



Galileo Services: Industry's Role in Building Galileo Markets

SERGIO BARBEDO
SKYSOFT

MIGUEL ÁNGEL MARTÍNEZ OLAGÜE GMV

ROB VAN ESSEN
TELE ATLAS

LIÉVIN QUOIDBACH
NAVTEQ

JEAN-PIERRE BARBOUX
THALES

GARD UELAND KONGSBERG SEATEX

ESA/Emviat

Unlike the other leading GNSS systems built as purely governmental programs, Galileo has long been promoted as a public-private partnership in which private companies share responsibilities for designing, implementing, operating, and contributing financial support. Usually, this is conceived in terms of the various consortia formed to compete for contracts to build the system infrastructure and operate the concession. However, "downstream" equipment and services providers are also carving out a stake in researching and developing applications markets.

The launch of the GIOVE-A satellite in December 2005 began paving the future road for GNSS applications. Despite dismal predictions, Europe has worked efficiently, so far, to establish an independent GNSS: Galileo. And many positive indications suggest that the road will not stop here.

Galileo will transmit a variety of signals in space supporting open, commercial, safety-of-life, and public regulated services. In the development of applications based on these services, industry needs to take an active role in the definition process.

Manufacturers and service providers possess unique knowledge about the market as well as know-how in the area of industrialization. Furthermore, from

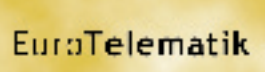
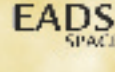
the Galileo marketing point of view, industry has well-defined channels for securing fast adoption and diffusion of technology, which is a key criterion for a rapid and successful acceptance of Galileo applications, products, and services in the marketplace.

In this context Galileo Services plays an important role, as the members of the association represent all aspects of the downstream industry—from product and service development to deployment. **Table 1** lists the current members of the association and their fields of expertise.

Members of Galileo Services have and will continue to raise crucial issues around technology and solutions for applications and services to be implemented with Galileo. They also are play-

ing important roles in leading Galileo research and development projects, primarily funded by the European Commission (EC). **Table 2** describes these projects and the Galileo Services member acting as the coordinator of each. (All of these projects are funded under the EC's Sixth Framework Program except for ARMAS III, funded by the European Space Agency, which is discussed later in more detail).

To illustrate the crucial roles that industry plays in advancing Galileo and expanding the GNSS market in general, this article will describe European efforts to implement electronic road tolling systems that incorporate Galileo-based positioning. It will also discuss the need for developing accurate mapbases in implementing such



GALILEO SERVICES

TABLE 1. Galileo Services is a non-profit making association of Industry covering GNSS applications and services, formed in March 2002 on the eve of the European Council decision to launch the GALILEO program. Its aim is to develop, promote and maximize the potential of the applications' market. The members are listed.

EADS Space Services	Space services provider	www.space.eads.net
Euro-Telematik	Mobile technology consultant	www.euro-telematik.de
Eutelsat	Satellite services provider	www.eutelsat.com
France Developpement Conseil	Engineering & consultancy	www.fdc.fr
Grupo GMV	Aerospace, defence, transport & IT Systems	www.grupogmv.com
Hispatat	Satellite comm. operator	www.hispasat.com
Indra	IT and defense systems	www.indra.es
Ineco	Transport engineering	www.ineco.es
Kayser-Threde	High-technology systems	www.kayser-threde.de
Kongsberg Seatex	Maritime positioning & AIS	www.kongsberg.com
LogicaCMG	IT services and solutions	www.logicacmg.com
Mapflow	Location aware technology	www.mapflow.com
Navteq	Digital Map Provider	www.navteq.com
Septentrio	Receiver design, manufacturer	www.septentrio.com
Skysoft	Systems, software engineering	www.skysoft.pt
Sogei	IT services	www.sogei.it
Tekel Lab	Location-based services	www.tekellab.org
Tele Atlas	Digital Map Provider	www.teleatlas.com
Telespazio	Satellite services provider	www.telespazio.com
Terma	High-tech civil, military systems	www.terma.com
Thales	Aerospace, defense, security	www.thalesgroup.com
TNO Space	Defense, security, IT	www.tnospace.tno.nl

systems. And it will explore how Galileo can exploit the technical advantage of signal authentication in its system design to build trust in Galileo's commercial services.

