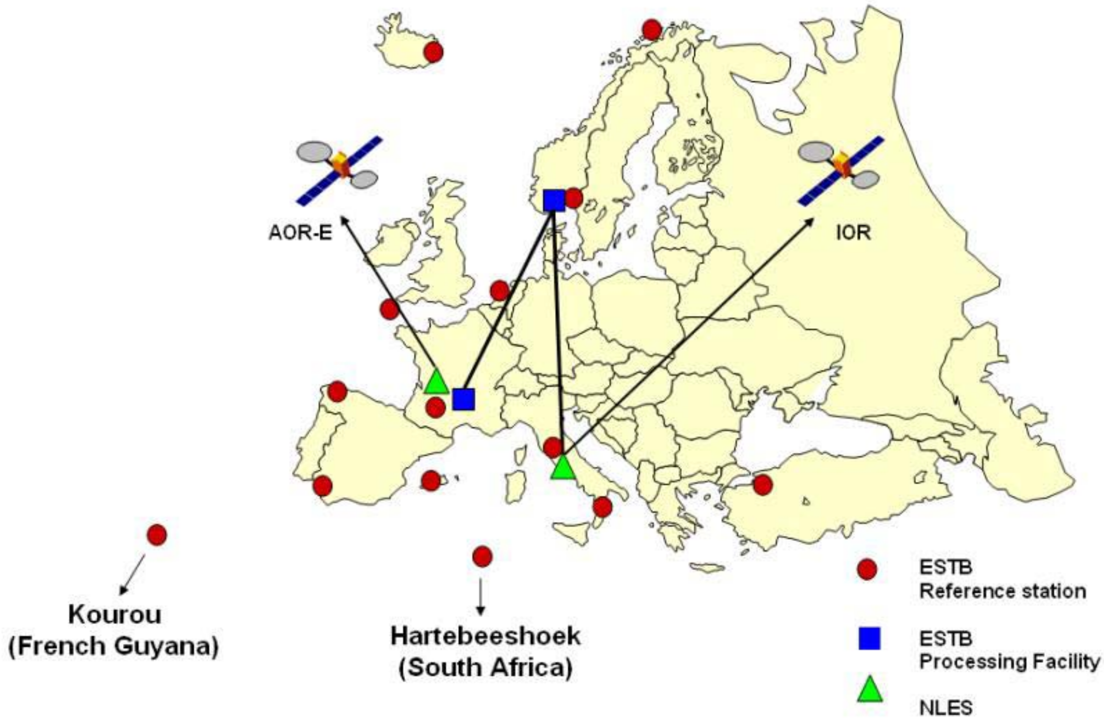

Figure 6 – Architecture of the EGNOS System Test Bed (ESTB)

The ESTB is also providing an integrity service, represented by the Vertical and Horizontal protection levels computed by the User with the ESTB information data, which are to bound with a probability of 2x10-7/150 sec the Alert limits associated to a particular operation. Values required for aircraft precision approach landing are ensured at that time in most of Europe. Results provide additional confidence in the current EGNOS design, especially considering the reduced number of reference stations available in the ESTB.

The ESTB has supported already a number of application demonstrations, including landing planes at several airports, guiding ships into harbours and also navigating cars. The European Commission, national agencies and ESA are supporting the demonstration initiatives of European industry and operators in a number of ways.

