



Photo courtesy of Kongsberg

Charting Future GNSS Markets

Exploratory Applications and Services

By investing in pilot projects that emulate Galileo for early application development, industry partners create new possibilities for the user communities to explore. This will in turn enable GNSS companies to field solutions by the time Galileo's infrastructure is in place and operational. Pilot projects in the maritime and road sectors, described here, give a flavor of what's to come.

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International trade and commerce grow more global in scope every day, and the Galileo satellite navigation system will play an important role in the global automotive, electronics, telecom, and other industries. The development of institutional and governmental applications provides another promising challenge for Galileo, due to the part that Galileo Guaranteed Services and Public Regulated Services (PRS) could play for applications such as border control and governmental fleet management.

To prepare for market adoption once the satellite navigation system becomes operational, and to ensure continued political support, the founding members of Galileo Services recognized the need to demonstrate the commitment of industry to invest in this

promising market — a key factor in ensuring that Galileo will become the first major European project with such a strong leverage capability. The members of the organization believe that investment of public institutions will generate significant economic growth, highly-skilled jobs, and a key European presence in the forthcoming revolution of mobility.

In the past, European companies have collaborated to develop and market GPS products, and this will be no different with Galileo. In the coming years, more European companies may therefore join the Galileo Services organization, to combine their expertise and efforts to take up the new challenges that Galileo offers.

The early involvement of non-European countries in certain applications and prospec-

tive commercial deals will also prove beneficial for Galileo's commercial success. Their participation will contribute to the promotion of the use of GNSS around the world, and is particularly important in applications and elements that address regional needs.

Market Expertise. Currently numbering 20 companies from 11 European states, Galileo Services members are all deeply involved in the Galileo program, and strongly committed to the development of the Galileo applications market.

Galileo Services members represent seven major industrial groups, two satellite operators, one satellite services provider, one map provider, eight small and medium-sized enterprises (SMEs), and one research institute. Due to their diversity in both size and market focus, Galileo Services members cover the full spectrum of expertise with an end-to-end vision from R&D and engineering to manufacturing of terminals and development of applications. New Galileo Services members are continually being announced.

Setting Standards

Galileo Services members represent leading players in all major GNSS application areas. These include location-based services, aviation, road, rail, maritime and high-precision surveying user segments. To achieve this position, members have already made substantial investments in development of technology and applications that will enable a wide range of users to benefit from the new features of Galileo. In many cases these investments have been complemented by contributions from the European Union (EU) or European Space Agency (ESA) as part of their investment and infrastructure programs ranging from core technology development, participation in a wide range of user forums, support to the Galileo program, development of new and adaptation of existing standards, development of new applications, pilot- and demonstration-projects and industry/user networks.

These companies' well-established position in the value chain together with the user communities enables them to have a best possible position for transforming these new opportunities into concrete products and services. Knowing the user requirements

is crucial for the downstream business, but using this knowledge to inform the definition of the Galileo system is just as important to ensure optimal performance of the applications. This influence takes effect both through participation in and support to the Galileo system design and application specific standardization tasks. As a natural consequence, Galileo Services members have taken lead roles in several pilot projects designed to demonstrate how the new services can be exploited in applications.

Maritime Applications

MARitime GALileo (MARGAL) provides an example of a Galileo application development project involving complementary competencies from a variety of key players in the maritime community, co-operating in a consortium proposing and demonstrating benefits and standards for optimal utilization of the Galileo system in the future. This project has been launched in the frame of



Galileo Services is a nonprofit organization, formed in March 2002 on the eve of the European Council decision to launch the Galileo program. Its purpose is to show that Galileo is not only a space infrastructure program, but also an opportunity for European industry to develop and benefit from a huge downstream market for equip-

ment, applications, and services.

Galileo Services focuses on developing, promoting, and maximizing the potential of the downstream market, in particular:

- Promotion of the use of Galileo in all market segments,
- Research & Development and demonstrations to reinforce market awareness and stimulate innovation,
- Assistance to the program implementation especially in the areas of regulation and standardization environment in order to ensure a complete end-to-end vision for the program.

the Galileo-related activities of the Sixth Framework program (FP6) for R&D of the European Commission (EC) managed by the Galileo Joint Undertaking (GJU).