Finally, at the conclusion of this article, we will return to the role of Galileo Services, recent developments, and its plans for the future.

Galileo-Based Road Tolling

The conventional model for financing road-transport infrastructure is currently being re-examined both in Europe and elsewhere in the world. Traditional tax-based financing no longer guarantees sufficient revenue with which to meet the road-building, upgrading, and maintenance needs of highways and motorways.

As governments move towards taxation systems that reflect use (for example, waste charges, water charges, and so forth), the choice of moving to "pay as you drive" for use of a member-state's infrastructure becomes appealing. In a revision to the Eurovignette Directive (1999/62/EC), the EC has outlined the principle that maintenance of the core European motorway infrastructure should be paid for by the users through electronic tolling.

The current urban traffic model appears likely to become unsustainable in the medium- to long-term for large metropolitan areas. The cost of growing congestion levels for society as a whole is very high and has led policy makers to develop a new concept, the "congestion charge." Such a system has been successfully implemented in London and is

being explored by other cities, including Stockholm, Singapore, and Melbourne.

The concept is very simple: a fee is charged to motorists entering heavily congested urban areas. Economists model and calculate this fee on a theoretical basis by weighing the contribution made by each vehicle to slowing down the rest. Revenue derived from congestion charges is typically spent on new public transport facilities and road infrastructure.

In the case of national road networks, the number of vehicles on European roads and the capacity of the Europe-wide road network show a glaring and widening deficit in transport infrastructure investment (See the citation for the EC White paper: "European transport policy for 2010: time to decide" in the Additional Resources section at the end of this article). Inevitably, public officials in charge of taxation policy face the question of who should pay for the maintenance and further required investment in such infrastructure.

One solution that is being deployed in central European countries is to require heavy goods vehicles (HGVs) using their motorways to pay a toll. Germany, Austria, and Switzerland have all introduced such electronic tolling schemes, and last year the Czech Republic awarded a tender to develop such a system for its infrastructure. Sweden, the United Kingdom, and The Netherlands are all looking to implement similar national electronic tolling systems in the medium term.

New RUC Systems

Road user charging (RUC) systems have to be very flexible to fit in with the varying rates set on diverse road types in urban, inter-urban, and even rural areas. Such systems must be able, for example, to change the distance or zone-stay criteria underpinning the toll from one day to another.

An RUC system also has to be able to take into account the type of vehicle, time of day, day of the week or month, time and/or distance travelled, as well as the starting point and destination

of individual trips. Traditional barrier tolling systems are clearly not flexible enough to handle the multiple variables used to design the RUC fee structure.

Two technologies are currently competing to serve as the basis for these new electronic toll collection (ETC) systems: dedicated short-range communications (DSRC) — used today in high-speed motorway toll plazas — and GNSS systems such as GPS or Galileo. GNSS systems can provide vehicle positioning information that is converted into road segments travelled and, ultimately, toll charges. In actual practice, hybrid solutions that use components of both DSRC and satellite systems will ensure interoperability between the two RUC technologies.

GNSS-Based ETC

The best example of GNSS-based ETC is the TollCollect service in Germany for HGVs using Germany’s motorway infrastructure. The basic concept involves use of a vehicle’s GNSS-derived position data to ascertain whether or not it has used the toll road and, if so, to calculate the toll charge. In theory, implementation is fairly simple. It calls only for an onboard device – including a GNSS receiver – and mobile data communication equipment connected to an ETC processing center where the vehicle information is received.

This concept has many advantages. Firstly, the charging system can be applied to any road, highway, or motorway without having to set up costly roadside equipment. Secondly, it makes urban congestion zones feasible for cities where there are no natural boundaries, such as rivers. Monitoring access to and from such areas is prohibitively costly due to the numbers of entrance and exit points. Finally, the system is very flexible in applying charging criteria – time of day, vehicle class, etc. A GNSS-based tolling system also has other advantages. A single system is capable of furnishing information for different charging jurisdictions. Moreover, the ETC equipment and infrastructure can also provide other tracking-based functions and value-added services.

For example, a GNSS-based toll system provides an immense collateral fleet of “floating probes,” for generating real-time traffic information. The toll system components can also be used to provide additional secondary services such as en-route navigation, pay-as-you-drive insurance, fleet management, and even law enforcement.