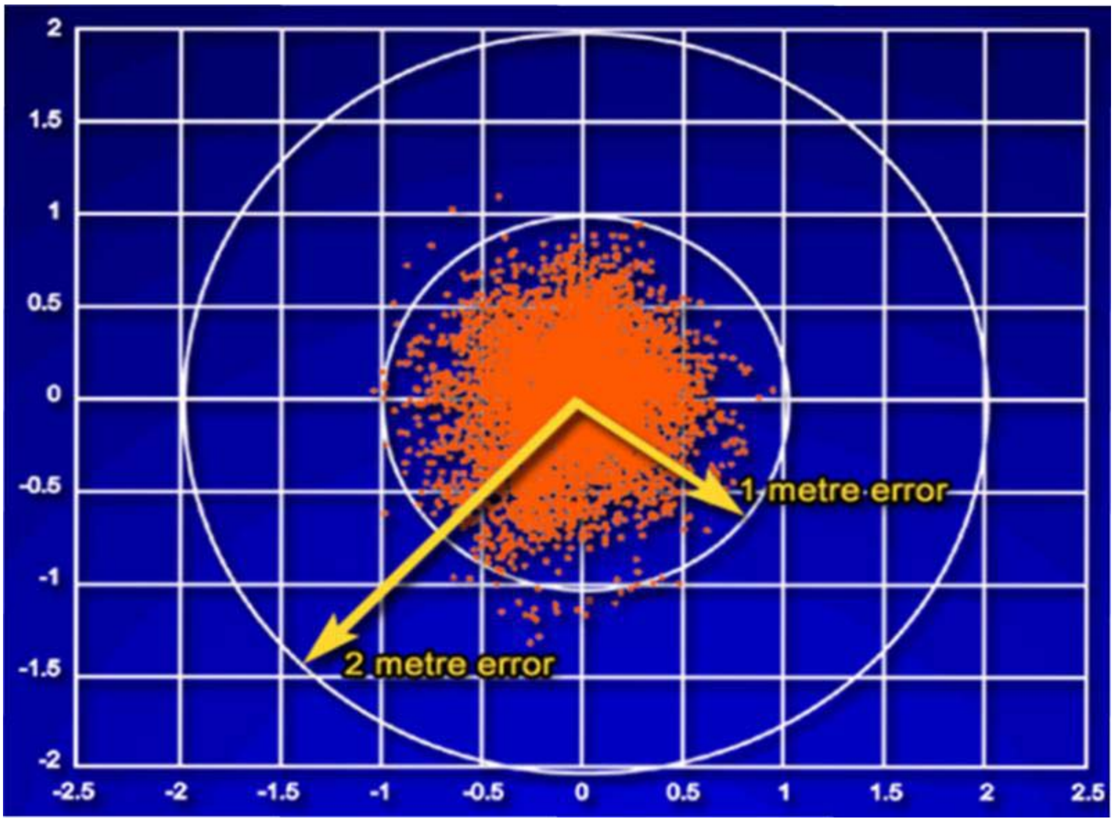

Figure 7 – Typical ESTB performances: sub-meter Horizontal (95%) and Vertical (95%) accuracies

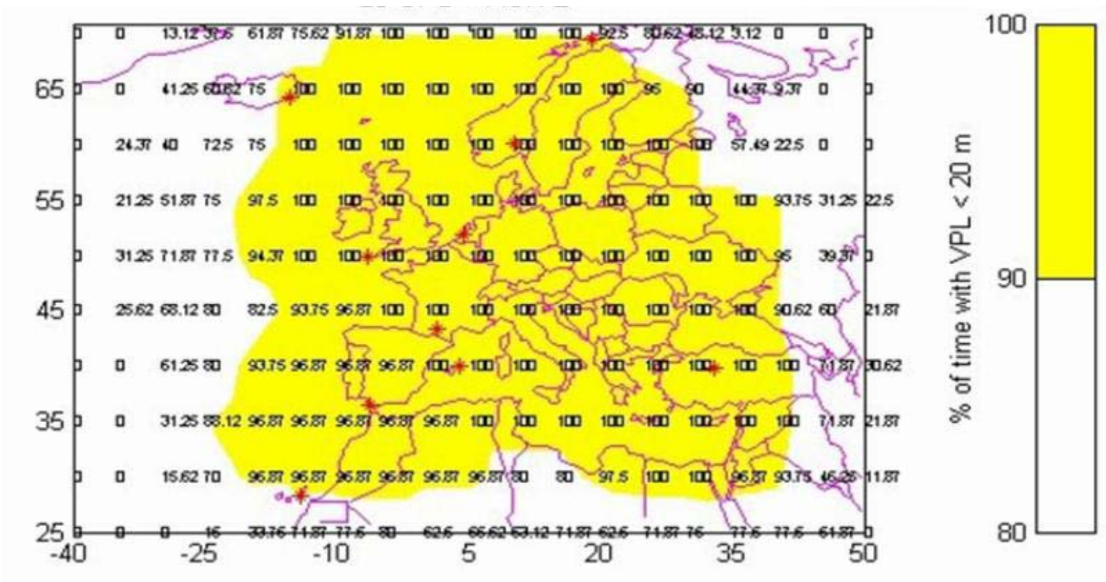

Figure 8 – ESTB APV-2 service area (based on real data)

