ESTB NEWS

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Editorial

During the last twelve months, ESA has taken great strides in its mission to attract users for EGNOS. We have set up the ESTB Help Desk, developed a useful web resource, and published the ESTB News. We keep hearing about new opportunities for EGNOS. In this issue you can read about using EGNOS for precision farming and on helicopters. We also describe some new pilot projects that have just been launched by the European Commission. The fruits of our labours were apparent at the ESTB Workshop held in November. Over 120 delegates listened to presentations that stressed system performance and user benefits. We summarise the proceedings in this issue. Elsewhere in this issue you will find a description of ESTB operations and an article that explains why EGNOS models the ionosphere.

We are anticipating a fascinating and busy year for EGNOS: the EGNOS Critical Design Review takes place in January - the final review before implementation and deployment; the ESTB will deliver improved levels of performance and achieve 95% availability; its service extension capability will be used to support trials outside the EGNOS Core Area; and we are looking forward to the results of recent EGNOS trials.

Finally, we would like to take this opportunity to wish you all a happy Christmas and a prosperous new year.

EGNOS Passes Helicopter Test With Flying Colours

Helicopters are the utility vehicles of the sky, *par excellence*. Their unsurpassed manoeuvrability together with their load carrying capacity means that they are used by both the civil and military sectors for many tasks including air ambulances, search and rescue, and moving people and freight. The opportunities for EGNOS during the en route and precision approach phases of civil applications are clear, but there may also be prospects in the government sector as a result of the peace dividend.

A mid-life avionics update of the Belgian Army's Agusta A109 helicopter provides an opportunity to assess different satellite navigation systems. The Army's activities are directed primarily towards United Nations

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European Commission Launches Pilot Projects

DG TREN has recently launched four pilot projects that will support the growth of GNSS applications in Europe. The scope of these projects is very wide ranging: INSTANT Olympic will trial GNSS-based infomobility and safety services during Olympic events; NAUPLIOS will demonstrate GNSS in the maritime navigation sector; GALLANT will look at GNSS to enhance road transport safety and mobility; and GADEROS will highlight the uses of GNSS in the rail sector. A further project, POLARIS, will develop a software tool to provide a link between the system designers and users.

These projects will last for two years. Technical support and co-ordination will be provided by the Galileo Interim Support Structure (GISS) under ESA and EC management.

From Satellite to Silo: Precision Farming with EGNOS

In August 2001, a Claas combine harvester was fitted with an EGNOS receiver to assess its benefits for precision farming.

The European Commission's GALA study summarised the pressures faced by farmers. Precision farming helps the farmer to manage arable variability and to maximise

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Precision Farming with EGNOS

EGNOS and the Ionosphere Explained

EGNOS improves accuracy by broadcasting wide area differential (WAD) corrections to users. Unlike conventional DGPS corrections that provide one term for each satellite, the WAD corrections includes terms for each error component including an improved ionospheric model for single frequency GPS users.

This article outlines the effect of the ionosphere on GPS measurements, introduces the complex and variable nature of the ionosphere, and presents different mitigation strategies, before emphasising the benefits of EGNOS for all GPS users.

Why do we need an improved ionospheric model?

The effects of the ionosphere can be breathtakingly beautiful: the *aurora borealis* or *northern lights* are shimmering sheets of light that occur when charged particles enter the Earth's atmosphere at high latitudes.

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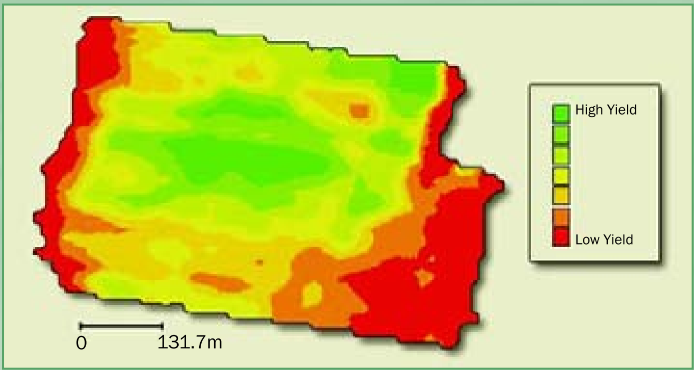
Precision Farming with EGNOS *(continued from front cover)*

financial advantage while operating within environmental constraints. Put simply, it turns one 100-hectare field into 100 one-hectare fields to help to optimise the yield/cost ratio by applying a custom prescription of chemicals to small areas. Precision farming can deliver significant cost savings to larger farms, but the high entry cost of precision farming



Wheat Harvest Yield Map

is a barrier, and many farmers have cash-flow problems. Farmers need cost-effective solutions including retro-fitting sensors, and this provides the motivation for using EGNOS.

