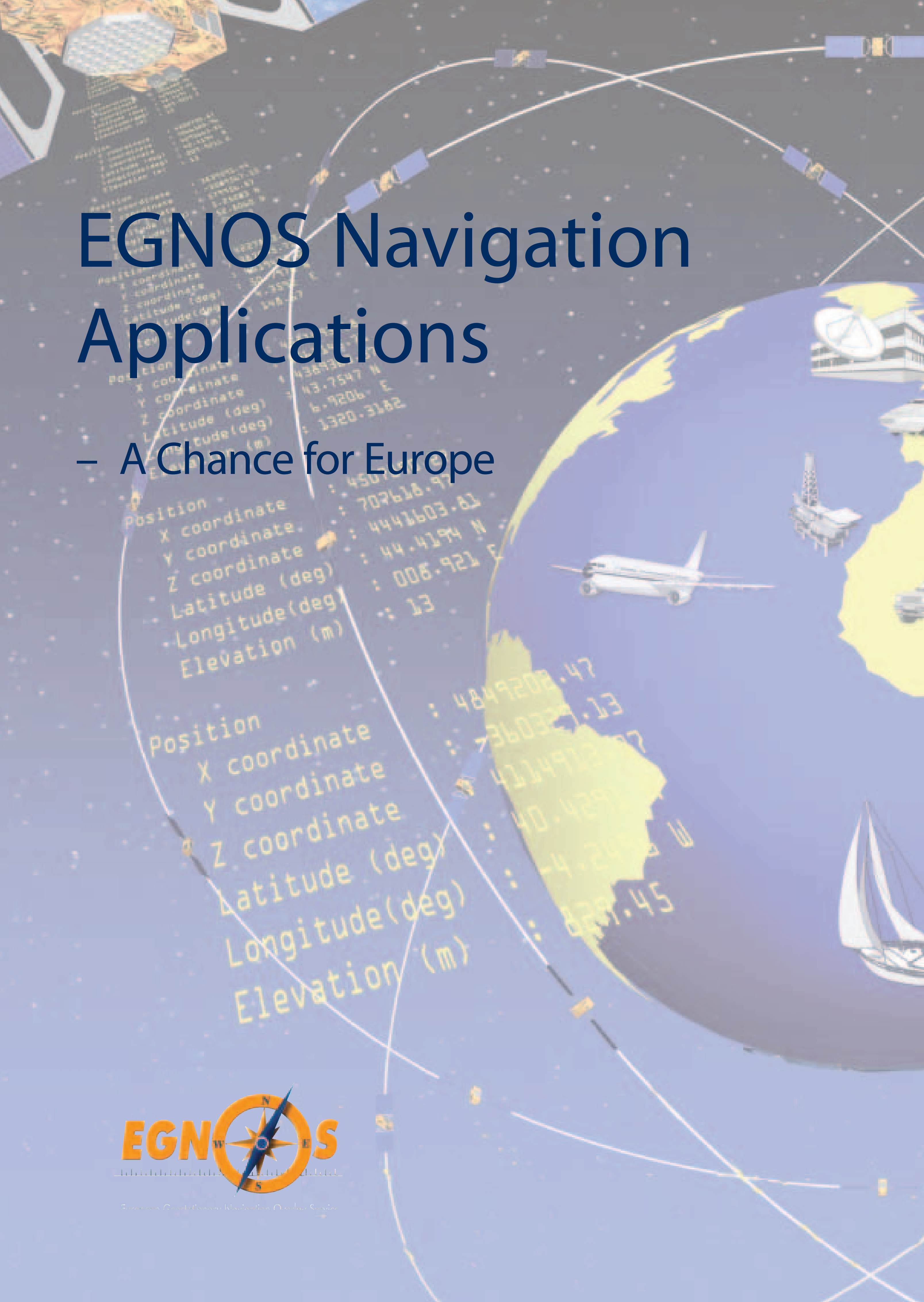
EGNOS Navigation Applications

– A Chance for Europe



EGNOS

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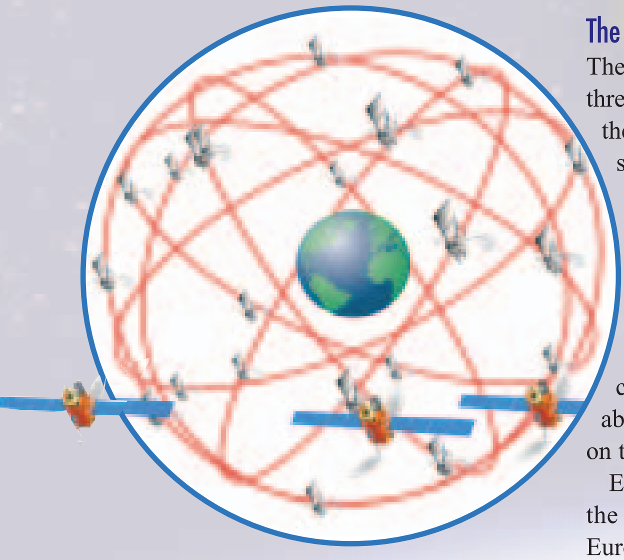
When the Global Positioning System (GPS) was first conceived in the United States in the late 1970s, it was intended for institutional use only. The US Navy needed a system that could provide it with accurate positioning information anywhere in the World. Nobody at that time could have imagined the huge growth in civil applications of global positioning that has occurred since then. The same was true when Europe embarked on the development of the European Global Navigation Overlay System (EGNOS) in the early 1990s with the primary objective of providing Civil Aviation Authorities with the accuracy and integrity needed for safe air-traffic control over European countries. It eventually transpired that in the improved performances brought by EGNOS lay the foundations for a wide range of new navigation applications in Europe for its roads, railways, inland and coastal waterways, and even its pedestrians. In 2008, when the Galileo system is fully deployed and offers an even higher level of service, yet another raft of as yet unforeseen applications for both professionals and the public can be expected to be triggered, based to a large extent on the precursor activities initiated with EGNOS.