The ESTB Help Desk service can be reached through the E-mail address **ESTB@esa.int.** General information on ESTB scheduling, signal standards, related news, available data, publications, etc. can be found through the ESA EGNOS for Professionals Website (integrated in the ESA Navigation Portal), at **http://www.esa.int /navigation/egnos-pro.**

6. Interoperability of SBAS Systems

In addition to EGNOS, there are other Satellite Based Augmentation Systems (SBAS) under development: the wide area augmentation system (WAAS) in USA, the multi-functional transport satellite (MTSAT) satellite-based augmentation system (MSAS), in Japan, the GAGAN system in India and the SNAS system in China. Although all SBAS are currently defined as regional systems, it is commonly recognized the need to establish adequate co-operation/co-ordination among the different systems, so that their implementation becomes more effective and part of a seamless world-wide navigation system.

To guarantee seamless and worldwide system provision, it is essential that the existing systems do meet some common interoperability requirements and do provide adequate system. The service providers of the EGNOS, WAAS and MSAS systems are regularly meeting through so called "*interoperability working group (IWG)*" meetings to conclude on a the precise understanding of the term interoperability, and on the identification of the necessary interfaces among SBAS that each conceivable interoperability scenarios may imply. The EGNOS system includes specific requirements so that interoperability with those systems (see Fig. 9) may be achieved.

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.