MARGAL focuses on future requirements for maritime navigation, already been defined by the International Maritime Organization (IMO) and other authorities. These future requirements include performance parameters such as accuracy, integrity,

continuity, and availability, as well as functionality related to security and safety at sea.

Specifically, MARGAL addresses challenges related to:

- Port and harbor approach, navigation, monitoring and docking,
- Inland waterways monitoring,
- Precise navigation and calamity abatement.

The MARGAL demonstration prototype

TABLE 1 Galileo Services members

EADS	www.space.eads.net	Space services provider
Euro Telematic	www.euro-telematik.de	Mobile technology consultant
Eutelsat	www.eutelsat.com	Satellite services provider
France Developpement Conseil	www.fdc.fr	Engineering consultant
Hispasat	www.hispasat.com	Satellite comm. operator
Indra	www.indra.es	IT and defense systems
Ineco Tifsa	www.ineco.es	Transport engineering
Kayser Threde	www.kayser-threde.de	High-technology systems
Kongsberg Seatex	www.kongsberg.com	Maritime positioning & AIS
LogicaCMG	www.logicacmg.com	IT services and solutions
Mapflow	www.mapflow.com	Location aware technology
Septentrio	www.septentrio.com	Receiver design, manufacture
Skysoft	www.skysoft.pt	Systems, software engineering
Sogei	www.sogei.it	IT services
Tekel	www.tekellab.org	Location-based services
Teleatlas	www.teleatlas.com	Mapping software provider
Telespazio	www.telespazio.com	Satellite services provider
Terma	www.terma.com	High-tech civil, military systems
Thales	www.thalesgroup.com	Aerospace, defense, security
TNO	www.tnospace.tno.nl	Defense, security, IT

will take advantage of the improved accuracy and integrity that EGNOS and Galileo will provide to enhance vessel safety in all areas of navigation.

Ultimately the MARGAL system will continuously provide vessels with precise position and integrity information based on Galileo/EGNOS and GPS. Static and dynamic information from each vessel will be broadcast to other nearby vessels and shore/inland stations. The automatic identification system (AIS) provides a suitable mechanism for the transfer of data from vessel to vessel and from vessel to shore. Already in use worldwide, AIS is mandatory for all ves-

sels conforming to the IMO's Safety of Life at Sea (SOLAS) convention, and on-SOLAS vessels are increasingly fitting AIS. The introduction of AIS on inland waterways makes it possible to create a seamless service for shore, inland, and ports/harbors.

The MARGAL system will provide integrity monitoring along with suitable communications and information exchange between vessels and shore-based installations such as vessel traffic services (VTS). The integrity monitoring concept works in a similar manner to the International Association of Marine Aids to Navigation and Lighthouse Authority (IALA) radiobea-

cons and uses RTCM Messages over AIS to broadcast this information to the mariner.

This furnishes the potential of harmonized use of ports and increased efficiency. For example, when a vessel approaches a port, an approach area may be defined so the vessel may be detected, and a member of the port vessel traffic management systems acknowledges their approach. A similar detection area can be set inside the port itself so that an approaching vessel could be kept informed whether its berth is available, and if not, what action they can take to ensure they arrive shortly after it has cleared, reduce speed, change berth, and so on.

This proactive management should save time (and therefore yield direct cost benefits) in vessel turnaround and also allow the port authority to make earlier decisions regarding piloting or towing. In today's ports, security is of utmost importance, and this system could also raise awareness of unannounced arrivals.

Maritime Demonstrations. To illustrate the perceived benefits of Galileo and EGNOS, two independent, harmonized public demonstrations have been organized. Both demonstrations, taking place in September 2005, use the MARGAL demonstration prototype shown in **Figure 1**.

In particular, this demonstrates the use of differential corrections and integrity alarms to provide more accurate and reliable posi-

tioning services, as well as providing a harmonized, seamless service from high seas to inland waterways.