* The development of navigation applications is managed within ESA by the Navigation Applications Office in the Navigation Department. The technical support is provided by the Radio Navigation Section in the Technical Directorate. In recent years, the latter has developed numerous innovative EGNOS navigation applications in order to stimulate European industry and help the EGNOS system penetrate the navigation market.



The EGNOS concept, with three geostationary satellites

The GPS and EGNOS Systems

The original GPS system is made up of three distinct elements, namely the space, the control and the user segments. The space segment consists of 24 satellites orbiting the Earth at approximately 20 200 km altitude every 12 hours. The constellation is designed in such a way that at any given time there will be at least four satellites visible (the minimum required for positional computation for most applications) above a 15° cut-off angle from any point on the Earth's surface.

EGNOS is a joint undertaking by ESA, the European Commission and the European Organization for the Safety of Air Navigation. It has been designed to provide a civil and safe complement to the GPS system over the European continent by transmitting, via geostationary satellites, GPS-like ranging signals containing differential corrections and integrity information that supplements the basic GPS positioning solution. At the same time, the ranging signals from the geostationary satellites themselves can also be used in the position determination.

The EGNOS Enabling Technologies

The widespread application of EGNOS is facilitated by recent advances in technology in several key areas, including inertial sensors, receiver technology and communications systems.