Publicly Funded Research

In parallel with commercial implementations, the EC, European Space Agency (ESA), and Galileo Joint Undertaking (GJU) have funded a number of research projects to examine how EGNOS and Galileo can be used to improve performance of charge calculation and to exploit the integrity information that both EGNOS and Galileo provide.

Galileo Services (GS) members are involved in two of these projects: Active Road Management Assisted by Satellite

(ARMAS), an ESA-funded project, and GIROADs an EC/GJU-funded project that is preparing the transport sector for the introduction of Galileo.

The ARMAS Project is coordinated by GS member Skysoft Portugal and has the leading participation of other association members, including Logica-CMG, Mapflow, GMV and Euro Telematik. ARMAS has demonstrated the feasibility of GNSS technology in transforming the transport infrastructure (roads, bridges, tunnels, etc.) into safer and more customer-friendly environments, by improving safety, increasing dynamic traffic management capabilities, and providing electronic fee collection mechanisms.

The project followed the technical “constraints” put forward in the EC directive 2004/52/EC on “Interoperability of electronic road tolling systems in the Community.” So, the ARMAS system architecture was consequently influ-

TABLE 2. On-going R&D Projects Coordinated by Galileo Services Members

Title	Scope	Coordinator	Website
AGILE	Application of GALILEO in the LBS sector	LogicaCMG	www.Galileo-in-LBS.com
GRAIL	GNSS introduction in the Rail sector	INECO	www.grail-project.com
MARUSE	GNSS introduction in the Maritime sector	Kongsberg Seatex	www.maruse.org
ARMAS II	Road management assisted by satellites	Skysoft	http://armasII.skysoft.pt
GIANT	GNSS Introduction in the Aviation Sector	INECO	www.gnss-giant.com
HARMLESS	Humanitarian Aid, emeRgency Management and Law Enforcement GNSS application5	GMV	http://www.galileo-harmless.eu
M-TRADE	Multimodal Transportation supported by EGNOS	Telespazio	www.newapplication.it/mtrade/
SWIRLS	GALILEO Professional Rx Development	Septentrio	www.swirls-gju.com
MAGIC	Interference, Detection, Mitigation and Isolation	Thales	http://uranium.stu-dif.com/sensors-processing
GARMIS	GALILEO Reference Mission Support	FDC	
GAC	GALILEO Advanced Concept	Eutelsat	
GISAR	GALILEO Interfaces Implementation for Search and Rescue	INDRA	
PROGENY	Provision of GALILEO Expertise, Networking and support for International Initiatives	FDC	http://progeny.galileoprojects.eu/
HELICITY	Precision Helicopter Guidance for Cities and Emergency Support	Skysoft	www.helicity.org
GUTD	GNSS and UMTS Technology Demonstrator	Skysoft	
GADEM	GALILEO Atmospheric Data Enhancement Mission	Kayser-Threde	

Further Information at : <http://www.galileo-services.org/library/library.html>



FIGURE 1 ARMAS in-car vehicle system

ARMAS II Field Trials

Field trials were conducted using two vehicles and covering a large area of Lisbon city and greater Lisbon area, methodically covering the same ground day after day logging GPS positions at a one-second update rate.

These followed

three different scenarios: *dense urban*, driving through very narrow streets in downtown Lisbon; *urban* (or open city), driving through large city avenues and wider streets; and *rural*, following highways around Lisbon and passing places with a low-density or absence of buildings and trees. Test days were divided into three time periods in order to prove the system against various ionosphere conditions, activity periods, and traffic density.

The trials lasted several weeks, followed by analysis of data collected during the trials. (See **Figure 2**.)

Factors evaluated included required navigation performance (RNP) variables: accuracy, availability, and data latency. Researchers also conducted an integrity analysis of all recorded GNSS

data and assessed the reliability of the ARMAS services implemented on the OBU prototype.

Two analytical procedures comprised the RNP assessment of GNSS positioning accuracy.

A Geodetic GPS (GGPS) Truth Source Analysis used postprocessed GPS carrier phase measurements as the truth source for positioning data logged on two vehicles with the ARMAS ICS and a roving GGPS receiver and antenna. **Table 3** presents the accuracy values of the ARMAS solution obtained using the GGPS for the truth source.