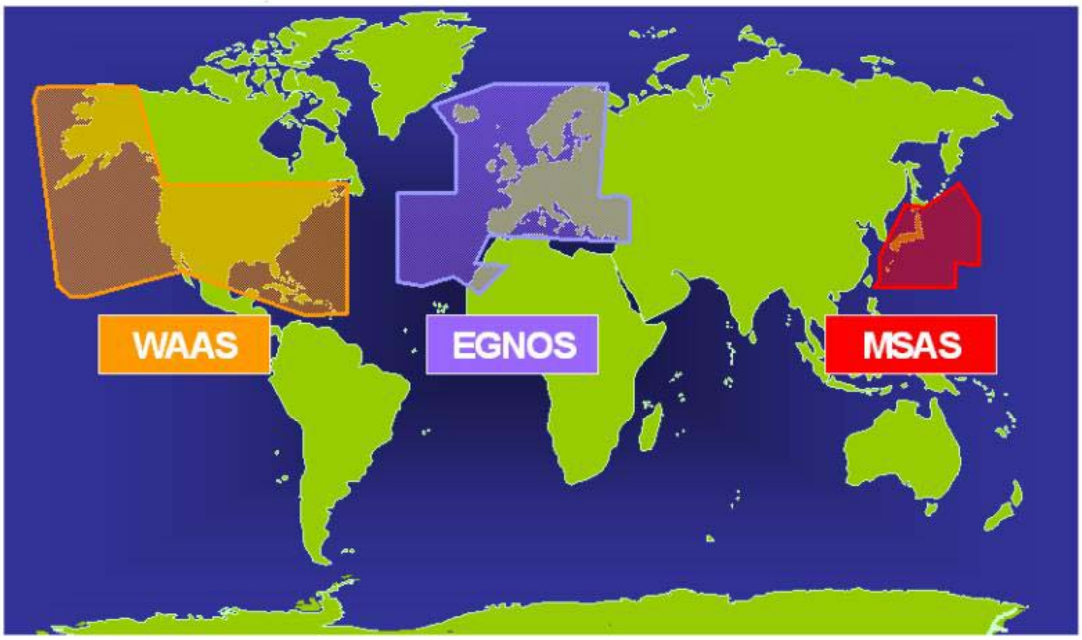

Figure 9 – SBAS interoperability

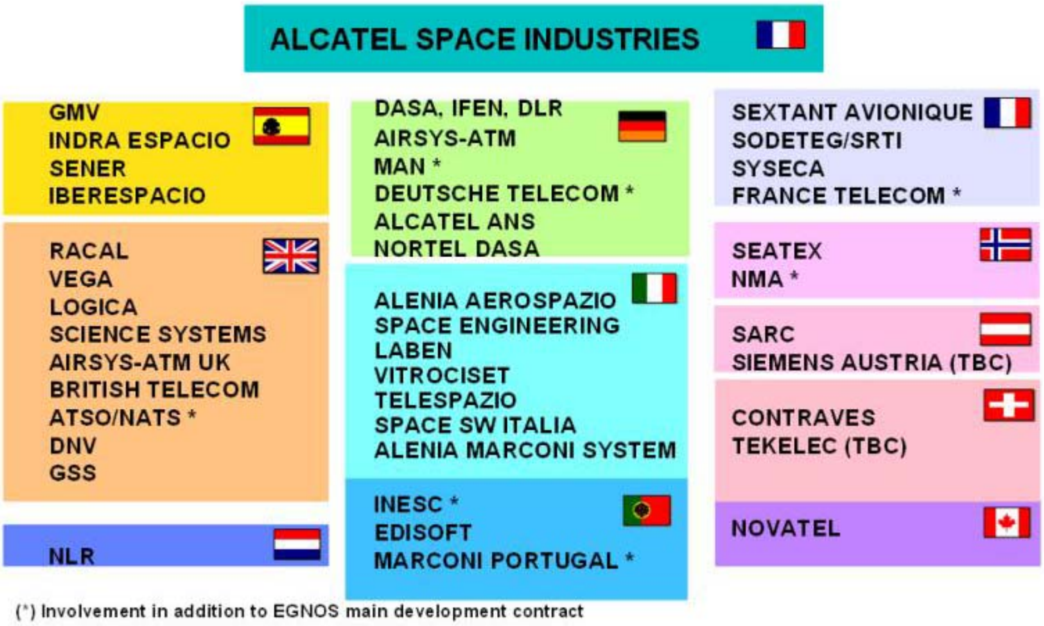

Figure 10 – EGNOS industrial consortium

7. EGNOS Programme Status Overview

The EGNOS programme comprises two different phases: Initial phase and AOC Implementation phase; The EGNOS Initial Phase was successfully concluded in November 1998 with the System Preliminary Design Review (PDR).

The industrial team in charge of EGNOS AOC development is led by Alcatel Space Industries (France) with the participation of companies from all participating States, as illustrated in Fig. 10.

The Agency's Program Board approved the full implementation of the EGNOS AOC System in December 1998; and the prime contract was signed with Alcatel on 16 June 1999. Since then, all sub-system activities were kicked-off in 1999, and the project continued with the detailed-design of the subsystems after progressive completion of all subsystems PDRs during year 2000. In December 1999, an important change request was signed with Industry to reflect latest evolutions in EGNOS interface requirements, including latest versions of international standards. Early 2002, the system Critical Design Review (CDR) was successfully completed.

After completing the system Factory Qualification Review (FQR), early 2004, the next major milestone is the EGNOS AOC Operational Readiness Review (ORR), planned in September / October 2004.

The EGNOS project includes significant contributions from the French Space Agency (CNES), the Norwegian Mapping Authority (NMA), and main European Air Traffic Management service providers like AENA (E), NAV-EP (P), DFS (D), ENAV (I), DGAC (F), NATS (UK) and Skyguide (CH). Those partners provide ESA with in-kind deliveries, including the infrastructure to host a number of the necessary EGNOS ground stations.

In parallel of those on-going development efforts, the actual integration of EGNOS into the GALILEO Mission is currently under detailed assessment. Current results are very promising, and demonstrate that the EGNOS system can be used as a sound building brick on which the GALILEO system architecture can capitalize.