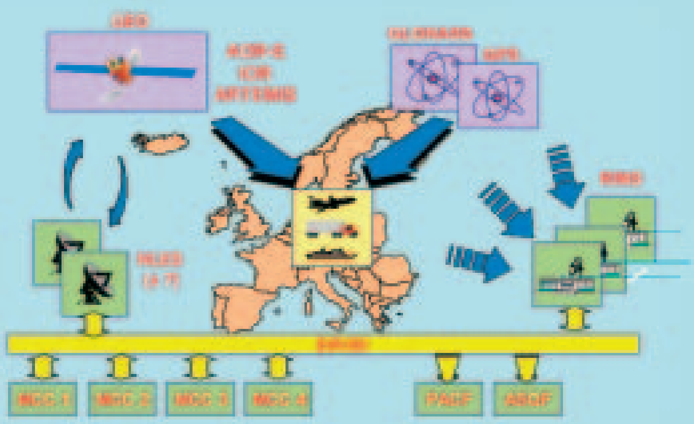
The latest inertial sensors (odometers, gyroscopes, accelerometers, etc.) are the ideal complement to EGNOS for improving the availability, accuracy and safety of the overall hybrid system. The availability of EGNOS depends unavoidably on the operational environment, in that the signal transmitted by the satellite can be temporarily blocked out, especially at high latitudes, by trees, mountains, buildings, tunnels, etc., whereas the inertial-sensor information is always available and can easily fill-in for short-term outages in the satellite-based data. On the other hand, inertial sensors provide good relative accuracy over short periods of time, but can 'drift' over extended periods and thereby fail in providing an absolute reference. EGNOS, however, provides superb long-term stability, which can be used to calibrate the inertial sensors. An integral part of the development of the positioning terminals for some of the applications has therefore been the design of an appropriate 'fusion algorithm' that combines the best properties of both types of information.

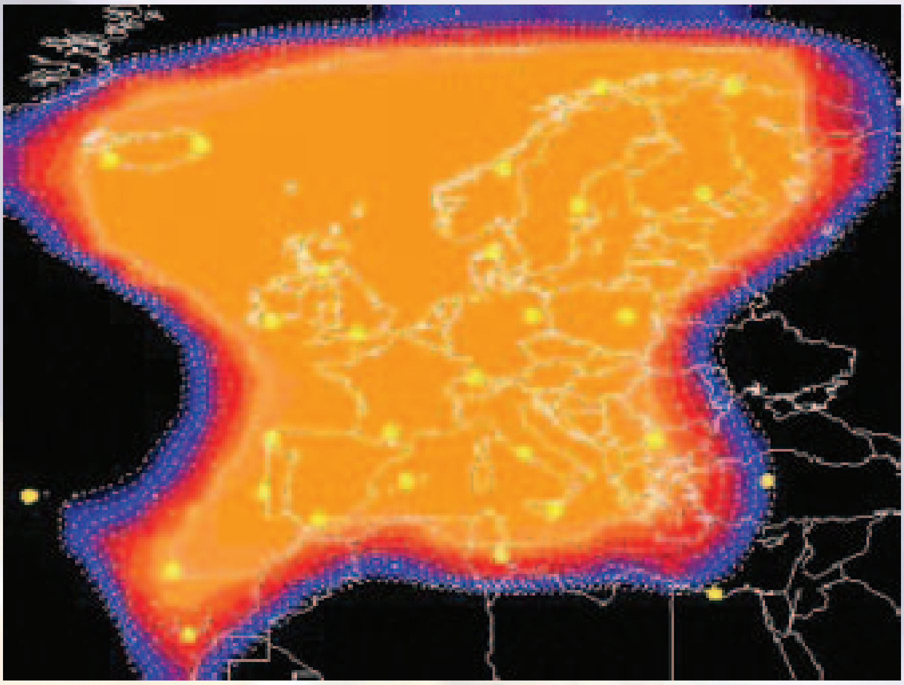
The advance in inertial-sensor technology due, for example, to MEMS (Micro-Electro-Mechanical Systems), has made cheap, small, high-performance devices a reality, leading to competitive hybrid positioning systems. Other types of sensors, such as high-speed digital cameras, have also progressed significantly of late and are also useful in combination with EGNOS receivers. Thanks to the wider availability of accurate digital maps, more and more applications will combine satellite navigation with map-matching algorithms.

The continuous advance in ASIC (Application Specific Integrated Circuit)

How EGNOS Works

The data-processing cycle starts at the Receiver Integrity Monitoring Stations (RIMS) which make pseudo-range measurements to the American GPS - and in future possibly also Russian GLONASS - satellites. These measurements are sent through the European Wide Area Network (EWAN) to the active Master Control Centres (MCC), where the corrections and integrity information are computed and uploaded to the geostationary (GEO) satellites by the Navigation Land Earth Stations (NLES). These GEO satellites broadcast GPS-like signals on which this information is modulated. The user can then combine the GPS pseudo-ranges with the EGNOS corrections, and compute the integrity of the computed positions. The differential corrections for the GPS signals consist of orbit and clock corrections and precise ionospheric corrections. The integrity information consists of estimated variances in these corrections, including some integrity margin. The foreseen European constellation is shown in the figure above, with three geostationary satellites covering the European service area.