Satellite positioning data in dense, built-up urban environments can be intermittent, however; so, GGPS Truth Source Analysis cannot always be relied upon exclusively to provide a truth source throughout all trial environments. Additional analysis was performed using “Linework Truth,” in this case the road centerline obtained from the underlying maps of the travelled journeys.

In “Linework Truth” analysis, the truth source takes the form of a line and the nature of the correlation with test data from the on-board ICS will be “nearest point.” This approach provides a good reference to compare performance in many environmental conditions and along all test routes. Road centerlines from digital maps were used

enced by the use of various standards, pre-standards, specifications and other technical documents.

Two main components that incorporated GNSS technology were:

- In-Car System (ICS) — Traditionally known as the on-board unit, ICS is the set of devices that reside inside the car and use a suite of technologies including GPS + European Geostationary Navigation Overlay Service (EGNOS) Signal In Space (SiS) + EGNOS over GPRS, DSRC, GSM Voice + GSM Data + GPRS, Inertial Sensors, Map Matching and RAIM (Receiver Autonomous Integrity Monitoring). (See **Figure 1**.)
- ARMAS Fixed-Part (AFP) — The set of devices that reside outside the car and employ GPS SiS + EGNOS SiS + EGNOS over GPRS, DSRC, GSM Voice + GSM Data + GPRS and Map Matching.

ARMAS has been divided into several phases. The ultimate objective of Phase I (performed between March and December 2003) was to assess the feasibility of the system, addressing such issues as legal and institutional aspects. Phase II, which ran between March 2004 and December 2005, had as its main goals the implementation of a test-bed for advanced intelligent transport system (ITS) applications and investigation of critical issues related to a successful introduction of GNSS-based ETC. This latter activity focused on such topics as reliability, integrity, and robustness against fraud.

TABLE 3. Field trials Accuracy (in meters), GGPS Truth Source

	Geographic Scenario				Time of Day		
	Global	Dense Urban	Urban	Rural	Day	Twilight	Night
Average	10.26	7.02	10.90	3.51	11.24	5.83	14.54
Std deviation	21.56	9.82	22.55	1.91	18.00	7.16	38.44
Percentile 95	37.87	21.49	39.58	6.48	73.93	16.52	35.19

TABLE 4. Field trials Accuracy (in meters), Road Centreline Truth Source

	Geographic Scenario				Time of Day		
	Global	Dense Urban	Urban	Rural	Day	Twilight	Night
Average	8.62	17.25	6.43	4.07	10.61	6.09	6.17
Standard deviation	22.14	38.20	7.93	5.18	27.70	9.47	13.31
Percentile 95	25.70	55.81	18.71	10.17	34.97	19.78	18.42
Percentile 99	81.99	194.24	32.76	15.34	111.62	46.54	56.39

to create the highly accurate linework required for the truth data.

Table 4 presents the accuracy and latency values that were obtained using the Road Centreline Truth Source Analysis.

The accuracy demonstrated in the tests coupled with the integrity obtained using EGNOS and RAIM meant that, as expected, the positioning solution provided by GPS+EGNOS+Inertial Sensors is appropriate for the tested tolling situations. Accurate charging was produced although an extensive trial with a large number of vehicles would be necessary for statistical validity.

The only environment where the results are not optimal is the dense urban areas where satellite signals were frequently blocked. As expected, the performance of the system becomes heavily dependent on the performance of inertial sensors, map-matching algorithms, and, if applicable, the tolling scenario (for example, the definition of the “Charging Zone” boundaries).

The accuracy of the positioning data from the on-board unit, which was designed primarily for testing GNSS-based ETC, easily supported the other two functionalities defined in ARMAS Phase II: “SOS Request” and “Warnings Provision.” This demonstrated that the approach followed is valid for providing additional service- and business-oriented functionalities to end customers over and above the ETC application.

The ARMAS project has recently been extended into a 18 months Phase III which will provide significant functional and technical enhancements to the ARMAS Phase II system, as well as foster an opportunity for real-life testing and benchmarking of the technology developed by the ARMAS consortium. Several demonstrations and extensive trials are planned, including end-user trials in Portugal, Ireland, Netherlands, and Germany. These trials include road user charging in Dublin and Lisbon, traffic information in The Netherlands, and incident management in Portugal (monitoring of “Dangerous Goods Transportation” and monitoring of “Children and Youths Transportation in Buses”).