The MARGAL demonstration prototype consists of a Ship User Terminal supported by a shore-based infrastructure made up of a network of base stations. The Ship User Terminal comprises a positioning and processing unit and an AIS mobile station, interfaced to a software-defined receiver. The shore-based infrastructure includes an AIS base station and a base station controller that is also used as a reference station and a local integrity monitor.

The AIS message type 17 transmits differential corrections and integrity alarm messages from the shore-based infrastructure to the user. This includes the capability of transmitting some additional messages to improve the user differential range error (UDRE) resolution and integrity performance compared to RTCM SC-104 format.

The demonstration in Budapest, Hungary will focus on calamity abatement services in an AIS-based river information services environment. This demonstration involves several vessels as well as actors along the value chain like Supreme Shipping Authority, Calamity Abatement Centre, and so on.

Another demonstration will take place in Harwich, U.K., showing port operations such as approach, maneuver, collision avoidance and vessel traffic management.

In short, MARGAL aims at:

- Providing inputs to standardization and legislation work for a common infrastructure for port and inland waterways,

- Providing a working prototype of an infrastructure to implement the services needed to support business cases on EGNOS and Galileo,

- Solutions to applications and business cases covering the safety and security issues connected with the use of EGNOS and Galileo, both SIS (Signal-In-Space) and distributed signals using local elements,

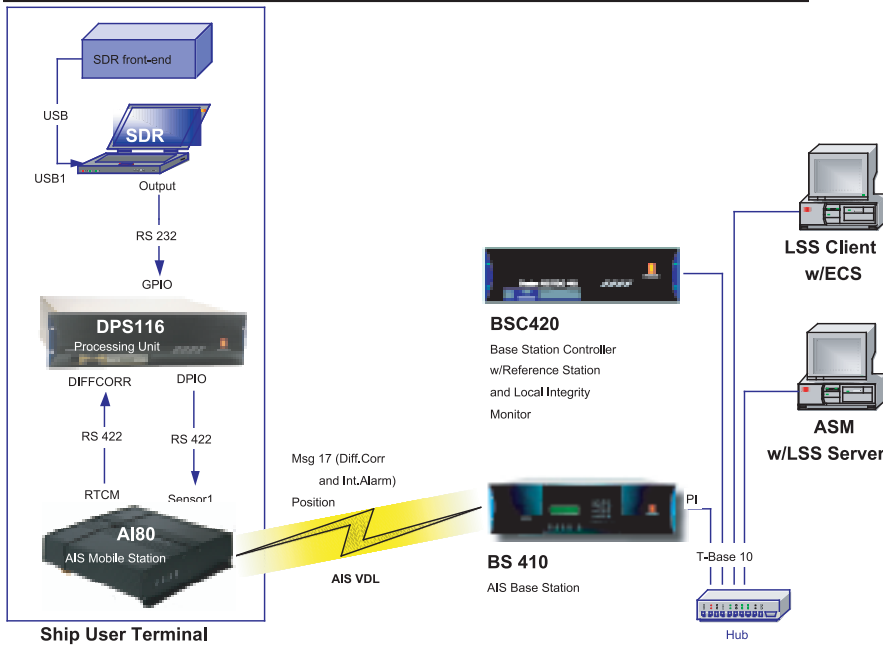
- Developing a technological platform enabling transition from EGNOS to Galileo to be cost effective from a user perspective by introducing software-defined receivers,

- Supporting networks of local elements to wide area coverage and integrity monitoring.

Road Applications

In the ARMAS project, under an ESA contract, we address issues relating to the introduction of Global Navigation Satellite Systems (GNSS)-based services for road users, such as SOS request, advanced warning provision and road charging.

Phase II of ARMAS, running since March 2004 and scheduled to complete in November 2005, is undertaking intensive trials with a primary focus on road usage charging aspects. Phase II seeks to demonstrate the applicability of GNSS, in particular EGNOS, and cellular network



▲ FIGURE 1 MARGAL demonstration prototype

technologies. The project has carried out detailed studies addressing GNSS positioning and geographical information issues

(such as accuracy, availability, latency and integrity), standardization, security, interoperability and fraud detection and preven-

tion. Initial trials for assessing GNSS performance took place in London mid-2004. The final project demonstrations will take place in Portugal and the Netherlands in October/November 2005.