Expected EGNOS coverage for a high-accuracy European service with 1 to 3 metres horizontal accuracy

technology directly translates into an improvement in GPS/EGNOS receiver technology. Nowadays, there are a large variety of receivers to meet all application needs, from the cost-sensitive and less-demanding solutions to dual-frequency high-performance implementations. For example, the reduction of power consumption and size are key aspects in applications using handhelds. Technology is also facilitating the integration of receiver components into a smaller number of chips, bringing further benefits in terms of cost, size, power and reliability. EGNOS receivers are present in the market in a variety of forms, including single chips, OEM boards and application-specific receivers, so that each assembler of positioning terminals can easily find the solution that best fits their needs.

For most service applications, the navigation terminal must include some communication functionality, in order to be able to:

- transmit or receive raw measurements so that it can support, for instance, real time kinematic positioning
- receive EGNOS corrections via alternative means other than the geostationary satellite
- transmit information (position, alarms, etc.) to a control centre and receive commands from it.

There are a variety of communication systems that may be used together with the navigation terminal, some of the most common being: GSM, GPRS, UMTS, LW/MW radio, FM RDS, FM Darc, IEEE 802.11x and satellite communications (Inmarsat, Orbcom, Globalstar, etc.). Others are application-specific systems, such as GSM-R for trains, AIS, Loran-C and IALA for maritime applications, and VDL-4 for aircraft. The communication and navigation functionalities can be integrated on the same board, and in some cases even on the same chip. It has been estimated that, for mass-market applications, adding mobile-phone functionality (GSM) to a GPS receiver would increase the cost of the unit by less than 10 Euros. It is just this combination of communications and positioning that is leading to a host of new applications for EGNOS.

Categories of EGNOS Service

EGNOS will benefit Europe's citizens by providing four particular categories of service:

The first driver for developing EGNOS was 'Safety-of-life applications'. EGNOS has been designed to comply with the strict requirements of civil aviation, but will also reduce the need for expensive ground-based equipment. EGNOS will also offer the possibility of performing curved rather than straight landing approaches at airports, which should result in both increased landing capacity and reduced noise pollution. Other examples of 'safety-of-life applications' are railways and particular maritime operations, where EGNOS can also lead to greater safety margins and reduced costs.

'Law-enforcement applications' are a second category of EGNOS services, whereby vehicle-position information can be used by authorities to monitor the compliance of vehicles with legal restrictions on their locations and speeds. By knowing a car's position, for example, an authority could charge the driver according to the type of road being used and the period spent on it ('road tolling'). Another example of 'law enforcement applications' could be an authority checking that fishing boats do not enter pre-defined exclusion zones at sea. Because GPS anomalies, which occur from time to time (e.g. satellite clock jumps), may not be detected by the user, a GPS-only solution is not sufficiently reliable for such applications. Since basic GPS does not provide integrity information, an anomaly could result, for instance, in a large number of road users being incorrectly billed. With the real-time integrity information broadcast by EGNOS, such anomalies cannot occur.

'Commercial services' are the third category. For the majority of commercial services, availability and accuracy are the most important navigation parameters. The use of EGNOS instead of GPS-only will improve both accuracy and availability, thereby creating the potential for new commercial services. For example, ESA has recently been contacted about using EGNOS for the 'Tour de France' cycle race, to provide accurate real-time information on the positions and speeds of the individual riders, as well as their relative positions.

The fourth category are 'Special services'. Some applications require a

EGNOS application developments will significantly improve operational safety and efficiency for many types of vehicles, including airport service units like snowploughs (Photo courtesy of Flughafen München GmbH)

certain level of integrity, but cannot be classified under the first three categories. One such example is the use of EGNOS for guiding blind people, where the improved accuracy and integrity of the system compared with a GPS-only solution can dramatically improve the quality of the service being offered.

