ESTB NEWS

Volume 2, Issue 2, September 2002

Contents

Editorial

The EGNOS development is progressing well. EGNOS RIMS and Master Control Centres will shortly be deployed, allowing us to start the countdown to EGNOS operations. The first real EGNOS signals are expected during the middle of 2003, and the Operational Readiness Review (ORR) is scheduled for April 2004. The first EGNOS services will be available once the ORR has been concluded, and ESA has recently issued a Request for Proposals for both EGNOS Operations and EGNOS Service Provision to ensure their prompt introduction.

In this issue, you will find articles describing SISNeT trials in Finland and ESTB trials at Dakar in Senegal. You will also hear about the potential for EGNOS in the rail sector. Elsewhere, there is an explanation of the EGNOS signal structure, and you will see how key upgrades to the ESTB have recently improved performance.

The EGNOS Signal Explained

The ESTB has been broadcasting a pre-operational EGNOS signal since February 2000. When operational in 2004, EGNOS will deliver improved levels of accuracy, integrity and availability to European aviation, maritime and land users.

This article outlines the differences between Differential GPS (DGPS) and EGNOS, describes the EGNOS signal structure, discusses how an EGNOS/GPS receiver processes the signal, and concludes by looking at the benefits of the EGNOS signal.

Why is the EGNOS signal different from DGPS?

DGPS was developed to enhance GPS accuracy. Conceptually, range errors estimated by a static reference station are broadcast to users where they are applied as corrections. The accuracy may be as good as 1m, but it is limited by the user/reference station distance, the need for common-view satellites, and receiver algorithms. Multi-reference station solutions can overcome some of these problems. Users also have to purchase an additional receiver to use the corrections.

(continued on page 2)

From Paris to Dakar... with EGNOS

The Africa and Indian Ocean (AFI) States have adopted a strategy to implement GNSS for aviation in their region. This has been approved by the International Civil Aviation Organisation (ICAO).

The first phase of this strategy comprises the deployment of mobile ESTB RIMS in the AFI region to extend the ESTB coverage. The improved EGNOS signal will then be used to demonstrate an EGNOS APV 1 service over the AFI land-masses.

An initial activity in Dakar has recently been launched by the Galileo Interim Support Structure (GISS) together with ASECNA – the Agence Pour La Sécurité De La Navigation Aérienne En Afrique. This aims to provide an APV 1 signal in the Dakar area and to verify the performance in static and dynamic conditions.

(continued on page 3)

EGNOS: Potential Benefits for Railway Applications

At the second ESTB Workshop in November 2001, the Czech SZT Laboratory of Intelligent Systems described how they had been using the ESTB in their APOLO project.

They installed GNSS and other sensors on two locomotives, and established track-side infrastructure to provide a source of "truth". Trials were then performed between two stations: Hradec Králové and Káranice. The ESTB delivered 95% horizontal accuracies of better than 1.5m, an improvement on GPS and comparable with local area DGPS. This

(continued on page 3)

