EGNOS System Test Bed Evolution and Utilisation

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BIOGRAPHY

Hugues Secretan joined the CNES (the French Space Agency) in 1983 after graduating with a degree in electrical and mechanical engineering. He works in the ESA GNSS-1 Project Office since 1998 as the ESTB Principal Engineer.

Dr. Javier Ventura-Traveset holds a MS in Telecom. Eng. from the Polytechnic Univ. of Catalonia (Spain, 1988); a M.S 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 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 has co-authored over 100 technical papers. He is Member of ION and Senior Member of the IEEE.

Felix Torán-Martí obtained his MS in Electrical Engineering from the Univ. of Valencia (Spain, 1999), where he is currently pursuing his PhD Degree. During years 1998-2000, he worked as the main Software Engineer on several European projects. In Sept 2000 he joined ESA (under the Spanish Young Graduate Programme) as System Engineer for the EGNOS Project, with major contributions on simulation Software development and on the ESA SISNET Project. Mr. Toran has co-authored over 50 technical papers.

Giorgio Solari, graduated in Mechanical Engineering at Univ. of Rome (Italy) in 1984, and obtained a MBA degree in 1998. 1985-1988 he worked as Mission Engineer at Italspazio. Since 1988 he is working at the European Space Agency, first (1988-1997) as System Engineer at ESA's System and Programmatic Department, later (1997-2000) as Head of European GNSS Secretariat. Currently, Mr. Solari is working at as EGNOS Coordinator in the Galileo Interim Support Structure (GISS), Brussels.

Dr. Sally Basker was awarded a Ph.D in Satellite Geodesy in 1990, and has 15 years wide-ranging GNSS expertise. She was appointed an Associate by Booz·Allen & Hamilton in 2000 with particular responsibility for European satellite navigation activities. Her current activities include supporting ESA's ESTB programme, assessing how the Southern Ring States can benefit from SBAS technology, and market sizing for Galileo. Dr Basker was elected a Fellow of the Royal Institute of Navigation in 1999.

ABSTRACT

Europe is fully engaged in the development of EGNOS, the European Geostationary Navigation Overlay Service, aimed at augmenting GPS and GLONASS navigation services in terms of precision, data integrity, continuity and availability of services [1]. EGNOS is now a reality as a test bed: a simplified version of the fully-fledged system has been readied in January 2000 by Alcatel Space Industries, the prime contractor leading the international industrial team that is developing the system.

Thanks to this test bed system, an EGNOS-like signal has since mid-February 2000 been transmitted from space, providing users with a GPS augmentation signal and enabling them to compute their positions to an accuracy of a few metres. The EGNOS test bed signal is currently available in the coverage area of the AOR-E satellite, and in the current year 2001 it will be also available in the coverage of IOR satellite.

ESA is responsible for the technical management and the overall operations of the EGNOS System Test Bed and, in performing this role, is working in close co-operation with the French space agency (CNES) and the Norwegian Mapping Authority (NMA), which have also made in-kind contributions to development. Development of the EGNOS System Test Bed was managed by Alcatel Space Industries, ESA prime contractor for EGNOS and by the subcontractors GMV (E), Racal (UK), Seatex (N) Astrium (D) and DLR (D).

The EGNOS System Test Bed (ESTB) is also a unique tool for the analysis and design of EGNOS. As such, the ESTB is an integral part of the ESA EGNOS programme. During 2000/1, the ESTB activity has mainly focused on the improvement of the SIS availability and the performance.

This paper will present:

1. An overview of the ESTB implemented architecture and a recall of the main features;
2. An introduction to the ESTB operations approach;
3. The description of the different ESTB User support initiatives launched by ESA during 2001;
4. An overview of ESA launched ESTB System upgrades including: the evolution of the signal-in-space standard; the addition of new reference stations; the expansion mode outside ECAC; and the provision of the of ESTB SIS through the Internet;
5. Information on today achievable performances with the ESTB;
6. A summary of some of the ESTB Trials performed during 2001/2002 and of the ESA launched GNSS application technology Contracts.

INTRODUCTION

The ESTB (EGNOS System Test Bed) is a real-time prototype of EGNOS. It provides the first continuous GPS augmentation service within Europe, and 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 ETG (European Tripartite Group, formed by ESA, EC and Eurocontrol). The ETG plans to promote the use of EGNOS and analyse its capabilities for different applications. In particular, ESTB availability will allow Civil Aviation authorities to adapt their infrastructure and operational procedures for future EGNOS use when it becomes operational.
  A specific workshop sponsored by ESA aimed at fostering the use of ESTB and analysing the needs of potential users was successfully organised on July 6-7, 2000. A second ESTB Workshop will take place Nov. 12, 2001 at Nice (France), preceding NavSat 2001 Conference. Registration can be done via E-mail at ESTB-News@esa.int
- ♦ The analysis of future EGNOS upgrades.
- ♦ To serve as a backbone for continuous EGNOS experimentation and design improvement process.