Selected Applications

The following are just a small selection of the twenty or more satellite-navigation applications that the Radio Navigation Section at ESTEC has helped to investigate and develop over the last few years, ranging from individual-user to system-level (EGNOS, Galileo) applications:

Winter road services

A major concern for public-service providers is the growing demand for legally sound documentation of their operations, to protect themselves against lawsuits after accidents caused by icy or otherwise treacherous winter road conditions. The integrity protection inherent in the EGNOS system allows this goal to be achieved without the need for expensive local augmentation systems.

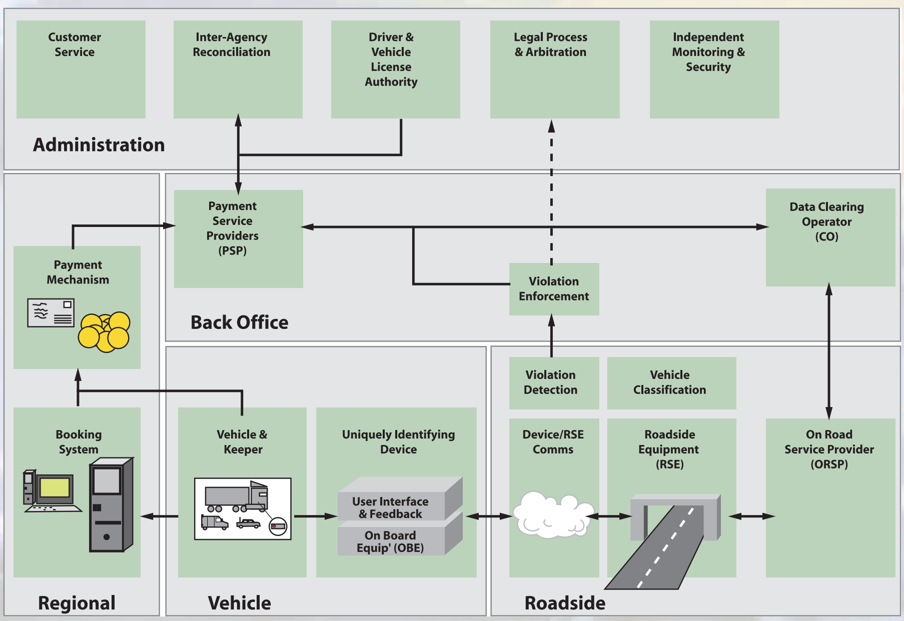
Another concern is the operation of snowplough services under poor-visibility conditions, be they caused by falling snow or fog, or simply because the limits of snow-covered roads are no longer visible. Thanks to the EGNOS system's superior precision, accurate driver guidance can be offered by equipping the vehicle with a detailed moving-map display.

In most cases, local authorities convert their snowplough vehicles outside the winter season to provide other services like street cleaning or the mowing of grass verges. Here again, the integrity provided by EGNOS can provide reliable operating records for legal and billing purposes.

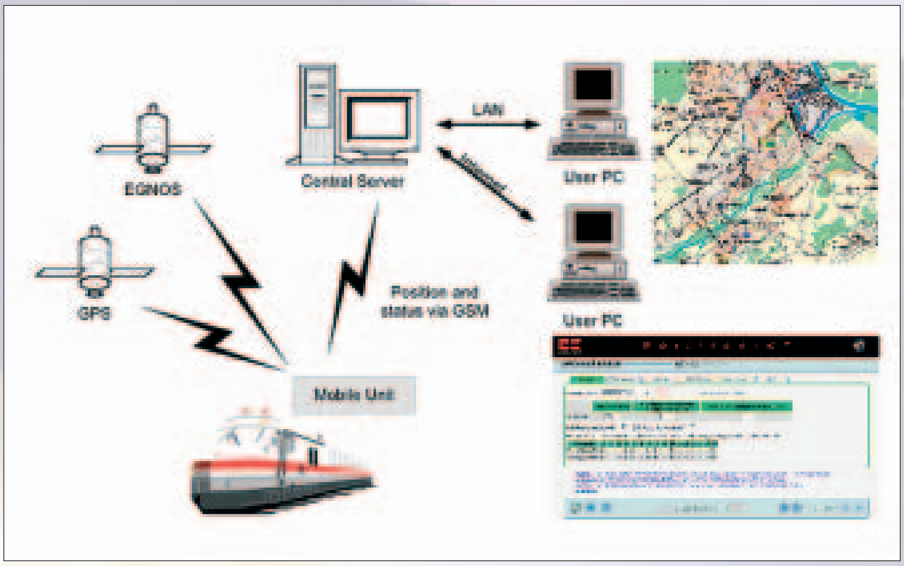
One example is the operational supervision and management of the winter service vehicles at Munich Airport in Southern Germany. As these services are operating on the entire airport premises – specifically on the taxiways and runways – an extension of the current system is being prepared with Euro Telematik (Germany) to provide a steering aid to the driver and to implement additional safety and warning functions.