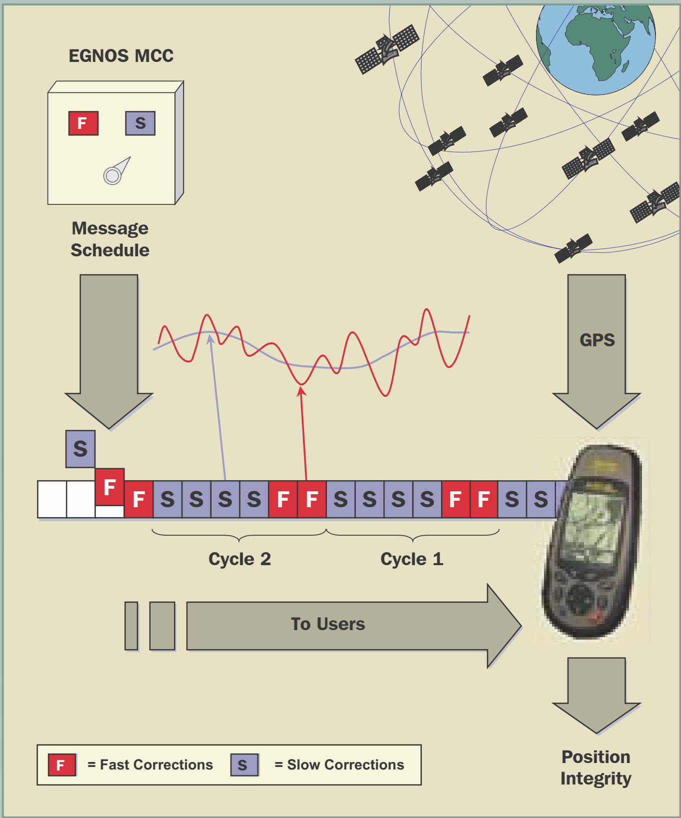
Czech Republic APOLO Railway Trials

First Trials of SISNeT in Finland

SISNet allows users to access the EGNOS signal-in-space over the Internet in real-time, improving the availability of EGNOS data in urban and other challenging environments. The concept was validated internally by ESA in August 2001, and the first SISNeT services were provided over the Internet in February 2002.

(continued on page 3)

The EGNOS Signal Explained: *(continued from front cover)*



EGNOS Data Processing

EGNOS is being been developed to enhance GPS accuracy, availability and integrity (quality of service) over and beyond the European region. 34 Reference and Integrity Monitoring Stations (RIMS) around Europe monitor GPS and relay their data to four Master Control Centres (MCCs). These generate a single set of integrity data and Wide Area Differential (WAD) GPS corrections for Europe. The latter comprise terms to correct for each satellite's clock and ephemeris errors as well as errors due to the ionosphere. The integrity data and WAD corrections are modulated on a GPS look-alike signal and broadcast to users from three geostationary satellites. The resulting performance (close to 1m across Europe) is independent of user/reference station distance. Users will benefit from enhanced availability due to the three additional ranges, as well as not needing to purchase a separate receiver to use the corrections.

The EGNOS message structure is different to DGPS because it needs to accommodate both the WAD corrections and integrity information that provides a 6-second time-to-alarm.

What information does EGNOS broadcast?

EGNOS uses the same frequency (L1 1575.42 MHz)) and ranging codes as GPS, but has a different data message format. Sixteen different message types have so far been defined to broadcast integrity data and WAD corrections. The message schedule follows a 6-second duty cycle. This is structured both to prioritise the 6-second integrity time-to-alarm and to minimise the time for EGNOS initialisation.

Integrity is provided at two levels: coarse *use/don't use* for all satellites in view of the service volume (including the GEOs); and two parameters – σ^2_{UDRE} and σ^2_{UIVE} – that are statistical estimates of the satellite and atmospheric errors remaining after applying the WAD corrections. These are used to compute a certified error bound for the position solution in an integrity assessment.

Fast and slow WAD corrections model the temporal decorrelation of the different error sources. The fast corrections model rapidly changing error sources include satellite clock errors. The slow corrections model more slowly changing error sources including long-term satellite clock drift and ephemeris errors. Ionospheric delays are provided at pre-defined grid points.

How does a user receiver process these data messages?

Processing the corrections is quite complex both because the messages have been designed to minimise the bandwidth requirements and because they need to account for updated GPS navigation information.

The receiver estimates corrections for satellite clock and ephemeris errors using the fast and slow satellite data messages. It has to account for both range-rate effects between successive fast corrections and performance degradation if a message is missed. The σ^2_{UDRE} term characterises statistically the residual range errors after having applied the fast and slow clock and ephemeris corrections.

