ESTB NEWS

Volume 1, Issue 2, September 2001

Contents

Editorial

Welcome to the second issue of the ESTB News. Much has happened since May, and this issue recognises both the successes and challenges of the EGNOS development during the last three months.

Two successful trials are reported in this newsletter: an aviation trial at high-latitudes that rewrites the rules about EGNOS availability; and SISNET, a novel approach for delivering the EGNOS messages over the Internet. Perhaps the greatest challenge is that of coaxing the Artemis satellite into operation following problems during the launch process. Artemis is due to play an important role within EGNOS, and we applaud the professionalism of the combined ESA/industry team that is recovering the Artemis mission. Elsewhere in this ESTB Newsletter you will find an invitation to the second ESTB Workshop, an article explaining integrity, and ESTB system news.

We hope you enjoy ESTB News. Please send us your comments, suggestions and inputs for further issues.

Artemis Satellite Recovery Continuing Successfully

Artemis is ESA's latest communications satellite. Besides advanced payloads for data relay and mobile communication, it carries a navigation payload for disseminating from 2003 onwards the EGNOS ranging, wide area differential correction and integrity signal for use by safety-critical transport and other navigation services.

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Integrity Explained

EGNOS will provide a European-wide, standardised and quality-assured augmentation service suitable for a diverse range of applications. Integrity is a key quality and safety parameter, alerting users when the system exceeds tolerance limits.

EGNOS will broadcast wide-area differential corrections to improve accuracy, and alert users within six seconds if something goes wrong (integrity).

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ESA Announces 2nd ESTB Workshop

Register at:
www.navsat-show.com
or by sending an e-mail to:
ESTB-News@esa.int
(please put "ESTB WS registration" as the subject and include contact details in the body of the message).

ESA's second one-day ESTB workshop will precede the "NavSat 2001" conference and will take place on 12th November at Nice in France. It should be particularly attractive to companies or users interested in exploiting GNSS for novel services and applications. Workshop topics will include an overview of the ESTB performance and its near-term evolution, details of EGNOS compatible user equipment, and the results of recent trials.

Participation is free of charge. Registration can be done over the Internet or via email. The deadline for registration is 12th October 2001.

Flight Trials Confirm EGNOS Signal Availability At High Latitudes

Aviation users have very stringent requirements for availability, and it is important to confirm that signal availability is maintained at high latitudes with low GEO elevations.

Aviation users have very stringent requirements for service availability - typically between 99% and 99.999% depending on the operational need. EGNOS service availability is dependent on maintaining connectivity between the user receiver and at least one of the EGNOS geostationary satellites (GEOs). Even using three well-spaced GEOs to help maximise signal availability, it is important to confirm that signal occultation at high latitudes does not result from terrain masking or airframe masking during the manoeuvres.

DERA's BAC 1-11 "Flying Laboratory"

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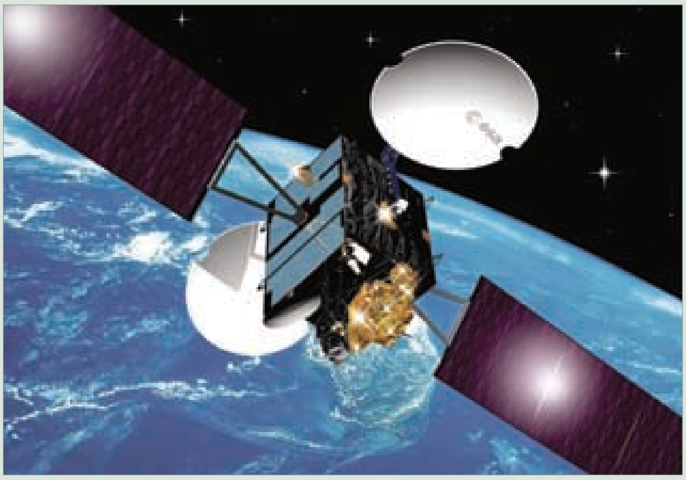
Artemis Satellite Recovery Operation Continuing Successfully *...(continued from front cover)*



The ARTEMIS satellite

Artemis was launched on 12th July on Arianespace Flight 142, but problems with the launcher's upper stage placed it originally in a lower than desired orbit. Since injection into that orbit, the spacecraft's behaviour had been nominal, allowing ESA and industry to rapidly adopt a recovery strategy that aims to take the satellite to the nominal geostationary position of approximately 36000 km, maximising the lifetime of the spacecraft originally planned to last ten years.