The Importance of Good Maps

Galileo will provide signals from which the geographic coordinates of a GNSS receiver’s position can be derived. As such these are of limited value for a computer and even of less value for a human.

In order to exploit the full potential of the geographic coordinates obtained from the Galileo signals, these need to be provided with a real world context. Where exactly on earth are these coordinates located? What is in the surroundings of this position? How far is it to another given location? These questions can be answered when the coordinates are matched to a map that supports the coordinate system of Galileo, known as the Galileo Reference Frame.

In the 1980s Galileo Services partners Tele Atlas and Navteq started to build digital road maps. These maps are used in a wide variety of applications ranging from disaster management to vehicle and personal navigation. (See **Figure 3**.)

Digital maps contain information of the earth’s surface with an emphasis on street, road, and highway networks. In the digital map database, road center lines are tagged with address information (e.g. street names, house numbers, postal districts) and traffic-related information (e.g., road classification, one-way regulations, forbidden turns, etc.) on top of their geometry.



FIGURE 2 ARMAS test vehicle with GPS antenna visible on roof rack



FIGURE 3 Personal Navigation device with a digital map displayed in “bird’s-eye” view on the screen

Further, the databases may contain points-of-interest (POIs) with a wide-ranging collection of locations of potential interest to a user. Typical examples include churches, museums, restaurants, ATMs, and parking garages. Additional cartographic information such as bodies of water, railways, built-up areas, and forests may also reside in the databases.

Mobile applications for which these maps are intended typically employ a GPS receiver as well. GPS receivers calculate their position coordinates in the World Geodetic System 1984 (WGS84). The map datum incorporated into GPS units is also defined in terms of WGS84.

Upon receiving a set of WGS84 coordinates, the mobile application usually

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FIGURE 4 Vehicle for field collection of coordinates and additional map information

matches the coordinates with the geometry of objects in the digital map and derives a location in terms of a map element, such as a road segment— providing that “real-world context to a coordinate” mentioned earlier.

With this location information, the application is then able to perform its chosen function, such as finding POIs in the vicinity of the user, calculating a route to a user defined destination, and guiding the user to that location. Certain applications are connected to external sources of information that add to the informational richness of the system and allow the use of dynamic information to help optimize the routing.

Maintaining Map Accuracy

The difference between the Galileo Reference Frame and WGS84 are minimal so that maps developed for WGS84-based systems can also be used with Galileo-based systems. Currently available maps have an accuracy of 5 to 10 meters. By the time Galileo becomes fully operational, the positioning accuracy requirements of applications are expected to increase to around 2 meters.

Some prospective applications have indicated a need for map accuracy at the centimeter level. It is fair to say, that business models for such high-accuracy mobile applications have yet to be presented. Nonetheless, to meet such requirements should they become practically useful, providers of digital map databases are currently improving the

accuracy of their maps.

As in most commercial endeavors, economic considerations are important for choosing appropriate technology. Aerial imagery is a possible source. A more frequent means to achieving the necessary accuracies, however, is the field collection of road coordinates by driving the

streets with an accurately positioned vehicle. In the absence of Galileo signals, alternative positioning means such as differential GPS and inertial systems need to be incorporated into field data collection units.

The accompanying photo shows a TeleAtlas truck that registers the track of the vehicle with an accuracy of two meters (2σ). (See **Figure 4**.) Position offsets caused by left/right-hand driving are automatically corrected by image-recognition techniques, which focus on the road center line in images captured by two forward-pointing stereoscopic cameras.

The emphasis on field collection of map information points to another important phenomenon associated with digital maps: They slowly become outdated from the moment they have been published. Updating maps, therefore, is an important ancillary activity of the mapmakers. Field data collection is necessary here, but not sufficient. To support updates, mapmakers also maintain extensive contacts with public authorities who are in charge of the ever-changing reality of the physical world that we live and move about in.