The receiver predicts ionospheric delays for each range in three steps: it estimates where the satellite – receiver range pierces the ionospheric grid; the vertical delay at the pierce point is then interpolated from the surrounding grid points; and finally this is applied to the range measurement. The σ^2_{UIVE} term is applied to the range vector where it characterises statistically the residual ionospheric errors. Tropospheric errors may be mitigated using a simple model related to the receiver's position and the day number in the year.

EGNOS receivers compute a certified error bound for the position solution based on data broadcast by the GEO satellites, the user/satellite geometry, and the probability of integrity non-detection. This was described in the September 2001 issue of ESTB News.

So what are the benefits of the EGNOS signal?

The EGNOS signal is compliant with international standards for satellite based augmentation systems. As such, EGNOS will be interoperable with similar systems in the US (WAAS), Japan (MSAS), Canada (CWAS), and India, contributing to a true worldwide seamless navigation service.

The EGNOS signal design is based on GPS. Consequently, a GPS receiver with minimal hardware modifications can track the EGNOS signal. This has two benefits: EGNOS provides additional range measurements that enhance availability; and EGNOS corrections can be used without purchasing a separate receiver.

Finally, EGNOS provides both enhanced accuracy and integrity (quality of service). The pre-operational EGNOS test bed is already delivering one-metre accuracy (similar to DGPS) that is independent of user/reference station distance. The integrity will give users additional confidence in the total system, alerting them within six seconds when something goes wrong.

Type	Comment	Type	Comment
0	Don't use this SBAS signal for safety applications	17	GEO satellite almanacs
1	PRN Mask assignments	18	Ionospheric grid point masks
2-5	Fast corrections	24	Mixed fast/slow error corrections
6	Integrity information	25	Slow satellite error correcions
7	Fast correction degradation factor	26	Ionospheric delay corrections
9	GEO navigation message	27	SBAS service message
10	Degradation parameters	63	Null message
12	SBAS Network Time/UTC offsets		

EGNOS Message Types

The First Trials of SISNeT in Finland: *(continued from front cover)*

SISNeT Trials Route

The first dynamic SISNeT trials took place near Helsinki, Finland, in June 2002. Helsinki was chosen because of its high latitude with less favourable GEO visibility conditions (the Inmarsat Atlantic Ocean Region East satellite has an elevation angle of about 20 degrees elevation), and because there is a strong mobile telecommunications background in Finland.

The Finish Geodetic Institute started developing a SISNeT receiver in March 2002. Funded by ESA, this receiver is based on personal digital assistant (PDA) integrated with a GSM/GPRS modem and a low-end GPS receiver. Software was written to apply the EGNOS corrections in the position domain and then to plot the corrected position on a digital map.

The SISNeT receiver was tested in static and dynamic modes. SISNeT performed very well, demonstrating consistently improved performance with respect to GPS. The dynamic tests on a 50km road loop at maximum speeds of 100 km/h were very encouraging. The 9.6 kbps GSM data-link was available 80% of the time, delivering a horizontal performance around 2m. This bodes well for the future.

There is considerable interest in SISNeT worldwide. As a result of this, ESA has initiated a number of projects that will be carried out in 2002. These include: improvements to the SISNeT network in terms of performance and security; software developments (e.g. drivers) to allow the use of existing GPS commercial software packages (e.g. map routers) with SISNeT enhanced PDAs; and demonstrations of SISNeT for blind pedestrians and in cars and buses.

SISNeT Trials Equipment

EGNOS: Potential Benefits for Railway Applications: *(continued from front cover)*

is expected to facilitate improvements in supervision systems for dispatchers and to support signalling systems for low-density lines.

ESA and the EC have since instigated a number of railway demonstrations that make use of the ESTB: ECORAIL, LOCOLOC, INTEGRAIL and RUNE.

In the ECORAIL project, a team led by Technicatome (France) is looking to demonstrate the safe use of EGNOS at level crossings. The benefits include cost savings for the railway operators by reducing the amount of track-side wiring, increased traffic flow for motorists by optimising closing times, and a reduction of car exhaust emissions due to shorter waiting periods.