In the meantime, the Artemis orbit has been circularised at about 31000 km. With a final step, planned to start during late September and lasting several months, Artemis will be "spiralled" from its current parking to nominal geostationary orbit using its novel electrical ion-propulsion system. Spacecraft commissioning will proceed subsequently. The on-board supply of propellant remaining after the orbit raising manoeuvres, i.e. chemical and xenon (the gas used for the electrical ion-propulsion system), should make possible a meaningful technology mission in geostationary orbit.

EGNOS will use three geostationary satellites, the Inmarsat AOR-E and IOR satellites already on station, and the Artemis satellite for disseminating the EGNOS signal. This Advanced Operational Capability (AOC) configuration will provide triple-redundancy of the GEO links over most of the European coverage area. It also minimises the probability of geometrical blockage of the satellite-to-user link, thanks to the well-separated satellite positions and it will improve user positioning performance, thanks to the additional GEO-ranging signals.Finally, it will facilitate the envisaged coverage extensions beyond the European ECAC zone.

Integrity Explained *...(continued from front cover)*

Integrity can be considered both in terms of confidence and risk - if one is 99% confident that the system is performing correctly, there is also a 1% risk that it is performing incorrectly. A confidence-based definition of integrity is given in the International Civil Aviation Organisation's GNSS Standards And Recommended Practices (SARPS):

> *Integrity is a measure of the trust which can be placed in the correctness of the information supplied by the total system. Integrity includes the ability of a system to provide timely and valid warnings to users.*

An alternative risk-based definition is:

> *Integrity risk is the probability of providing a signal that is out of tolerance without warning the user in a given period of time.*

Integrity requirements are application-specific and generally specified in terms of three parameters with values specified by governing institutions.

Integrity is generally specified in terms of an alert limit, a time-to-alarm and a probability of non-integrity detection. These are all present, explicitly or implicitly, in the previous integrity definitions.

The alarm limit or alert limit (AL) for a measured parameter is the error tolerance not to be exceeded without issuing an alert to the user. It represents the largest error that results in a safe operation.

The time-to-alarm or time-to-alert is the maximum permitted duration between the onset of a failure and an alert being issued by the user's receiver.

The probability of non-integrity detection quantifies risk. It represents the probability that an error exceeds the AL without the user being informed within the time to alert.

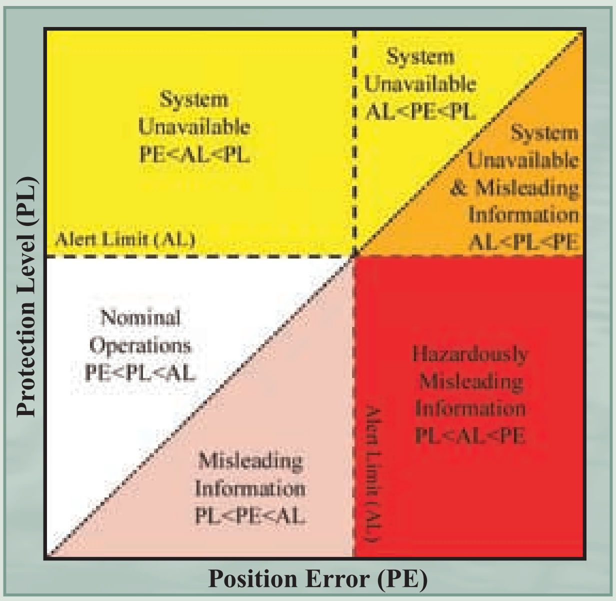
The values assigned to these three parameters depend on the specific application and intended operation, and are generally determined by institutions (e.g. the International Civil Aviation Organisation or the International Maritime Organisation).

EGNOS receivers estimate protection levels based on data broadcast by the GEO satellites, the user/satellite geometry, and the probability of integrity non-detection.

EGNOS broadcasts corrections for errors in the GPS satellite clock and ephemeris data, as well as corrections for the ionospheric delay experienced by a single frequency user. It also broadcasts parameters that describe the residual range errors after application of both the clock and ephemeris corrections (the User Differential Range Error - UDRE) and the ionospheric corrections (Grid Ionospheric Vertical Error - GIVE).