1. ESTB ARCHITECTURE

The ESTB architecture is presented in Fig. 1. It has been driven by high performance objectives in order to be able to assess the operational capabilities of EGNOS.

Also, in order to reduce the development time of the ESTB and to optimise the overall ESTB effort, a number of existing assets have been taken into account to build up the ESTB:

- ♦ From NMA in Norway, based on the existing SATREF system,
- ♦ From CNES, based on the EURIDIS ranging system (EURIDIS was implemented in order to provide the GPS ranging capability on the INMARSAT III AOR-E navigation payload),
- ♦ From ENAV, based on the MTB (Mediterranean Test Bed) composed of one NLES for broadcast on IOR and two reference stations located in Fucino and Matera.

The following paragraphs detail the ESTB design and elements, highlighting the contributions of the IKD providers:

- A network of 10 reference stations (RS), expandable in the future, and which are permanently collecting GPS/GEO/GLONASS data. These include two RS provided by AENA (Spain), recently connected (July 2001), located in Palma de Mallorca and Gran Canarias.
- A Control and Processing Facility (CPF) generating the WAD (Wide Area Differential) user messages. This CPF is located in Honefoss (Norway), and supported by SATREF™ platform.
- Three EURIDIS reference stations for the purpose of the Ranging function. These RS 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 EURIDIS processing centre located in 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.
- Two Navigation Land Earth Stations (NLES) are used in the ESTB. The NLES located in Aussaguel, close to Toulouse (France), is part of the EURIDIS Ranging system and transmits through the INMARSAT III AOR-E satellite; the other NLES is placed in Fucino (Italy) providing access to the INMARSAT IOR satellite.
- A real-time communication network based on frame-relay links, allowing the transfer of the RS data to the processing centres, and of the navigation messages from Honefoss to the NLES.
- Independent User receivers to test the system and perform demonstrations.
- Post processing tools to analyse the ESTB performances.