LOCOLOC (Locomotive Location) is a project to develop an innovative, safe and cost-effective system for train navigation based primarily on GNSS. The project team is being led by Alstom (Belgium). This builds on a project funded by the European Commission – LOCOPROL – that aims to develop a low-cost satellite-based signalling and protection system for low density traffic lines.

One of LOCOLOC's major tasks is to build a safety case for the system so that they can demonstrate that GNSS is safe for low-density train navigation. They need to show that the required level of safety can be met by EGNOS integrated with other sensors to overcome coverage gaps.

LOCOLOC has the potential to deliver cost savings by transferring the safety functions from the track to the train, thus allowing expensive track-side infrastructure to be decommissioned.

The INTEGRAIL project is being led by Kayser Threde (Germany), and is looking at improving the use of EGNOS on low-density traffic lines following European Rail Traffic Management System (ERTMS) requirements. The team will be developing four prototype integration systems based on EGNOS and inertial systems. These will be deployed on two trains where they will provide information to both the driver and the control system. The benefits include: cost-savings to the rail infrastructure provider by minimising track-side eqiupment; cost-savings to train operators by harmonising signaling systems used in Europe; and improving journey times by keeping the same locomotive when a train crosses national boundaries.

In the RUNE (Railway User Navigation Equipment) project, a team led by Laben (Italy) is using EGNOS as part of an integrated solution to improve the train driver's situational awareness. Today, he does not receive advanced warnings of the status of signals or speed restrictions and, as a result, it is harder to deploy drivers on new lines. RUNE integrates EGNOS/GPS with other on-board positioning sensors, and signalling and speed restriction information from a central control centre. This will significantly improve safety as a result of improved situational awareness, and should also speed up the deployment of drivers on new routes.

From Paris to Dakar... with EGNOS: *(continued from front cover)*

A transportable RIMS was installed at Dakar and connected to the ESTB in July 2002. A static user receiver was also installed at the same time. The first preliminary results indicate that an APV1 service is available about 95% of the time, and that vertical positioning accuracies of between 5 and 6 metres (95%) are being achieved. Investigations are being undertaken to improve the availability.

The dynamic flight trials will be conducted at Dakar at the end of November following preliminary system validation tests at Bordeaux in October.

This is the first time that an ESTB RIMS has been deployed to deliver a service outside the core European Civil Aviation Conference (ECAC) area. Deploying the Dakar RIMS has been beneficial not only because it provides a service in the Dakar region, but also because it has enhanced the performance of the ESTB in the Mediterranean (from APV 1 to APV2) and further improved the performance of the ESTB in the Canary Islands.

Performance Parameter		APV 1	APV 2
Accuracy (m, 95%)	Horizontal	16/220	16
	Vertical	20	8
Integrity	Time to Alarm (s)	10	6
	Integrity Risk (Per Approach)	$1\text{-}2 \times 10^{-7}$	
Continuity	(In any 15 seconds)	$1\text{-}8 \times 10^{-6}$	
Availability		0.99 to 0.99999	
Associated RNP		0.3/125	0.03/50

Aviation Performance Requirements

Behind the Scenes: ESTB Upgraded to Improve Performance

The ESTB Central Processing Facility software has recently been upgraded to improve reliability and compliance with RTCA DO229B/C standards.

The new features in this upgrade include additional message types (6, 17 and 24) and fast corrections for the geostationary satellites. Users will have noticed some signal variability during the first half of July caused by system tests, but this new release will be used continuously from mid-September.

A new RIMS was installed at Dakar in June (see "From Paris to Dakar with EGNOS" in this issue) to support tests in North Africa. Progress has also been made towards the permanent connection of the Mediterranean Test Bed to the ESTB. This will augment the current ESTB ground segment with two Italian RIMS and will allow the broadcast of ESTB signals through the Inmarsat Indian Ocean Region satellite. These enhancements will significantly improve the ESTB performance over the Mediterranean region.