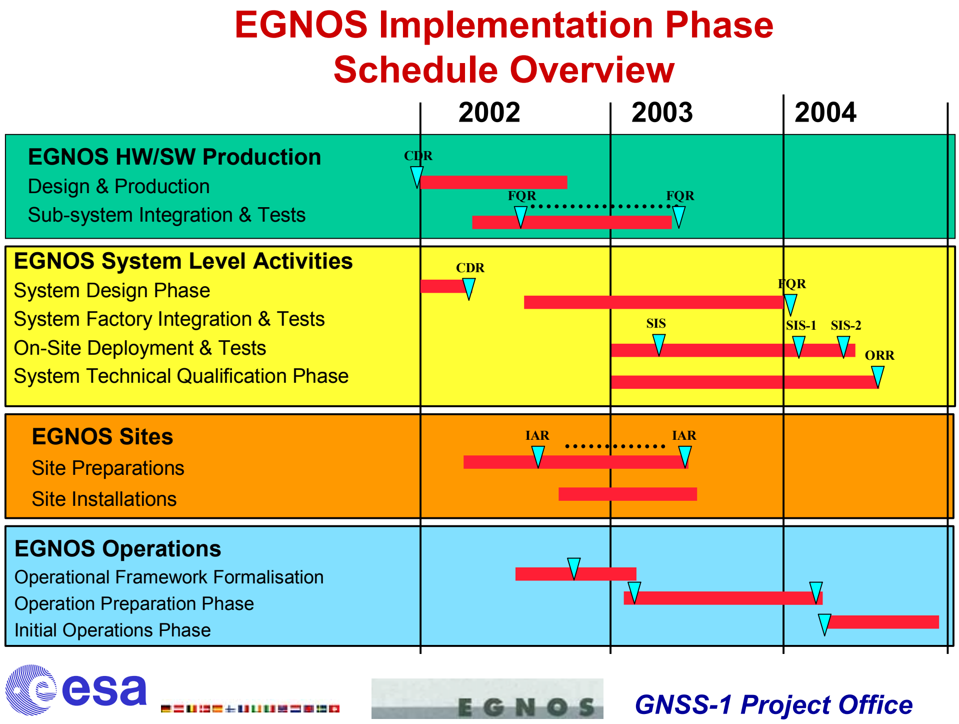

Figure 11 – EGNOS AOC schedule

Aligned with the system deployment, the EGNOS SIS is being broadcast through three successive steps, called SIS0, SIS1 and SIS2. The SIS0 event took place during 2003. The system included a minimum configuration, consisting of 6 RIMS, 1 MCC and 1 NLES. The main goal was to provide confidence in the basic functionality of EGNOS in an early stage. The SIS-1 event took place in April 2004, based on a configuration of 16 RIMS, 1 MCC and 1 NLES. The Inmarsat IOR-W GEO satellite was employed to broadcast a stable signal during 48 hours. The next key event, just preceding the ORR milestone, is SIS-2. In this third SIS transmission step, the system configuration will be quite close to the final EGNOS one. The SIS-2 transmission will cover 417 hours, and after that, a stable signal will be continuously transmitted (notice that, from SIS0 to SIS2, transmissions have been not regular). It is important to highlight that the EGNOS SIS transmissions are only usable for integration purposes. The EGNOS SIS will be usable for non Safety of Life (SoL) applications starting from the ORR (planned in September / October 2004). The EGNOS SIS is expected to be certified for SoL applications by 2006.

8. EGNOS Measured Performances

ESA successfully completed the EGNOS SIS-1 milestone in April 2004. Although this milestone has no qualification credit (it was essentially a dry run exercise of future EGNOS performance qualification formal exercise), it has provided quite promising results. With a partial deployment, containing just 16 RIMS – versus the 34 RIMS of the final EGNOS system –performances obtained in central ECAC are similar to those offered by the American WAAS system in the CONUS area.