Qualifying GNSS. One important aspect is the need to establish Service Level Agreements with the GNSS service provider, that is, the concessionaire in the case of Galileo. This enables road authorities to fulfill their safety and legal obligations, and commercial road operators to underwrite their revenue collection schemes. In other words, the stakeholders (authorities, operators, and others) need sufficient proof that the systems they intend to use for their operations are capable of meeting their requirements. This became one of the key tasks of the project: demonstrate that GNSS-based applications can meet the user requirements for road charging.

But these requirements are often defined from a political or legal perspective, and it

can be difficult to translate them to system requirements, or in this case to navigation performance. So the project looked for an approach to translate user requirements like “The determined usage charge shall be accurate to within 1 per cent” into clear requirements for navigation performance with parameters such as accuracy, integrity, latency and availability.

Our initial approach to translate performance requirements was based on the use of failure tree (FT) analysis. The FT analysis is a mathematical approach that considers the failure probabilities of all components of a system. The difficulty we ran into is that a given navigation performance may lead to a failure (wrong identification of a road segment) at one location and to a success at another. We know that in reality the required navigation performance varies according to the environment, depending on parallel roads, high buildings, and so on. Furthermore, this approach would require additional insight in the design and characteristics of the system, for instance the performance of the map-matching routines.

This led us to the conclusions that a formal FT analysis would not deliver realistic figures and we needed to follow an alternative and more pragmatic approach.

London Trials. For this we used the navigation data that had been collected during our extensive London trials. To improve our insight into the current system performance, the relationship between the functional components of the system was captured in a bottom-up model. This model took the performance of the input (sensors, maps, and so on) and reflected the behavior of the system as these inputs were combined. In this way the model could lead us to conclusions such as “with input GPS accuracy of X meters, Y percent, and map performance typical of London, and . . . , we can expect A per cent missed charges.”

To create a better understanding of the performance of the system, we also undertook a sensitivity analysis. By adjusting the inputs up and down by a small percentage, we were able to characterize the minimum required input performance to achieve the user requirements. For instance, we were able to say that “while X -meter Y percent GPS performance is acceptable, W -meter

Z percent would likely be unacceptable,” due to the significant drop in business level performance, when moving from XY to WZ .

To specify and hybridize the GNSS technology for the ARMAS system, we needed to study how they affected system performance. Our major finding from this work has

been that the non-GNSS components of the system have an equal impact on the performance of the system as a whole. Determining the precise value for the required GNSS accuracy, availability or any other single value is very difficult when there are so many other variables, such as environment, road geom-



▲ **FIGURE 2** Analysis of navigation performance, with respect to environment. Detailed 3D models were used to study, empirically, the relationship between building geometry and error.



▲ **FIGURE 3** Analysis of navigation performance, with respect to environment. The London trials also looked for a relationship between the on-street vegetation and navigation performance. Routes driven in winter were compared to those driven in spring.

etry, usage of vehicle, and so on, that have an equal impact.

Aviation and Rail

Galileo Services also leads the application of Galileo and GNSS to other important transport sectors such as aviation and railway, conducted in the frame Galileo-related activities of the EC 6th FP, managed by the GJU.

The GNSS Introduction in the Aviation

sector (GIANT) for aviation will be the first time in which GNSS demonstrations will be performed onboard a commercial aircraft in Europe, while the GNSS introduction in the Rail sector (GRAIL) project will continue to explore applications in European Rail Traffic Management System/European Train Control System (ERTMS/ETCS) including demonstrations on an operational high-speed line.

LBS Market

Location-based services for personal mobility have long been recognized as a major future market for Galileo in terms of the number of users and potential revenue.