These contacts allow them to be “pre-actual.” For instance, knowledge of transportation infrastructure projects and plans enables mapmakers to include a new motorway intersection in a map before the intersection is opened so that at the time of publication the map is up-to-date. In order to streamline this

process, the Digital Maps working group of the EC’s eSafety forum recently published a final report that recommends a cooperation model between the mapmakers and public authorities. (For more details, see the Internet site referenced in the Additional Resources section at the end of this article)

More Than Map Databases

Apart from accuracy and quality requirements, the new Galileo-enabled applications will also result in expanded content requirements. Road tolling applications will require details such as toll gates and fees to be incorporated into digital map databases so that motorists can anticipate their travel costs. Fee information will likely have a dynamic character and, therefore, needs to be integrated into the map in real-time. Techniques such as the Agora-C on-the-fly location referencing, developed with funding of the EC’s Fifth Framework program, are appropriate mechanisms for that.

Upcoming mandates for vehicular automatic emergency calling (eCall) applications will need eCall locations to be added to digital maps, while dangerous goods monitoring will require forbidden zones, dedicated routes, and parking places. No technical hurdles are expected in this extension process, which will be mainly governed by business parameters. Standardization requirements can be addressed in databases compliant with guidelines of the International Organization for Standards Technical Committee 204 (ISO/TC 204: Intelligent Transport Systems) Working Group 3.

Continuous production has resulted in maps that currently cover the entire western Europe, North America, and important parts of eastern Europe, Middle East, South America, and Asia. By the time Galileo is operational, map databases will be available that make the system’s satellite signals fully useful.

Recently, the European Union (EU) funded the GST-CERTECS project, which looked at the issue of map certification for safety- and liability-critical applications. Navteq developed the Geo-

graphic Data Quality Inspection (GDQI) to support the certification process. (See **Figure 5.**) Major European OEMs and a certification body are now testing and validating GDQI, after which it will be proposed to all stakeholders.

In Galileo We Trust

Market analysis studies (GEMINUS, GALILEI) conducted during the Galileo Definition Phase suggested that a number of very large mass market applications will exist for GNSS in the future. Some of these will require the use of location systems linked to charging schemes, for example, road tolling, which has already been discussed, or “smart car” insurance that sets rates based on actual vehicle usage. A substantial portion of Galileo revenues is projected to come from such application markets.

As with any system that includes a charging scheme, customers will insist on a very high level of trustworthiness in the overall system. They will also seek strong assurances that what they pay fairly represents their use of the system, service, or facility for which they are being charged.

In a very symmetric way, service providers will want confidence that the system provides:

- A high level of availability (percentage of users charged – e.g. 99.9%)
- A high level of integrity (very low percentage of incorrect charging)
- A high level of security against fraud and evidence for enforcement.

Let us take just one example, portrayed simply in **Figure 6.** (Undoubtedly, many complex designs will arise for similar systems requiring signal authentication, but the diagram will suffice for the points that need to be made.)

The application outlined in the figure represents a road-tolling system of some sort. In it, a user vehicle with a Galileo-capable receiver, possibly integrated with other sensors in the on-board unit (OBU), receives GNSS signals from which it calculates ranges to the satellites. Vehicle position (and perhaps speed) is computed from the ranges. Periodically, the vehicle submits a distance travelled log, and the user receives a bill. The user

pays the bill to the toll operator.

Within the overall application boundary of Figure 6 are a number of “transactions” or events where data moves between the subsystems. The arrows represent these data flows. Because users will one day get a bill for the service, they can be expected to demand — and must be provided with — a highly trustworthy system.

The application provider must build its system with trustworthy blocks, connected by trustworthy links. If any trust sub-system fails, the customer base will reject the system — and rightly so. Therefore, when the application integrator reaches for the GNSS block, it will only be included in the application if the GNSS and its signal link are as trustworthy as the overall system.

So, the system and its subsystems must work properly, and a fair bill must be presented. A robust design and thorough, certified testing achieve this aim.

Gaming the System

However, because payments are expected, experience shows that some people will try to find ways of avoiding the payments. This avoidance could include deliberately tampering with some part or parts of the on-board system to cause a false log to be generated at a lower than true mileage; and electronic jamming or spoofing of GNSS signals in an attempt to trick the system into calculating a low mileage.