Electronic road tolling

In the road sector, several Intelligent Transport Systems (ITS) are currently being designed, many of which will make use of satellite-navigation equipment. The latter will be used to provide new services that require particular levels of safety and reliability. EGNOS is ideal for that purpose and so ESA, together with the Portuguese firm SKYSOFT, initiated the 'Active Road Management Assisted by Satellite' (ARMAS) demonstration project. Its aim is to show how to transform the transport infrastructure (roads, bridges, urban roads) into a safer and more user-friendly environment, by improving safety, increasing dynamic traffic-management capabilities, and providing Electronic Fee-Collection (EFC) mechanisms through the



A generic Electronic Fee-Collection (EFC) system for road tolls



The INTEGRAIL system architecture (Courtesy of Kayser-Threde GmbH)

use of satellite positioning. Other functionalities foreseen include ‘warning messages’ and ‘SOS requests’.

A recently approved Directive calls for the creation of a European Electronic Road Toll System based, in the longer term, primarily on the use of satellite-based systems. The proposal advocates the use of satellite positioning and mobile communications technologies, namely GPS/EGNOS and Galileo, for the deployment of the European toll service as well as for all new national systems, these technologies being more flexible and better suited to the new Community charging policies. Moreover, they are already a component of many of the active safety systems that manufacturers are starting to install in their vehicles.

The ARMAS architecture has been influenced by the existing Traffic Control Centres (TCCs). The Regional Navigation Control Centre (RNCC) is seen as an evolution of the TCC, with greater functionality. Existing Road-Side Equipment (RSE) does not need to be replaced, but can be integrated into ARMAS (see figure).

Low-density railway traffic

The train command and control systems in use today are too expensive for cost-effective application on lines with low traffic densities, for instance just one train per hour. Consequently, many such lines all over the World are still equipped with outdated or human-based safety systems. The new ERTMS/ETCS system (European Rail Traffic Management System/ European Train Control System) will provide a unified safety standard at European level, but it will be used mainly on high-speed and trans-European lines. Although this new common standard will provide clear safety benefits, the very high installation and maintenance costs are not viable for lines with low traffic densities.

There is therefore a clear need for an innovative and cost-effective system for low-density routes based on new available technologies, including satellite-based positioning. Just such a system, known as LOCOPROL/LOCOLOC, is currently being developed in cooperation with Alstom BSI (B). This GNSS-based system will provide the same level of safety as on high-density lines, whilst greatly reducing deployment, operating and maintenance costs. The LOCOPROL project, supported by the European Commission as part of the 5th Framework Programme, essentially addresses the location, control centre, and communications elements, while the complementary LOCOLOC project, supported by ESA, is focussing on the safe-speed measurement element and the service centre for future users.

The greater cost-effectiveness of the LOCOPROL/LOCOLOC solution is achieved mainly by relocating the safety functions from the ground (ERTMS standard) to the train, removing the need for such expensive elements as track points, balises, and many other sensors required today.

A successful live demonstration of the system has already been conducted using an SNCB train on 15 kilometres of track in Belgium.