In the pathway from SIS-1 to SIS-2, deployment of the system has progressed notably, and several interesting transmission periods have taken place, this time using more RIMS and broadcasting the signal through more than one GEO. ESA, together with its IMAGE partners, has quickly reacted to those transmission episodes, generating very revealing performance reports. As an example, Figure 12 shows the performance measured in Paris on the 23rd of April 2004, through a Stanford histogram, corresponding to a partial deployment including 28

RIMS. Results talk by themselves: the APV-I and APV-2 levels of service are available 100% of the time.

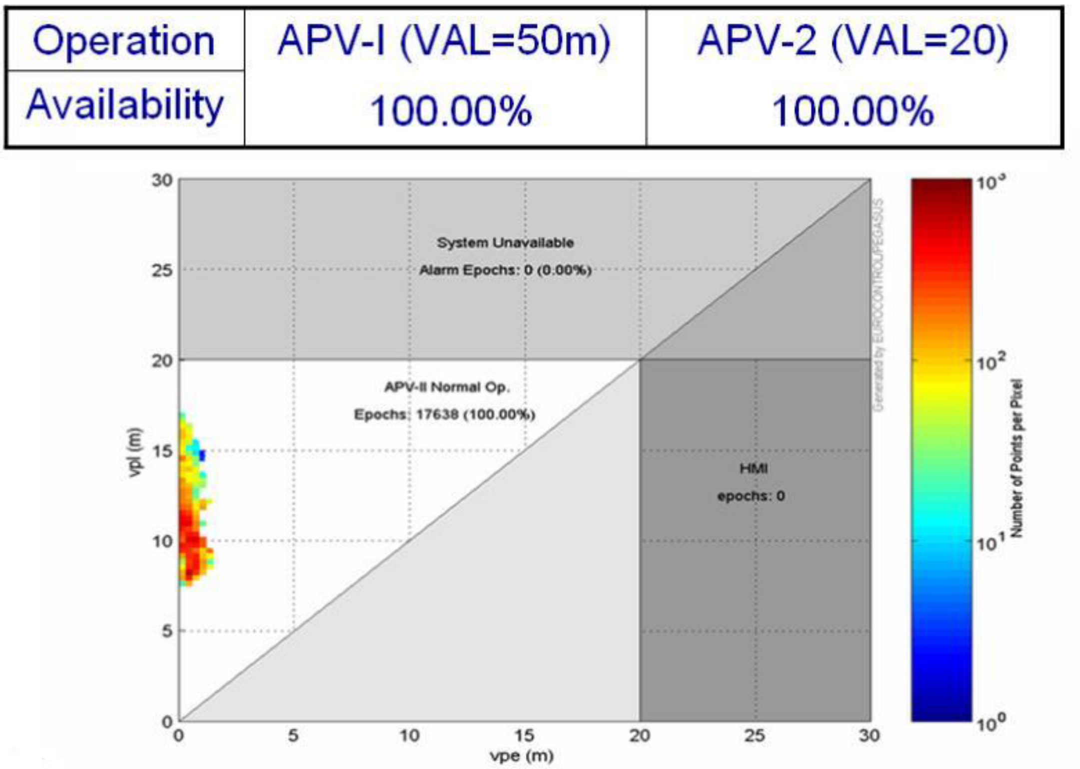

Figure 12 – EGNOS performances measured in Paris on April the 23rd, 2004 (corresponding to a partial system deployment including 28 RIMS stations)

Table 3: EGNOS measured accuracies in April the 23rd, 2004

	Toulouse	Palma de Majorca	Fucino	Scilly Islands	Paris
HNSE 95%	1.2 m	**0.8 m**	1.3 m	1.5 m	1.1 m
VNSE 95%	2.1 m	1.9 m	**1.3 m**	2.1 m	**1.1m**

In terms of accuracy, Table 3 summarises the Horizontal and Vertical Navigation System Errors (95%) obtained in different sites. Excellent vertical (1 to 2 meters) and horizontal (around 1 meter) accuracies are obtained, well bellow the 7.7 meters ICAO requirement. Moreover, it is worth to note that this is the first time that sub-meter horizontal accuracies are measured in EGNOS. The promising results obtained during the SIS-1 to SIS-2 timeframe foretell a successful SIS-2 event and draw a promising path towards the ORR milestone, expected in September / October 2004.