Finally, there are always those individuals who seek to disrupt the system,

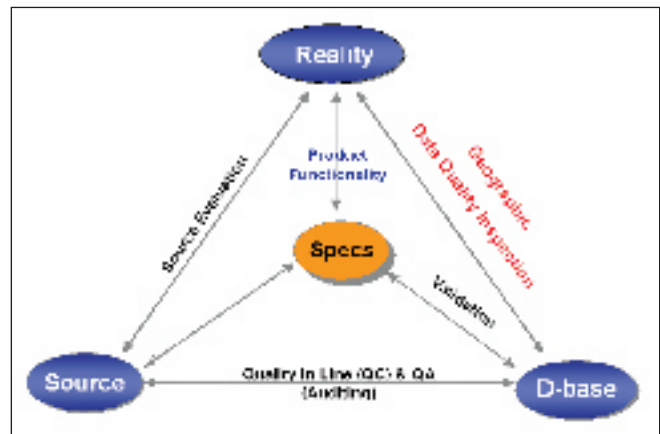


FIGURE 5 The quality triangle (Source Navteq)

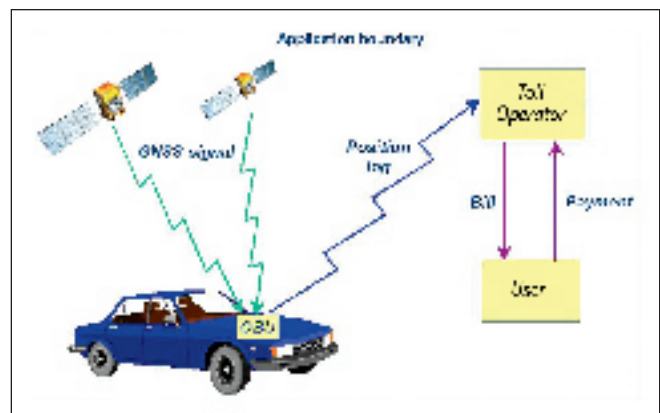


FIGURE 6 A road-tolling application scenario

just for the intellectual challenge — like the Internet hackers and virus fraternity. This threat may only be addressed by keeping one technological step ahead of the attacker. Effective defense must stretch broadly and reach deep within the signal and the terminal.

Sadly, very little can be done about jamming without moving to very expensive anti-jam hardware solutions — which are just not practical for mass-market systems. The anti-jamming capability for most GNSS consumer applications will be mainly provided by signal diversity and spread spectrum signal processing. Here, the real protection will be intelligent receiver design, backed by the enforcement of legislation by the authorities.

Attacks on the “trust” capabilities within such systems will most likely be very localised. No doubt, many will attempt to tinker with their in-car logging system, and anti-tampering

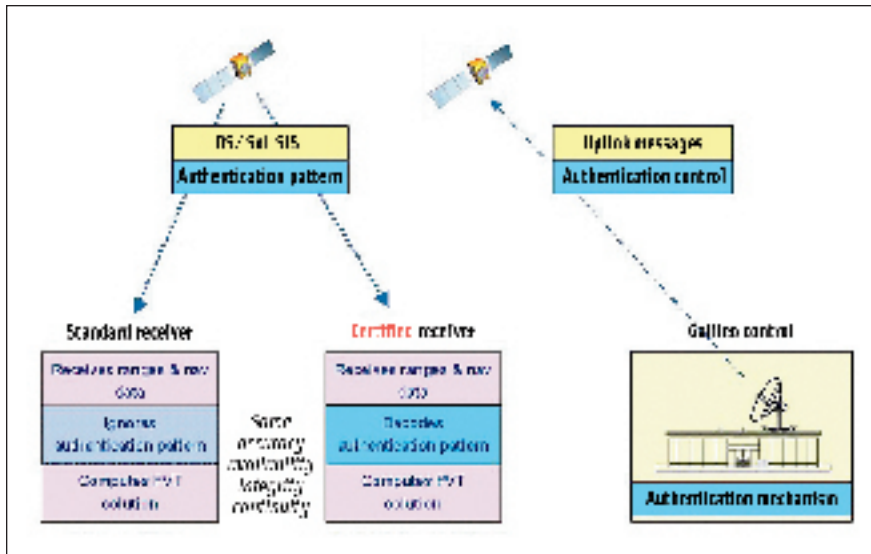


FIGURE 7 Galileo Signal Authentication Methodology

designs for the terminals will provide a major protection of the trust boundary.

Spoofing is clearly possible but would require a high degree of sophistication to spoof an integrated terminal design. Techniques may be embedded in the signal and receiver to help mitigate the effects.