The receiver combines satellite/user geometry information with EGNOS-corrected pseudo-ranges and internal estimates of the tropospheric delay to compute the user position. Ideally, the user wants the difference between the computed position and the true position, the true position error (PE), to be less than the AL. However, the true position is not known, and so the PE cannot be determined and an alternative approach is required.

In fact, the receiver continuously estimates a predicted position error, known as the protection level (PL), for each position solution. The PL is estimated based on the UDRE and GIVE parameters and other local error-bound estimates. It is scaled for compatibility with the probability of non-integrity detection so that the PL should always be larger than PE.



Graphical Illustration of Integrity

Integrity assessments are based on PL and AL. Users will benefit from enhanced quality provided by the EGNOS integrity signal.

A new PL is estimated for each computed position solution. It is compared with the required AL, and an integrity alert triggered if PL>AL.

The relationship between PL, PE,

AL and integrity is shown on the opposite page. There is an underlying assumption when assessing integrity that PL>PE, and this is the "safe" zone to the left of the leading diagonal. In the nominal operation case, PL<AL and the system is available. If the PL>AL for a particular operation, then the EGNOS integrity cannot support the operation, and the system is unavailable.

There is also an "unsafe" zone to the right of the leading diagonal where PL<PE and the integrity assessment provides misleading information. In theory, the case at the bottom left corner of the diagram (PL<PE<AL) is also "safe" because the AL has not been exceeded, but it should be noted that EGNOS also protects against these out of tolerance situations.

EGNOS has been designed to meet aviation's demanding performance requirements including a 6 second time to alert. Consequently, all EGNOS users will benefit from the enhanced quality and safety provided by the EGNOS integrity signal.

ESA Launches Six More GNSS Application Development Contracts

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

Up to ten individual applications will be demonstrated. Six concern the dissemination of the EGNOS signal by terrestrial means, for maritime and civil aviation, as well as for dangerous goods and personal protection services in urban areas. Use will be made of existing terrestrial communications or other networks including VHF and the forthcoming GPRS infrastructures. Four other demonstrations will promote the introduction of GNSS in the rail sector as part of the forthcoming European Rail Traffic Management System (ERTMS). The initial emphasis will be on low-density rail routes but two specific developments also aim to introduce satellite positioning on high-density rail routes.

These 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.

Flight Trials Confirm EGNOS Signal Availability At High Latitudes *...(continued from front cover)*

High latitude flight trial locations showing geostationary satellite elevation angles.

A signal availability of 99.68% was achieved during these trials. These results indicate that high latitude masking should have little impact on flight operations once EGNOS procedures have been designed and the GEOs are operational.

Flight trials designed to assess high latitude availability during the critical approach and departure phases of flight were carried out in March 2001.

This led to a set of flight trials designed to assess high latitude availability during critical approach and departure operations. These were carried out on the 14th and 15th March 2001 by the British National Space Centre, the Defence Evaluation and Research Agency (DERA) and National Air Traffic Services Ltd (NATS) with the assistance of the Norwegian Mapping Agency (NMA).

DERA's BAC1-11(200) "flying laboratory" aircraft was equipped with two aviation EGNOS receivers. These were connected to a single antenna along with a survey-quality receiver to provide a truth trajectory.

The aircraft flew three sorties taking in three Norwegian airfields at Trondheim, Tromso and Bardufoss. Trondheim was chosen as a logistics base for refueling the aircraft. Tromso and Bardufoss were chosen for their high latitude (greater than 69° North) and close proximity to challenging mountainous terrain.

The ESTB signal was only available from the AOR(E) satellite during the trials, and was monitored at Gatwick throughout the trial to establish an availability baseline.

The results of these trials, albeit based on a limited data set, give some cause for optimism.

EGNOS messages were unavailable for only 55 seconds from a total flying time of 4 hours and 47 minutes above 60°N. This equates to a signal availability of 99.68%.

Outages were not caused by terrain shielding and did not occur during the approach/departure operations. Outages only occurred during dynamic manoeuvres, and a roll angle of greater than 30° was needed to break lock in the worst case scenario, and might have been avoided if all three GEOs had been available.

From an operational perspective, it should be possible to predict masking when designing an SBAS procedure. If a bank angle of the order of 30° is required within an approach procedure, this turn should be kept outside of the critical SBAS Precision Approach Region - the area in which an SBAS system can be used to provide guidance for a precision approach.