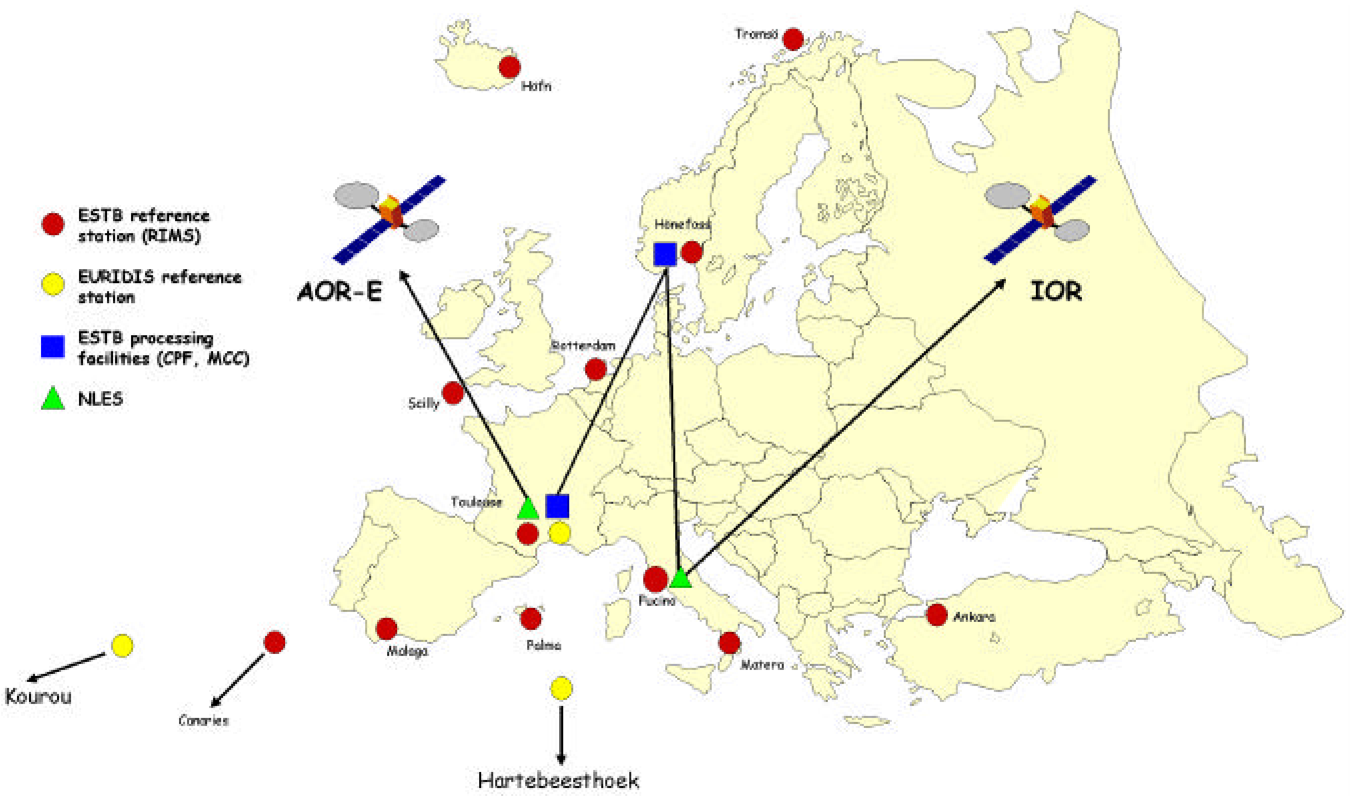

Figure1 - ESTB ground elements location

2. ESTB OPERATIONS

2.1. Operations Team

ESA plans to operate the ESTB continuously until EGNOS becomes operational. The ESTB ground segment is controlled on working hour's basis, but the system is able to run continuously unless there are no hardware failures.

The operational tasks are under ESA responsibility. Different parties contribute to the daily operations, either under a contract with ESA or through co-operation agreements:

- CNES for the Ranging ground segment (EURIDIS) operations, the AOR-E signal generation and the overall ESTB co-ordination
- The Norwegian Mapping Authority (NMA), for the operations of the reference stations and the CPF processing facility in Honefoss
- Telespazio, for the MTB operations including the IOR SIS generation
- Thales for the Frame Relay network operations

2.2 SIS robustness: providing a 24h service

The SIS availability (% per month) is shown in Fig. 2.

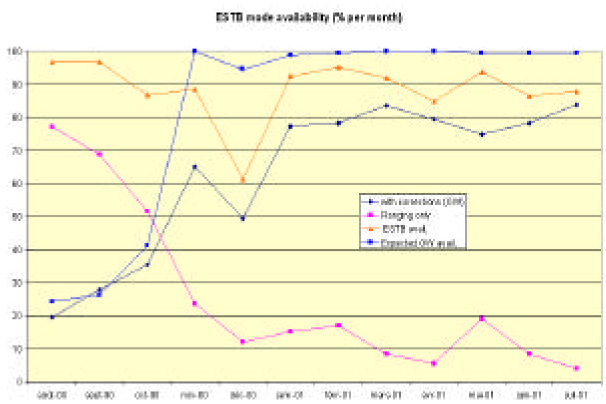

Figure 2 - ESTB SIS availability (% per month)

Major losses of availability are due to interruptions during weekend (NLES long Loop and CPF interruptions). To reach **a target of 95% availability** before end 2001, ESA has planned some improvements of the CPF processing and of the NLES long loop with automatic restart capability. Also, to avoid interruptions when industrial tests are performed, a redundancy Platform of the CPF processing will soon be provided at Honefoss.

The broadcast schedule for the ESTB can be found (including monthly forecast and day to day information) on the ESA's web site with address http://www.esa.int/EGNOS/pages/indexEST.htm

3. ESTB USER SUPPORT

3.1 ESTB Newsletter

ESA has just launched an ESTB Newsletter [6,7] (see Fig. 3). Issue 2 [7] has just been launched in coincidence with ION GPS 2001. The ESTB News is aimed at all potential future EGNOS users, as well as anyone else with an interest in state-of-the-art of satellite navigation. ESTB News will contain the latest information and results from trials performed using the ESTB. The ESTB editors can be contacted by email at ESTB-News@esa.int.

Figure 3 - ESTB News, Vol. 1, Issue 1, May. 2001

ESTB Newsletter is available both in hard copy and from ESA's web http://www.esa.int/navigation.

3.2. EGNOS / ESTB Web Sites

ESA has established four headline web pages to support its navigation activities:

- Navigation;
- EGNOS;
- ESTB; and
- Galileo.

These well-referenced web pages are designed to be a source of useful information for users and system developers. They are constantly being upgraded with news, system highlights and EGNOS demonstrations, and contain links to copies of the ESTB News for download. The ESTB website also include daily operational information and performance results. The URLs are given in Table 1.