9. EGNOS Evolution Plans

In parallel to the start of EGNOS operations, EGNOS needs to respond positively to the dynamic GNSS environment.

The EGNOS AOC is based on a Mission Requirements Document (MRD) developed in 1998, which allows EGNOS provision in 2004 with excellent performances. However, since then, the GNSS environment has changed considerably, due to the apparition / launch of:

- The Galileo program;
- The GPS modernisation program;
- New L1 / L5 GEO satellites;
- Export opportunities for SBAS technology;
- GPS/SBAS L5 standardisation work;
- WAAS FOC program;

In June 2003, the Council of the European Union stated that EGNOS is an integral part of the Satellite Navigation policy, thus, highlighting the need of integrating EGNOS into Galileo. As the principal conclusions, it was stated that EGNOS should:

- Become operational as soon as possible;
- Allow for service availability in the long term;
- Be used as a precursor to Galileo;
- Enable Galileo to penetrate rapidly the market;
- Meet the obligations of the International Standards, and
- Be extended determinedly to other parts of the World

In response to that need, a Post-ORR ESA / EC program, called "GNSS Support Program" has been defined in two steps:

- **Step 1**, covering the 2004 – 2005 timeframe, already approved early June 2004.
- **Step 2**, covering the 2006 – 2008 timeframe, to be formalised / agreed early 2005.

This post-ORR program integrates four main tasks:

- **Task 1**: provision of EGNOS SIS and data (EGNOS operations);
- **Task 2**: sustenance / evolution of the EGNOS system;
- **Task 3:** technical support to certification, validation and applications;
- **Task 4:** technical support to international co-operation.

Throughout this evolution plan, three intermediate releases of the EGNOS system are foreseen, identified as V2.1, V2.2 and V2.3. The main features characterising each version are summarised in Figure 13. A dedicated article, presenting in detail the EGNOS evolution plans can be found in [4]. For the specific evolution called INSPIRE, further information can be also found in [5].

EGNOS V2.1 (end 2005)	EGNOS V2.2 (in 2007)	EGNOS V2.3 (in 2008)
- EGNOS products over non-GEO data links (INSPIRE) - Extension to MEDA and East of Europe - Other issues (MT0/2, Standard necessary adaptations)	- EGNOS MT 28 - Extension in Africa -Modernised RIMS receivers - SAR return link	- L5 standards and L5 GEO broadcast - GNSS "sole service" using combined EGNOS/GALILEO - L1/L5/Galileo (TBC) enhanced RIMS receivers

STEP 1 STEP 2

Figure 13 – EGNOS V2 core infrastructure evolution plans

10. Summary and Conclusions

EGNOS is the main European contribution to GNSS-1 to serve the needs of, maritime, land transport, time and aeronautical applications in the European and neighbouring regions. For aviation, EGNOS AOC will be used in the ECAC Region as a primary means of navigation for all phases of flight down to APV-2.

EGNOS will be interoperable with equivalent US (WAAS) and Japanese (MSAS) SBAS systems, in addition to other emerging initiatives – as India's GAGAN system and China's SNAS system – aiming at contributing to a true world-wide global navigation system.

EGNOS System Test Bed (ESTB) signal-in-space is available since early 2000, and is used to support demonstrations and trials in Europe, Africa, South America and interoperability trials with Japan and US. The ESTB provides a unique opportunity for validating new application developments in a realistic environment, in preparation not only for the EGNOS operations but also for future GALILEO services.

Version 1 of the EGNOS system is close to conclusion. Initial performances are excellent. A stable signal is expected June / July 2004, and the formal start of operations is planned in the third quarter of 2004, delivering a very valuable service to users. It is to be noted that, from the start of EGNOS operations until 2008 (with the advent of Galileo), EGNOS will be the sole source of GNSS services in Europe.