ESTB System News

The ESTB now has ten reference stations since AENA deployed new reference stations at the Canary Islands and Palma de Mallorca in June. AENA has also moved the Cadiz reference station to Malaga. This will significantly improve coverage and integrity over southern Europe.

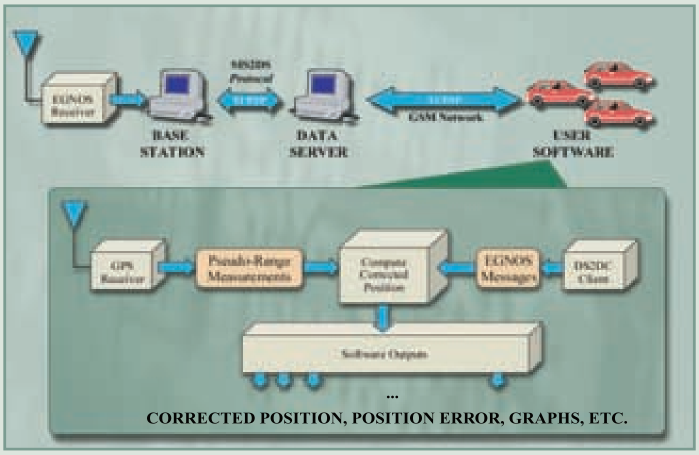
In July, the ESTB signal-in-space was upgraded to the RTCA DO229A standard. A further upgrade (to RTCA DO229B) is expected in early 2002.

ESTB broadcast schedules and performance statistics are now available on the EGNOS web site at www.esa.int/EGNOS/pages/indexEST.htm. These should prove to be essential reading for EGNOS users.

Ongoing improvements in the robustness of the the ESTB software and the duplication of the Control Processing Facility will enable the ESTB to broadcast full-time early in 2002.

Gran Canaria ACC tower

SISNET: Making EGNOS Available Over the Internet



SISNET architecture

EGNOS will broadcast correction and integrity messages through three GEO satellites. This is an efficient strategy for many users (e.g. aviation and maritime), but others (e.g. land mobile) may prefer EGNOS corrections to be broadcast over other transmission lines. This has prompted ESA to launch specific activities through its Advance Telecommunications and Navigation Technology Programme (ASTE) to assess and demonstrate architectures where the EGNOS signal could be broadcast using different links.

SISNET (Signal In Space through the interNET) is an internal ESA project that aims to provide access to the ESTB messages over the Internet. ESA has developed the first prototype where a proxy server makes the EGNOS messages available over a local area network to user equipment software implemented on a PC. The user software enables real-time positioning, dynamic ESTB analysis, and the production of EGNOS performance monitoring maps.

SISNET has clear benefits for many users (e.g. land mobile or GIS). It is, however, currently restricted to the ESA development team during this phase of the project. We look forward to bringing news of further developments.

Frequently Asked Questions

Q1: Can the ESTB be used outside Europe?

A1: The ESTB has been designed primarily for operations in the European area. However, its service area can be expanded by installing additional reference stations outside Europe, increasing the ionospheric grid mask to cover the enlarged area, and using Message Type 27 to extend integrity beyond the nominal service area. Some tests have already been performed, and the “expanded ESTB” will be used during 2001/2 in Africa, the Middle East and Eastern Europe.

Q2: When will the ESTB provide a consistent level of service?

A2: A pre-operational service has been available from the ESTB since February 2000, providing a signal during the working day. There are several ESTB upgrades currently in progress designed to improve its robustness and to provide a fully stable signal, 24 hours each day. This will be operational early in 2002.

Please send your questions via e-mail to ESTB@esa.int

Forthcoming Events

ION GPS-2001, Salt Lake City, US.11-14 September 2001.
www.ion.org

ESA DSP 2001, Digital Signal Processing Techniques for Space Communications. Lisbon, Portugal, 1-3 October 2001
www.estec.esa.nl/conferences/01C14/index.html

NAV01, London, UK. 6-8 November 2001.
www.rin.org.uk

2nd ESTB Workshop, Nice, France, 12th November, 2001.

NAVSAT 2001, Nice, France. 13-15 November 2001.
www.navsat-show.com

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

Help Us to Help You

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The Editorial Team would welcome your comments, suggestions, and inputs for the December 2001 issue.
Please send emails to ESTB-News@esa.int.

Links and Contacts for Further Information

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 ESTB Help Desk e-mail:
ESTB@esa.int

ESTB News e-mail:
ESTB-News@esa.int

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

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

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

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