ESA WWW URLs	
ESA Navigation Web Page	http://www.esa.int/navigation
ESA EGNOS Web Page	http://www.esa.int/navigation/EGNOS
ESA ESTB Web Page	http://www.esa.int/EGNOS/pages/indexEST.htm
ESA Galileo Web Page	http://www.esa.int/navigation/Galileo
ESTB Email Addresses	
ESA ESTB Help Desk	ESTB@esa.int
ESTB News Editor	ESTB-News@esa.int
ESTB MCC info	Christophe.texier@cnes.fr

Table 1 - ESA WWW URLs and Email Addresses

3.3. ESTB Helpdesk

The ESTB provides a unique opportunity for validating and demonstrating new service and application developments in a realistic environment, in preparing for the EGNOS operations from 2004 onwards but also in getting ready for the initiation of the Galileo system later this decade. To support these initiatives, the European Space Agency has set-up an ESTB Helpdesk e-mail service (ESTB@esa.int).

The ESTB Helpdesk e-mail service is available for all current or future ESTB users as well as anyone else with an interest in state-of-the-art satellite navigation. The ESTB Helpdesk will respond to questions on the ESTB architecture and performance, EGNOS receivers, ESTB Signal in Space (SIS) status and on ESTB evolutions. Moreover, it will try to assist potential users in every possible way on how to exploit the ESTB for their specific application or service developments.

Daily SIS operational status information is distributed also by E-mail under request (sending a request E-mail to the ESTB MCC E-mail of Table 1) . This information will soon be available on line on the ESA's ESTB website

4. ESTB UPGRADES

Even after very satisfactory results, the ESTB is still evolving. In particular, the following upgrades may be mentioned:

- As per July 2001, the ESTB signal in space has been updated to comply RTCA MOPS DO229A standard. The next upgrade to RTCA MOPS DO229B version is now expected to be operational in early 2002.

- The ESTB-CPF embraces capabilities for providing an enhanced navigation service. Expansion Service is aimed at providing a controlled service out of the nominal service area. Different concepts and architectures have been investigated depending on the relative location of the secondary service area and EGNOS primary service area. Only one CPF, as currently designed, is sufficient to provide WAD corrections and integrity to both areas simultaneously.

- The processing of the ionospheric vertical delay has been developed and verified for low latitude ionosphere conditions (ionosphere equatorial crest region, a zone of enhanced electron density at both sides of the geomagnetic equator).

4.1. Signal specifications: MOPS DO229A

The ESTB SIS is conforming to the MOPS DO229A [2]. Differences are only applicable to receivers used within expansion areas (usage of message type 27).

- Message type 27 will broadcast *ESTB UDRE Increment Indicators*.
- Only one type 27 message with up to 7 regions will be broadcast.
- The *ESTB UDRE Increment Indicator* will be the same for all regions included in message type 27. Moreover, such a value will be a configuration parameter.
- ESTB users within the designated region will translate the broadcast *ESTB UDRE Increment Indicator* to *ESTB UDRE Increment Factor* by means of a table different from the Table A-20 in [2].
- ESTB users will translate the broadcast *ESTB Region Radius Indicator* to degrees by means of a table different from the table A-21 in [2] and provided in Fig. 4.

Region radius indicator	Region radius in degrees
0	5
1	10
3	15
4	25
5	30
6	35
7	40

Figure 4: Table for MT27

The next upgrade, compliant with RTCA DO229B [3], is now expected to be operational in early 2002.

4.2. Expansion service: ECUREV project

The major objectives of the ECUREV project (awarded by the European Commission to GMV) were:

a) To design and develop a Test Facility, composed of a portable monitoring station (RIMS) with autonomous communication means, and a User Monitoring Unit (UMU tool) for performances monitoring. The Portable RIMS has been designed for an easy transportation and installation. In order to avoid any dependency from local communication means, each RIMS is equipped with a VSAT (Very Small Aperture Terminal). The User Monitoring Unit, consist of one receiver compatible with ESTB SIS plus some SW tools that support the specific implementation of message type 27 in ESTB-CPF. These tools are also intended for the performance analysis of collected data. User Monitoring Unit has been designed to remain static, though future upgrades for a mobile platform environment will be possible with minimum changes.

b) To design and develop the necessary software changes in the Central Processing Facility (CPF) of the ESTB aiming at providing APV-I performance over an expansion area located out of Europe. The major changes are:

- **Ionospheric Corrections Module:** Implementation of modelling supported by a-priori information.
- **UDRE Computation Module:** It is necessary to degrade UDRE in the Expansion Service area while maintaining the values in the nominal service area, by means of message type 27. The expansion service area is defined through the use of such a message. For the sub-areas identified in this message, a particular UDRE increment common to all satellites can be defined, thus ensuring integrity over the expansion service area. The definition of an appropriate “UDRE increment” is one of the key issues for the service expansion.
- **Message Selection and Generation Module:** Usage of message type 27, and optimise the available GEO payload bandwidth (this specially affects to ionosphere corrections and GIVE over the expansion service area).

c) To conduct a test campaign in Canary Islands, in order to analyse the possibilities of expanding the EGNOS service outside of Europe, and to prove the correct performance of the changes implemented in the ESTB-CPF.