In parallel with the EGNOS V1 operations, and without any operational interruption, EGNOS will keep modernising and improving services in the 2004 – 2008 timeframe, in response to new identified needs (e.g. Galileo and GPS modernisation).

A post-ORR ESA / EU program, called "GNSS Support Program", has been defined, including the EGNOS operations, maintenance and functional evolutions. Step 1 of this program – covering the 2004 - 2005 timeframe – has been recently approved (early June 2004). This step includes the release of EGNOS V2.1 end 2005, with 2 main new missions: service extension and non-GEO service multimodal provision (through an interface known as INSPIRE). Step 2 is to be confirmed mid 2005, including the EGNOS extension in Africa (in 2007) and the provision of SBAS L1 / L5 services (in 2008).

EGNOS V1 is the first step of the European Satellite Navigation strategy and a major stepping-stone towards GALILEO (Figure 14), future Europe's own global satellite navigation system for which ESA has a major role and responsibility. The EGNOS evolution program will contribute to the success of Galileo and its quick market penetration.

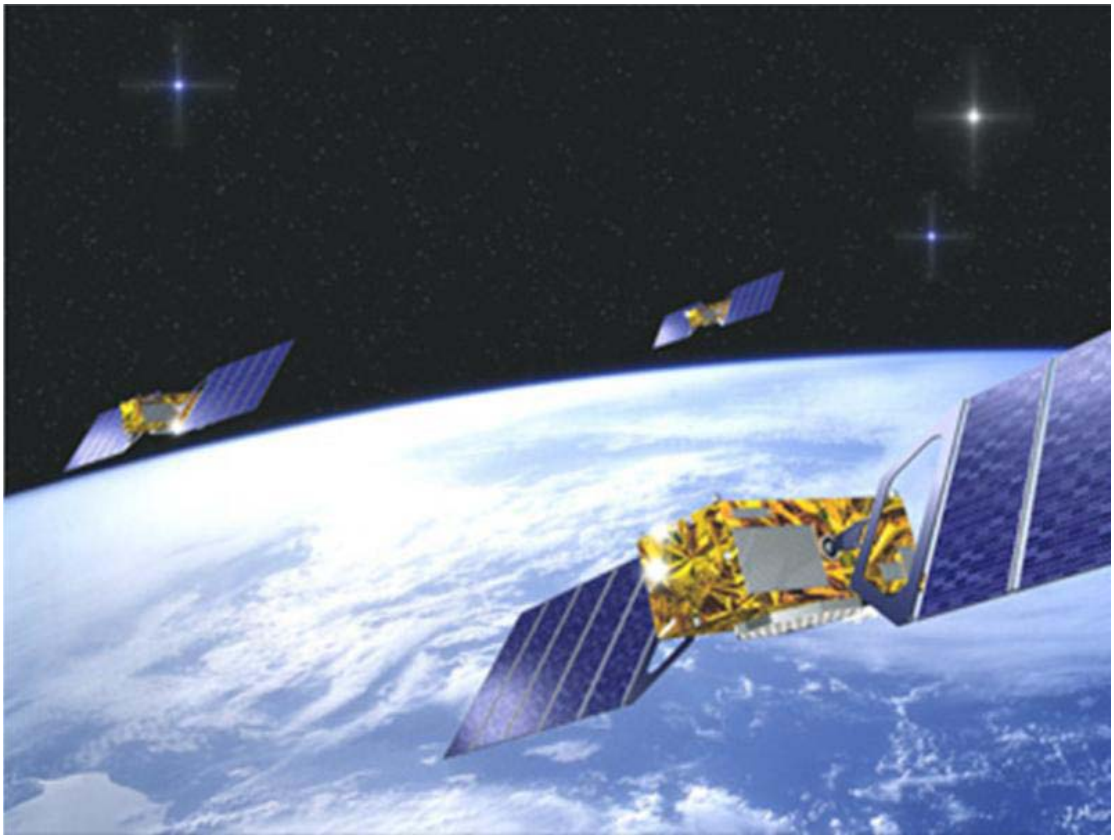

Figure 14 – Artist's impression of the Galileo constellation (J. Huart)

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