The INTEGRAIL unit installed in a locomotive for test purposes (Courtesy of Bombardier GmbH)

Challenging navigation in narrow waters (Photo courtesy of Seatex-Konsberg)

Advanced rail-traffic management and safety

INTEGRAIL is a prototype demonstration system that uses EGNOS for the autonomous and reliable determination of a train's position, direction and speed under practically all weather conditions. It is an advanced train and signalling control application that imposes much more stringent safety requirements than the current fleet-management information applications. It also promises significant improvements for the rail-traffic operator in terms of cost, redundancy, and reliability by adding satellite-navigation information and, even more importantly, the integrity information provided by EGNOS.

INTEGRAIL has been developed by Kayser-Threde, Munich (D), as prime contractor, in partnership with Bombardier Transportation/Rail Control Solutions, Ulm (D) and ifEN (D). The complete system consists of mobile units to be mounted in the locomotives and a Control Centre.

A necessary prerequisite for the adoption by the rail operators of EGNOS-based systems for train control and management is to conduct extensive field trials and to characterise their performance under representative conditions. Two such demonstrations have been conducted over a period of 8 months; the first took place in Austria using trains from LogServ, and the second in Belgium with trains belonging to SNCB. The extensive data that were collected showed that the INTEGRAIL system delivers a mean accuracy of better than 5 metres.

Guiding and monitoring maritime vessels

The accuracy of the EGNOS system makes it extremely suitable for guiding shipping, including coastal navigation, dredging operations and manoeuvering within harbours. It is also very economical as it means that the expensive deployment of the local reference stations required for systems like Differential-GPS can be dispensed with.

For vessel-monitoring applications, it is EGNOS's integrity that is key. EEC Regulation 2847/93 requires, since 1 January 2000, that all Community fishing vessels more than 24 metres long carry a 'blue box' for a satellite-based Vessel Monitoring System (VMS). This box provides automatic reporting of the vessel's position at all times, as well as communication with the Fisheries Monitoring Centre (FMC) of the State in which the vessel is registered. EEC Regulation 489/97 stipulates that the tracking application must provide reliable position reporting for effective control by the authorities. EGNOS's integrity makes its positioning information usable in a court-of-law, which GPS-only-based VMS would not be.

VMS was developed in Portugal and is being upgraded by INOV under ESA contract.

Vessel monitoring in narrow waters

As a result of Regulation V/19, paragraph 2.4, of the International Convention for the Safety of Life at Sea (SOLAS), introduced in 1974, it is mandatory for all ships larger than 300 gross tonnage engaged in international voyages, all cargo ships of more than 500 tons, and all passenger ships irrespective of size, to be fitted with an Automatic Identification System (AIS). The EGNOS TRAN project has been exploring the benefits of integrating the EGNOS technology with a VHF link like AIS, which is normally used for communication between vessels and with the shore. A system was set up in the fjords of Trondheim (Norway). The AIS stations were equipped with EGNOS signal receivers and its differential corrections and integrity information were then specially formatted and transmitted through AIS to the vessel, in order to ensure compatibility with the local Differential-GPS equipment onboard. Field trials were conducted during the winter of 2002/3 with the EGNOS Test Bed signals using the coastal vessel MS Nordlys, which plies continuously between Bergen on the Norwegian west coast and Kirkeness close to the northern border with Russia. These trials based on the use of only two AIS stations demonstrated good complementarity in terms of EGNOS coverage and continuity of service, meeting the accuracy and integrity requirements laid down by International Maritime Organisation (IMO) regulations for coastal and harbour navigation.

Conclusion

European expertise in the development of satellite navigation systems has been initiated with EGNOS and is now being successfully applied to Galileo. Similarly, the applications being developed with EGNOS are the forerunners of Galileo applications. ESA has been complementing the efforts of the European Commission and the Galileo Joint Undertaking in this direction in order to stimulate institutional and commercial interest in a wide range of safety-related and other essential services that can be provided across a broad range of European business sectors. This has boosted interest in the development of navigation applications by companies throughout Europe, ranging in size from the large to the very small. It is ESA's intention to maintain its effort in this domain to ensure that European companies achieve a strong position in this new and very promising market. esa