EGNOS will provide farmers with a new and cost-effective source of differential signals and offers important operational benefits: it has better European coverage than the marine radio beacons; it is free of direct user charges; and removing a separate radio for DGPS corrections cuts the cost of the user equipment.

Booz Allen Hamilton, under contract to ESA, joined up with LH Agro (UK) Ltd and CBI Ltd to demonstrate the use of EGNOS for yield mapping. The demonstration was run at St Ives near Cambridge in England on 21st and 22nd August 2001. Both an EGNOS receiver and a beacon receiver were installed on the combine harvester. A 36.5 hectare field full of wheat was harvested, eventually providing an income of about 38 k€ to the farmer.

The data processing scheme was tuned to exploit existing hardware and software. The beacon and ESTB positioning solutions agree to 3 metres (95%) once the antenna offsets and reference frame errors were removed. The final yield map is based on fitting contours to sample points based on smoothed data. Areas with good and bad yield can be seen clearly.

We see EGNOS making a positive contribution, extending the benefits of precision farming. It is our view that combing the operational benefits of EGNOS with advances in receiver technology will drive down the cost of the positioning element of precision farming. This vision sees the benefits of precision farming technology being extended to more farmers with smaller farms, producing cost savings, enhancing economic competitiveness, and helping to improve the environment.

ESA's 2nd ESTB Workshop Stresses User Benefits

Over 120 people attended ESA's second ESTB workshop at Nice on 12th November.

The morning session concentrated on system performance and evolution. The ESTB currently meets aviation's APV I and APV II requirements with an availability of 100% and 80-90% respectively. Studying the accuracy of the ESTB corrections is delivering interesting results, and we can expect 1σ horizontal and vertical accuracy to be improved to around 0.5 m and 0.7 m. This is very encouraging for both the system developers and users.

The ESTB is evolving with improved performance, improved availability and a service extension capability. The latter will be used to support trials in South America, North Africa and the Middle East.

The afternoon session complemented the system information by presenting the results of EGNOS trials and demonstrations. These included aviation trials in France and Norway, helicopter trials in Belgium, maritime trials in Greece, rail trials in the Czech Republic, land mobile trials in Italy, and precision farming trials in England. Laurent Gauthier, ESA's EGNOS project manager, summarised the successful workshop in his closing comments, "The ESTB performance is outstanding, and it is my impression that EGNOS will provide an augmentation service that will deliver benefits to users with a diverse range of applications".

All the workshop presentations are available in the publications section on the ESTB web site.

EGNOS Passes Helicopter Test with Flying Colours *(continued from front cover)*

peace-keeping, mainly in the Balkans, and their aircraft have to comply with civil aviation regulations during peace-time. Consequently, civil systems may provide a viable solution, and this has prompted the Belgian Royal Military Academy to evaluate EGNOS.

In August 2001, the Royal Military Academy fitted an Agusta A109 helicopter with a dual frequency EGNOS receiver and a second dual frequency survey receiver to provide a reference trajectory. A single antenna was mounted on top of the tail. Two static reference stations were deployed for the trial, allowing differential and real-time kinematic trajectories to be computed.

Agusta A109 Helicopter

The Agusta flew a sortie comprising three distinct sections: a steady liaison flight; a high-speed tactical flight along river valleys in southern Belgium; and stomach-turning "special" manoeuvres designed to stress the receiver hardware. These included 360 degree turns with banking angles up to 60 degrees, and parabolic trajectories with periodic positive and negative vertical accelerations. Accelerations greater than 2g were experienced!

The performance of EGNOS is generally expressed in terms of accuracy, integrity and availability. During the liaison section of the sortie, the EGNOS accuracy was stated as 1.2m (1σ), better than both the DGPS and GPS solutions.

Integrity requirements are specified according to the phase of flight and integrity is computed using data broadcast by the EGNOS satellites. The precision approach integrity model was applied throughout the entire flight … a truly demanding safety requirement.

The trials reported that the EGNOS AOR-E satellite was tracked for 98.3% of the time. Losses of availability can be accounted for by high banking angles causing airframe masking during the special manoeuvres. The availability would be higher if the helicopter maintained the liaison phase of flight and all three EGNOS satellites were operational.

These tests have shown how EGNOS can deliver operational benefits to helicopters in terms of performance and safety. There are also clear cost savings with respect to conventional DGPS resulting from removing the communications interface and overcoming the need for a dedicated ground segment.

Looking to the future, the challenge is to explore how these benefits can be extended to current users by developing EGNOS procedures for helicopters.

EGNOS and the Ionosphere Explained *(continued from front cover)*

The effects can also be devastating: solar storms can cause widespread power blackouts, disrupt navigation systems and radio communications, and destroy the payloads on commercial satellites.