A portable RIMS has been deployed at Tenerife Sur airport and linked to the ESTB-CPF.

Fig. 5 shows a map with the GIVE obtained in ECUREV expansion scenario. This figure, when considering the RIMS location, shows the high dependence of the ionospheric delay quality determination on the RIMS geometry, resulting in lower errors in the estimation and, hence, lower GIVE values.

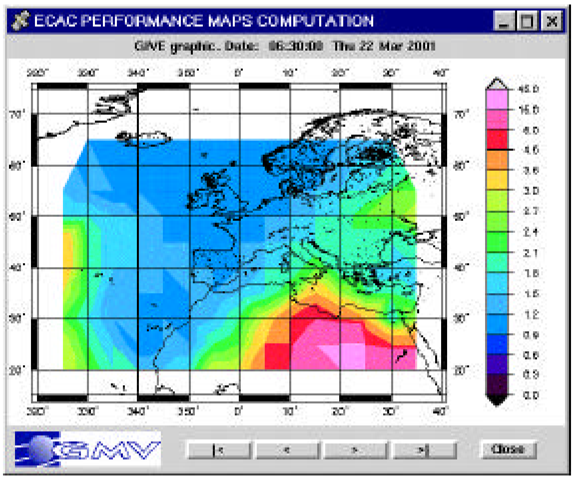

Figure 5 - GIVE estimates (ECUREV scenario, 9 RIMS)

By ordering additional RIMS units, ESA and the European Commission will be then in a position to conduct tests in different areas, to show to interested parties the augmentation navigation capabilities provided by ESTB, and in turn, by the future operational EGNOS System.

4.3. ESTB SIS access through Internet: the ESA SISNET Project

Satellite broadcasting through GEO means is proved to be an efficient strategy for many users (e.g. aviation and maritime), but others (e.g. land mobile) may experience reduced service availability due to topography and urban canyons. Since the EGNOS message will still be very useful for those applications, a different transmission link may need to be considered to take the utmost advantage of the EGNOS potential. For this reason, ESA has recently launched specific contract activities (through the Advanced System Telecommunication Equipment programme –ASTE–) to assess and demonstrate architectures where the ESTB signal is broadcast through non-GEO means (e.g. FM or GSM broadcasting). Within this framework, ESA has also launched an internal project, called SISNET (Signal in Space through the Internet), which set sights on providing access to the EGNOS test bed messages through the Internet.

Fig. 6 shows the architecture of the SISNET platform. The three principal components are the following:

- **The Base Station (BS)** consists of a PC computer, equipped with an EGNOS receiver. A set of software components allows acquiring the EGNOS messages and sending it to a remote computer (the Data Server) in real-time (1 message per second, i.e. 250 bit per second). All the components are integrated into a user-friendly software application, called Base Station Application.

- **The Data Server (DS)** is a high performance computer, optimised for running server software with a big amount of connected users. The DS software receives the EGNOS messages from the BS and transfers them to the remote users in real time, using a specific protocol, totally based on TCP/IP. In addition, the DS implements other extra services provided by SISNET (e.g. broadcast of text messages to the users). The DS periodically sends the most recent EGNOS messages to a remote Web server, enabling the development of Web / WAP applications.

- **The User Application Software (UAS)** is a flexible software application that accomplishes the SISNET interface control specifications and defines each specific application of SISNET. Developers can create particular implementations of the UAS, by applying one or more processing blocks to the received messages. The UAS can be embedded in different kinds of computers and electronic devices (e.g. Personal Data Assistants).

A first prototype of the SISNET platform has been successfully set-up by ESA during August 2001, demonstrating the feasibility of the SISNET concept. In this first prototype, the UAS runs on a PC computer, and the connection to the Internet is achieved using a LAN environment (via a proxy server). In order to demonstrate the SISNET potential, ESA has developed the first UAS implementation, including three parallel processing blocks (thus, enabling three different applications):

- **SISNET-augmented GPS positioning**. The EGNOS corrections are applied to the measurements coming from a GPS receiver. The result is an improvement of the position accuracy with respect to the GPS-only configuration.
- **Real time analysis of the ESTB messages**. A multi-threaded real-time processing block presents the information contained in the ESTB messages, through graphical user interfaces.
- **Real time performance monitoring.** An interface with the ESA ESPADA simulation tool allows real-time monitoring of the ESTB performance. Maps of the XPL availability over the last 24 hours are periodically updated and stored in the form of PowerPoint presentations and AVI video files.

The next step of the project points towards complementing the preliminary prototype development with industrial work. The expected achievements include developing a SISNET-powered GPS receiver (by integrating a GPS receiver and a GSM connection to the Internet), embedding SISNET receivers into cars and optimising the SISNET network.