Improvements in the ionospheric delay processing and the RIMS coordinate accuracy have enhanced the ESTB performance. During July 2002, receivers at Toulouse met aviation's APV 1.5 requirements 99.4% of the time and APV 2 requirements 97.43 % of the time. This translates into 95% accuracies of 1.5m horizontal and 2m vertical.

News from Brussels

The European Commission's Sixth Framework Programme on Research and Technology Development will contribute to the implementation of the European Strategy for Space. As part of this, it will address Galileo and co-ordinate efforts with ESA and Member States.

The Sixth Framework documents identify core research areas for Galileo: applications, user segment, standardisation and certification, and deployment of local augmentations. The programme will probably be implemented in three successive annual calls for proposals, starting at the end of 2002.

The Sixth Framework projects will be managed directly by the Galileo Joint Undertaking. They will contribute to market take-up of navigation, positioning and timing technologies in diverse sectors including transport, agriculture, telecommunications, and scientific research. EGNOS will be a key enabling technology in many cases. The focus on market take-up stresses the need to commercialise project developments.

Frequently Asked Questions

Q1: Do I still need EGNOS now that Selective Availability (SA) has been removed?

A1: Removing SA has significantly improved accuracy. The US GPS Standard Positioning Service (SPS) specification commits to 95% accuracies of 13m horizontal and 22m vertical, but many users are experiencing horizontal accuracies better than 5m (95%). However, removing SA has not improved GPS integrity. EGNOS will enhance GPS accuracy to around 1m (95%). Most importantly, it will also deliver an integrity service that provides a certified error bound for the GPS position solution, and alerts users within six seconds when out-of-tolerance events occur. EGNOS enables GPS to be used for safety-of-life applications. Prudent users with commercial or safety-related applications will value the added confidence provided by guaranteed EGNOS services.

Q2: GPS is being modernised. How will this effect satellite based augmentation systems (SBAS, e.g. EGNOS)?

A2: SBAS technical teams are currently assessing the potential benefits that GPS modernisation offers to SBAS systems. Modernisation will augment GPS with new signals, while ensuring backward compatibility with the existing GPS Standard Positioning Service. It will also open up new opportunities for EGNOS. While modernisation is ongoing, EGNOS will continue to deliver services that meet its performance requirements. When concluded, EGNOS will provide even better services to larger areas, with greater resistance to interference. Users can invest in EGNOS today, knowing that they will continue to benefit from the current level of performance long after modernisation has taken place.

Help Us to Help You

This ESTB Newsletter has been produced by Booz Allen Hamilton under contract to ESA and is made available by the ESA EGNOS Project Office for general promotion purposes with the understanding that no rights can be derived from the information contained here. The Editorial Team welcomes your comments, inputs and suggestions for the next issue.

Please send emails to ESTB-News@esa.int

Links and Contacts

ESA Navigation Web Page:
http://www.esa.int/navigation

ESA EGNOS Web Page:
www.esa.int/EGNOS

ESA ESTB Web Page:
www.esa.int/ESTB

ESA ESTB Help Desk:
ESTB@esa.int

ESTB News:
ESTB-News@esa.int

ESA SISNeT Web Page:
www.esa.int/navigation/sisnet

ESA Galileo Web Page:
www.esa.int/Galileo

ESA Artemis Web Page:
www.esa.int/artemislaunch

EC Galileo Web Page:
www.europa.eu.int/comm/energy_transport/en/gal_en.html

FAA GPS Product Team:
gps.faa.gov

USCG Navigation Center GPS Page:
www.navcen.uscg.mil/gps

Forthcoming Events

ION GPS 2002, Portland, Oregon, USA,
25-27 September 2002, www.ion.org

NAV 02, London, England,
5-7 November 2002, www.rin.org.uk

NAVSAT 2002, Nice, France,
12-15 November 2002,
www.navsat-show.com

GNSS 2003, Graz, Austria,
22-25 April 2003,
www.gnss2003.com