GPS broadcasts timing codes and data on two frequencies, L1 and L2. The magnitude of the ionospheric effects on GPS measurements is dependent on the signal frequency and the level of ionospheric activity. The maximum vertical delay on GPS L1 measurements is about 15 m, but low elevation angles increase this by a factor of three. The ionosphere may also cause intermittent signal fading, in severe cases causing losses of availability.

We need a model to reduce these errors. The ionospheric model broadcast by GPS corrects for only 50% of the delay, and this is now the largest error source in a GPS error budget. This is why EGNOS is broadcasting an improved model for single frequency users.

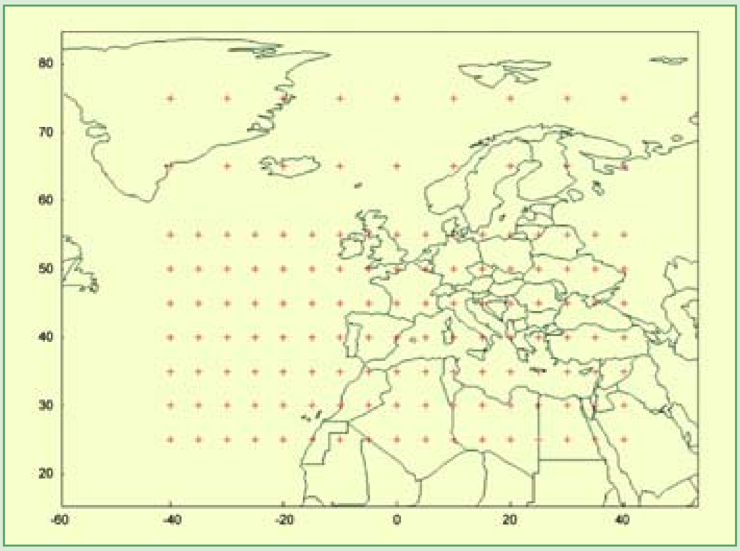
What is the ionosphere?

The ionosphere is the ionised part of the atmosphere that extends from an altitude of around 50 km to more than 1000 km. There are a significant number of free electrons and positive ions although it is electrically neutral. The level of ionospheric activity is generally described in terms of electron density. The interaction of solar radiation or charged particles with the Earth's atmosphere drives ionospheric behaviour.

The structure of the ionosphere is very complex. The vertical structure comprises four layers or regions (D, E, F1 and F2). The electron density of each layer varies with time of day, and is a maximum in the F2 layer at an altitude of around 350 km.

The different ionospheric charging mechanisms allow us to predict the temporal and spatial variability of the electron density with some degree of confidence. Predictable temporal variations include: an eleven-year solar cycle, the Earth year, the 27 day solar rotation, and the 24 hour Earth rotation. The Earth's magnetic field is the reference for spatial variability, and some effects are more prevalent in specific regions - for example, the fountain effect near the Equator and polar cap absorption at the poles.

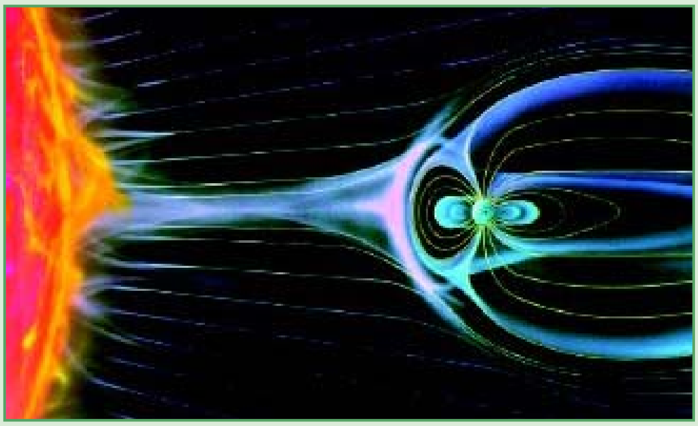
However, it is the unpredictable variability that is critical for many users, especially those requiring high levels of performance. Sudden ionospheric disturbances raise the electron density and cause signal fading at some frequencies. Travelling ionospheric disturbances can move at speeds up to 1000 metres per second, causing sudden changes in the electron density. In addition, ionospheric scintillations, which manifest themselves as rapid variation of phase and amplitude of the received signal, can cause GPS receiver to loose lock, thereby interrupting the reception of one or more satellites.



EGNOS Ionospheric Grid Model

How can we mitigate the effect of ionospheric propagation?