SISNET can grant noteworthy advantages to the GPS land-user community. It is firmly believed by the authors that the access to the EGNOS messages through the Internet and the possibility of using standard GPS receivers with EGNOS augmented performances, will open a large amount of applications for Satellite Navigation. More information on the ESA SISNET Project may be obtained in [8].

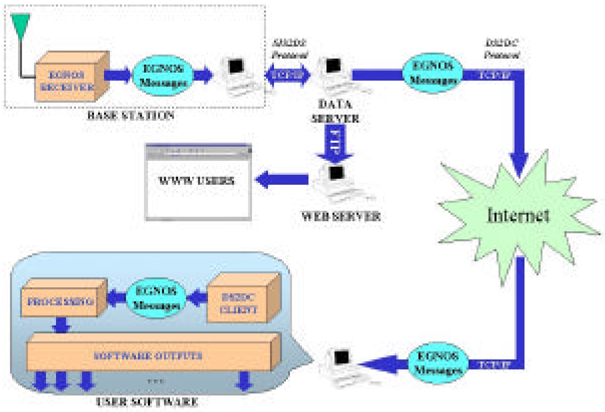

Figure 6 - Architecture of the SISNET

5. CURRENT TYPICAL PERFORMANCES

5.1. Integrity availability

The current ESTB typical performances measured on different point of the ESTB service area with 10 Reference stations (without using the GEO ranging capability) are as follows:

- For APV-II service (VAL=20m), the achieved availability reach 93%
- For APV-I service (VAL=50m) the achieved availability is very close to 100%.

These results are illustrated by the diagrams introduced by the Stanford University where VPE (in horizontal) and VPL (in vertical) pairs as computed every epoch are plotted. Figures 7 and 8 shows the VPL versus VPE and HPL versus HPE performances computed with 10 RS in Toulouse over 24 hours (15 March 2001)

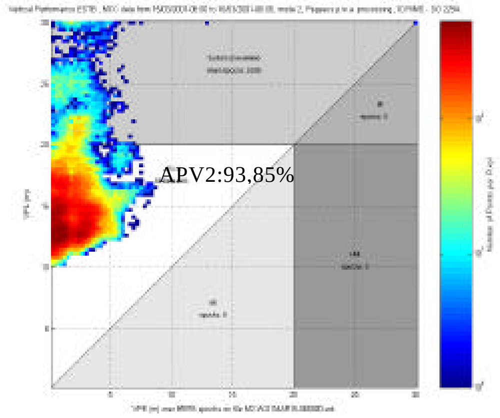

Figure 7 - VPL vs. VPE (24 hours duration)

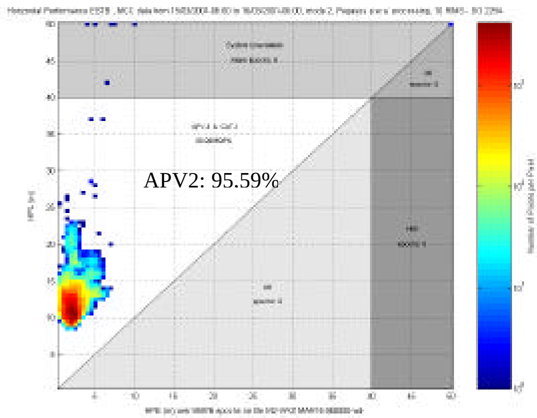

Figure 8 - HPL vs. HPE (24 hours duration)

5.2. Accuracy performances

The typical accuracy achieved within the ESTB service area is (without using the GEO ranging capability):

- HNSE: 3m 95%
- VNSE: 5m 95%

The average estimated VNSE with current 10 ESTB reference stations is shown in Fig. 9.

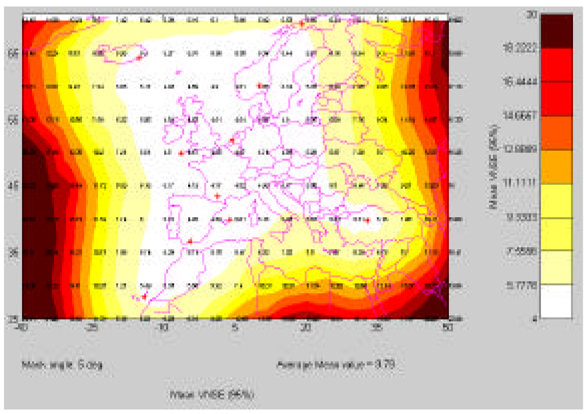

Figure 9 - Average VNSE of the ESTB

6. ESTB TRIALS AND GNSS RELATED APPLICATIONS

In this Section we first addressed some trials involving the EGNOS Test bed performed in 2000 and 2001. Recently launched ESA ARTES-5 GNSS applications programme and on-going ESTB trials are also addressed. These activities, which concern a large variety of GNSS applications, are discussed in turn.