As part of the Galileo-related activities of the EC 6th FP managed by the GJU, a number of Galileo Services members led by LogicaCMG brought together a 20-strong team of major actors in the European telecommunications, LBS, and satellite navigation industry, and created the Application of Galileo In the LBS Environment (AGILE) project. Its objective is to address the overall LBS mass-market, focusing on all aspects (marketing, institutional, technical) that may facilitate the acceptance and success of EGNOS and Galileo based solutions from the perspective of delivering profitable business returns.

AGILE brings together the technological building blocks needed to enable precise, accurate and reliable navigation anytime, anywhere, through the full hybridization of space and ground-based geo-location systems. This merger of technologies takes place at the terminal, network and local element level. AGILE also brings together the core components of wireless telecommunications, advanced navigation, and commercial geographical information systems (GIS) within a flexible architecture, based on the principles of an open business model for LBS applications and compliance to industry standards.

The ultimate benefits of AGILE are:

- To contribute to the worldwide user acceptance of Galileo and Galileo-based applications in the mass market,
- To set the business framework for the generation of potential revenues for EGNOS and Galileo and support Galileo concession initiatives,
- To federate and coordinate all stakeholders in the LBS community; and involve telecom actors in the long-term success of EGNOS and Galileo.

Receiver Development

Galileo Services founding members have been heavily involved in Galileo Receivers development since the beginning of the Galileo program. This led to delivery of the first fully compliant Galileo receivers to ESA



▲ **GNSS INTRODUCTION** in the Rail sector (GRAIL) will conduct GNSS demonstration on an operational high-speed rail line.

in the summer of 2004 and the first commercially available professional GPS/Galileo receivers. In the future, Galileo Services members will be the major suppliers of the Galileo receivers developed for the Galileo infrastructure.

Two types of test users receivers are developed for the purpose of the In-Orbit Validation (IOV) Phase of Galileo. These Receivers are the core part for the demonstration of the Galileo Services (Open Service, Commercial Service, Safety of Life, Search and Rescue, Public Regulated Services). The Ground Reference PRS Receiver, which allows the capture of the PRS signal for the ground mission segment is also a key element of the infrastructure validation.

Looking Forward

A key issue for Galileo's market success will be the relationship established between Galileo Services members with the European GNSS Supervisory Authority and with the future Galileo concessionaire. Both should have a strong interest in keeping Galileo Services as a key player. The motivation of Galileo Services member companies will accelerate the development of the Galileo market, and hence the growth of the potential revenues, and the success of the implementation of new European policies such as virtual tolls or emergency services. Galileo Services members currently act as the best representatives of eventual end-users, because they are the closest to the navigation market, and they invest their money in what they consider as the most

promising applications. 🌐

Manufacturers and Providers

The MARGAL consortium consists of nine partners from nine countries: coordinating partner **Kongsberg** (Norway), **Trinity House Lighthouse Services** (United Kingdom), **FDC** (France), **Telematica** (Germany), **CRUP** (Croatia), **via donau** (Austria), **VUD** (Slovakia), **RSOE** (Hungary) and **Nordnav** (Sweden). Kongsberg supplies the *MARGAL DPS 116* user terminals and AIS infrastructure and mobile stations. NordNav furnishes the software-defined receiver.

For further information on Galileo Services, visit booth 314 at the ION GNSS 2005 exhibition (September 13–16, 2005, Long Beach, California), or e-mail: marie-laure.mathieu@galileo-services.org. See also www.galileo-services.org

Skysoft, Mapflow and LogicaCMG carry out the ARMAS project.

INECO-TIFSA (Spain) leads the GIANT and GRAIL projects, with participation by **Thales, FDC, Septentrio, Terma, and Indra**.

Septentrio and Thales have been involved in Galileo receiver development since the beginning of the Galileo program. Septentrio delivered the first fully compliant Galileo receivers to ESA in the summer of 2004 and has provided the first commercially available professional GPS/Galileo receivers. Three contracts for Galileo Test User Receivers have been awarded to consortia led by Septentrio and Thales Avionics.

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▲ **APPLICATION OF GALILEO** in the LBS Environment (AGILE) seeks to develop a sector expected to be a major future market for Galileo in terms of the number of users and potential revenue.