The most accurate and most expensive strategy is to combine carrier or pseudo-range data from dual frequency receivers to eliminate the ionospheric delay. The critical issue is decoding the encrypted Precise (P) code. Authorised users have keys for the encryption, and hence can use this approach. Some manufacturers have developed techniques that allow civil receivers to access both frequencies, but these receivers tend to be rather expensive. Later this decade, GPS will transmit a second civil code on L2, and that will make this approach more widely available. Nevertheless, we must stress that dual frequency users are subject to signal fading and L2 is not a protected frequency for safety-related application. In severe conditions their receivers may revert to single frequency, and they will need a model for the ionosphere.


The Solar-Terrestrial Environment

Single frequency receivers are less expensive but an ionospheric model is required, and there is a clear trade-off between accuracy and economies in terms of the number of parameters broadcast to users.

The GPS model users errs towards economy. Each satellite transmits eight terms that represent the global ionosphere in terms of the amplitude of the vertical delay and the period of the model. They are updated at least once every six days, and provide at least a 50% reduction in the single-frequency user's error. This cannot hope to model the short-term regional ionospheric effects.

The EGNOS model optimises both accuracy and integrity by providing corrections for specific grid points in the European service area. Grid Ionospheric Vertical Delays (GIVDs) improve accuracy, and Grid Ionospheric Vertical Errors (GIVEs) guarantee integrity. The density of the grid points has been chosen to cope with expected spatial variations in the ionospheric vertical delay during periods of high solar activity. The parameters are updated at least every five minutes, and the residual grid point ionospheric vertical delays are expected to be less than 0.5m.

So what are the real benefits of the EGNOS ionospheric model?

If you are a user with an expensive dual frequency receiver, you can overcome nearly all the delay effects, but you are still subject to signal fading. This could reduce your functionality to single frequency with large errors resulting from the GPS broadcast model.

When you choose EGNOS, you will see significant improvements in position accuracy compared with dual frequency GPS, but at a similar price to low-cost single frequency GPS. The improved ionospheric model also enhances availability for dual frequency users when they suffer from signal fading. Finally, you will also see improvements in integrity for safety-related applications, and this is driving the long-term need for EGNOS.

Behind the Scenes: Operating the ESTB

Operating the ESTB

ESA has overall responsibility for the ESTB, and has outsourced key activities to the French Space Agency (CNES) and the Norwegian Mapping Authority (NMA). The CNES co-ordinates the ESTB operational activities and runs the ESTB uplink and Euridis facilities in Toulouse. The NMA runs the ESTB central processing facility in Hønefoss.

WAD corrections and integrity data are generated at Hønefoss. These are then sent to Toulouse where they are mixed with GEO ranging data and then transmitted from the Aussaguel earth station to the Inmarsat AOR-E satellite for broadcast to users. Both ESTB facilities are staffed during normal working hours. During evenings and at the weekend the system runs automatically. The ESTB is currently being upgraded to achieve its target 95% availability in early 2002.

The teams also operate EGNOS receivers and analyse the system performance. Results of the analyses are made available to users through the ESTB web site. Users can also subscribe to a daily status report (email christophe.texier@cnes.fr).

Frequently Asked Questions

Q1: When will handover from ESTB to EGNOS occur, and will the ESTB service be interrupted?

A1: The handover from ESTB to EGNOS should be transparent to users with no interruptions of service. The current ESTB service is guaranteed until the middle of 2003 when EGNOS starts broadcasting. At that point the signal availability will be enhanced with the operational EGNOS system, and users will then experience further improvements in the service provided by EGNOS. Following the ESTB's success, ESA is thinking of extending ESTB operations beyond 2003 to provide a complementary system for specific testing purposes.

Q2: What is the current status of the EGNOS AOC development?

A2: The EGNOS AOC development is proceeding well according to plan. This year, we have seen successful Critical Design Reviews (CDR) for all the EGNOS subsystems, and we are expecting a successful EGNOS System CDR in January 2002. This will be followed by final production, deployment and validation of the EGNOS subsystems, leading to the Factory Qualification Review in early 2003 and the Operational Readiness Review in early 2004.

Forthcoming Events

NAVITEC 2001, ESTEC, Noordwijk, The Netherlands.
10-12 December 2001
www.estec.esa.nl/conferences/01c09/index

ION National Technical Meeting, San Diego, California, USA.
28-30 January 2002, www.ion.org

PLANS Position Location and Navigation Symposium 2002,
Palm Springs, California, USA 15-18 April 2002
www.ewh.ieee.org/soc/aess/plns/main

GNSS2002, Copenhagen, Denmark, 27-30 May 2002,
www.gnss2002.com

Farnborough International 2002, Farnborough, UK, 22-28 July 2002, www.farnborough.com

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

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www.esa.int/artemislaunch

EC Galileo Web Page:
www.galileo-pgm.org

FAA GPS Product Team:
http://gps.faa.gov

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