6.1. Maritime Trial in Genoa

The Istituto Idrografico della Marina (IIM) and ESA conducted the first EGNOS maritime trials in Genoa using signals from the EGNOS System Test Bed (ESTB) in February 2000. The IIM is, among other tasks, responsible for hydrographical surveying in the waters under Italian responsibility as well as investigating navigation systems for the Italian Navy. It is interested in EGNOS as a cost-effective alternative to local area differential and commercial services.
Its ship, MIRTO (Fig. 10), was equipped with four different satellite systems: Natural GPS (NGPS), Local Area Differential GPS (LAD), EGNOS, and Long Range Kinematic GPS (LRK).

Figure 10 - "Mirto" used during the Genoa trials

EGNOS met the hydrographic and maritime requirements during the trials for the following operations:

- Hydrography;
- Coastal and precision navigation;
- Port entrance and exit operations; and
- Use of electronic navigation support (ENC).

EGNOS offers the following attractive benefits for hydrographical operations:

- EGNOS is accurate enough for ordinary hydrographical surveys (i.e. excluding harbours, berthing areas and associated channels with minimum under-keel clearances);
- EGNOS versatility and performance (suitable for Order 1 large scale surveys) means that chirographers do not need to establish geodetic points on land, thus minimising the logistic support required; and
- The use of Geostationary satellites for broadcasting the EGNOS corrections overcomes the range limitations of the VHF or UHF communications links used by many DGPS and LRK systems.

EGNOS demonstrated its suitability for both coastal navigation and coastal approach operations. The availability of EGNOS receivers at similar prices to current GPS receivers will encourage its acceptance as an alternative positioning system in the Mediterranean.

6.2. Land-mobile trials in Turin

ESA and the Centro Ricerche Fiat (CRF) performed the first EGNOS land-mobile trials to coincide with the Intelligent Transport Systems conference in Turin in November 2000. The trials were carried out at the Fiat Safety Centre near to Turin.

An EGNOS receiver was installed in a car and linked to a PC running digital mapping software (Fig. 11). The car drove around the test track, capturing data. A reference trajectory was obtained from a digital map based on DGPS. An accuracy of 1-3 metres was achieved using an EGNOS receiver, and accuracy plots from the ESA project office in Toulouse indicated the relative consistency of EGNOS compared with GPS, even with Selective Availability de-activated.
EGNOS can make an important contribution towards many of the key areas for progress identified during the conference:

- A minimum common functionality template;
- Interoperable electronic fee collection;
- Adoption of best practices from other main modes of travel; and
- The development of a safety policy framework within which applications can be developed, tested and brought to the market.

Figure 11 – Fiat car used for the Turin tests

EGNOS is a strong contender in any market based on accuracy/Euro, and is highly desirable in a market where integrity/quality will become an important differentiator. Including EGNOS functionality enhances performance with little or no cost impact.

6.3. Marine trials in the Aegean Sea

Ktimatologio and ESA conducted an EGNOS trial on the "Blue Star Aegean " in March 2001 in the framework of the European Commission's GALA project. The aim of the trials was to identify and demonstrate an accuracy and integrity performance equivalent to that expected from the future Galileo system. However, EGNOS has the potential to bring significant benefits to maritime users in terms of safety in an area that currently lacks the marine radio beacon differential GPS systems available in other parts of Europe.

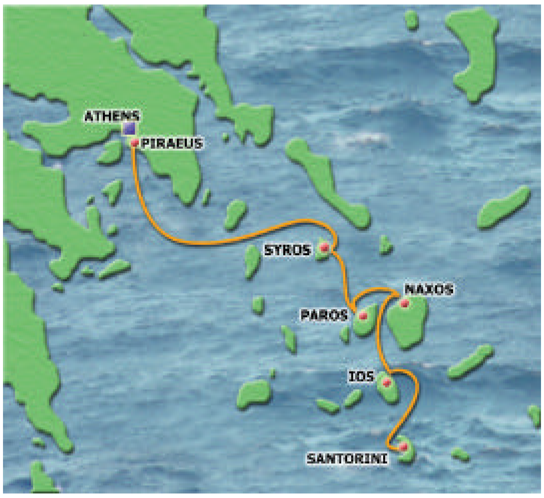

Figure 12 – Route of the "Blue Star Aegean"

The trial took place on one of the ship's normal voyages, starting at Piraeus (Athens' main port) with visits to Syros, Paros, Naxos, Ios and Thera (Santorini) (Fig. 12). These trials used the ESTB signal (with the Mediterranean Test Bed stations connected to the ESTB for the first time) in a number of different navigation modes: open sea, coastal approach and port entrance.
The trials were based on the use of three receivers:

- "Natural" GPS;
- EGNOS; and
- Real-time kinematic for the first part of the voyage.

The accuracy performance was assessed at 1-3 m, and the integrity benefits were demonstrated by plotting the protection level on the chart.
This high-level trial stimulated significant interest from a number of Greek Government departments as well as the Greek Navy. Detailed results, including a video, are expected shortly.

6.4. Flight trials at High Latitudes

A set of flight trials, designed to stress strength high latitude availability during critical approach and departure operations, were performed during March 2001. These were conducted by the British National Space Centre (BNSC), the Defense Evaluation and Research Agency (DERA) and the National Air Traffic Services (NATS).

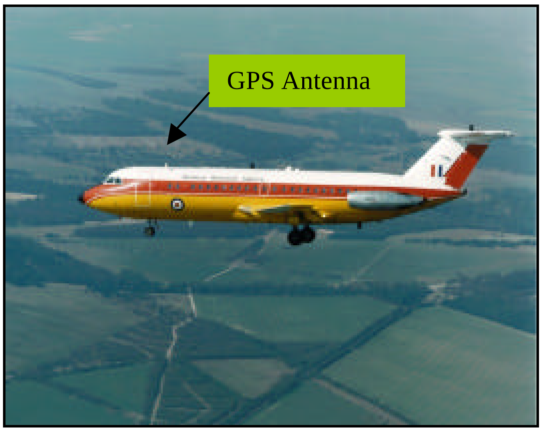

Figure 13 - DERA BAC 1-11 Flying Laboratory

A Dera BAC1-11(200) "flying laboratory" (see Fig. 13) was equipped with two aviation EGNOS receivers. The ESTB Signal from AOR-E was used during these tests.

During the tests a signal availability of 99.68% was achieved. There were no losses of availability during the approach or departure operations. The results are quite encouraging, indicating that high latitude masking should have little impact on flight operations once EGNOS procedures have been designed and the three EGNOS AOC GEOs are operational.

6.5. GNSS Application development contracts

Following the release of two tender actions under the ESA Artes-5 programme, ESA is placing six more contracts concerning Global positioning and Navigation Satellite System (GNSS) service developments. All activities include several months of demonstrations in quasi-real environments, making use of the ESTB and involving normally the application developer as well as the potential service provider.

The new contracts include the demonstration of ten individual applications. Six demonstrations concern the dissemination of the EGNOS signal by terrestrial means, for maritime, civil aviation as well as for dangerous goods and personal protection services in urban areas. Use will be made of existing terrestrial communication or other networks including VHF and the forthcoming mobile telephone network service GPRS infrastructures.

Four other demonstrations are to promote the introduction of GNSS in the rail sector as part of the forthcoming European Rail Traffic Management System (ERTMS). Initially, emphasis will be on low-density rail routes but two specific developments also aim at the introduction of satellite position determination on high-density rail routes.

The activities have been co-ordinated with parallel initiatives of the European Commission. Furthermore, relevant user organisations are being consulted on specific requirements such as standardisation.

6.6. Other on-going Trials

By the time of writing this paper (August 2001), the following additional EGNOS trials (as known by the authors), are planned to take place during second half 2001:

- Precision farming trials in UK, conducted by ESA.
- ESTB tests in Middle East involving ENAV, the Italian air traffic service provider, Telespazio and ESA
- Tests in Dakar (Senegal) using the ESTB expansion ECUREV service.
- Flight trials at Nice (France) aiming at investigating GNSS/EGNOS aircraft-guidance performance along curved approach procedures and the correlation between static and dynamic performances. These are organized by EUROCONTROL with the technical support of ESA, DGAC and NLR.

7. SUMMARY

The ESTB is now providing a pre-operational signal in space, allowing a high level of positioning accuracy above Europe. It supports four main domains:

1. Industrial activities for the development of EGNOS: assessment of the overall system and the mission performances to establish confidence in the system design and that the final accomplishment of the mission requirements can be reached.

2. Validation of algorithms during EGNOS implementation phases, including subsystems testing with real data.

3. Preparation of the EGNOS operational phase: In the year 2000, the ESTB was used for static and in-flight data collection activities, and for 2001 new operational activities are scheduled.

4. Demonstrations: the ESTB plays an important role in demonstration activities not only for aviation but also to prove EGNOS functionality for other modes of transport. Multi-modal trials, some of them addressed in this paper, have already been performed involving aviation, land, maritime, and rail users.

The performances obtained with the ESTB are very impressive. Being the ESTB a prototype and reduced version of the final EGNOS AOC operational system, these results stress European reliance on the final operational EGNOS performances.

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