The trust regime for the entire end-to-end system must therefore:

- provide a sound technical solution that generates fair bills
- be tamper resistant and indicate that tampering has been attempted
- be robust to spoofing hacker-type attacks via the (many) inputs.

The application provider must build its system with trustworthy blocks, connected by trustworthy links. If any trust sub-system fails, the customer base will reject the system.

Service providers will build the overall road-tolling system or other fee-based applications, but the Galileo Operating Company (GOC) provides the GNSS signal – or at least the Galileo part of it. Therefore, if the GOC wishes the signal to be used in such applications in order to derive fees from a value-added service, then the design of the signal must cater to this high degree of trust that must be placed upon it.

The remainder of the discussion on this topic will concentrate on how the trust capability can be implemented in the Galileo signals, recognising that GNSS is just a constituent part of the trust features of the overall application. Furthermore, in order to fit our signals seamlessly into the overall trust regime, we must understand how the other areas provide their trust elements so that we augment, rather than conflict with, the overall design.

Signal Authentication

Whatever these “Trust” features are, they must meet user expectations for reliability, robustness, and integrity.

System designers must translate these user requirements into system requirements. In this, the key Galileo-specific challenge is to provide a mechanism by which to identify authentic Galileo signals (i.e., the signals have come from real Galileo satellites) and reject or mark those that have not, be they generated intentionally or unintentionally.

A related challenge is developing cost-effective means to reject reradiated

or artificially generated Galileo signals — an antispoofing capability. Employment of antispoofing techniques will allow the user to be confident that, if the receiver processes Galileo-type signals, then they are from authentic Galileo satellites. This anti-spoofing capability will be referred to as “authentication,” the subject to which we now turn.

Let us begin by defining the Galileo-specific requirement for authentication:

Galileo Signal Authentication will add information to the satellite signals that will allow a Galileo receiver to identify authentic Galileo satellite signals from unwanted GNSS signals, or re-played Galileo signals, generated intentionally or unintentionally. Galileo commercial Authentication does not certify or authenticate the signal quality or data content, but merely the origin of the signal.

A point to stress overall is that the authentication function is an addition to the Open Service or Safety of Life Service. Hence, these services will provide full and open navigation performance without the authentication function. The latter function merely adds a layer of trust or confidence to these services.

Another key point is the difference and complementarities of “authentication” and “integrity.” Integrity as discussed earlier in connection with the ARMAS project creates trust in the performance of Galileo by providing protection levels (an upper boundary on the position errors), assuming the signals and data processed are genuine Galileo ones. *Authentication* provides a guarantee that this assumption of genuine signals is indeed true, and consequently that the user or service provider trust is effectively placed in Galileo and not elsewhere.

Coming back to our example application, the combination of integrity and authentication is what will truly allow Galileo derived positions to be trusted.

The definition of Open Service signals is public. Therefore, generation of false satellite signals is relatively easy regardless of the user mode or trajectory being simulated or “spoofed.” Con-

sequently, authentication requires the addition in the signals of some secret “authentication pattern” unpredictable by would-be spoofers.

The diagram in **Figure 7** is, again, a simplification, but it captures the outline of the requirement and implementation. “Authentication” blocks are marked in blue.

The Galileo Control Segment is the “owner” of the secret authentication mechanism. Ad hoc commands and data are uploaded into the satellites to permit the generation of the “authentication pattern” and its addition to the broadcast signal in space. “Authentication-capable” receivers are fitted with a specific algorithm to decode the received authentication pattern and, when activated with the proper key, to check its validity. “Standard” receivers on the other hand will just ignore the authentication pattern and perform normally.

At the time of writing, specific implementation details are still being discussed between the GOC and the Galileo Joint Undertaking (GJU) regarding the authentication service. However, both parties seem to recognise the importance of this feature, which in combination with integrity is a true enabler of GNSS-based “liability critical applications.”

Galileo’s “Third Partner”

The Galileo program is now entering a new phase. The European GNSS Supervisory Authority (GSA) is replacing the GJU and the future concessionaire or the Galileo Operating Company (GOC) will eventually take on the task of deploying and operating the Galileo system. In this process, it is still crucial to have a good link with the ultimate customers of Galileo – namely the end users.

Galileo Services and its members have played a vital role thus far in the Galileo development by establishing and maintaining such links. By already being well grounded as leading players in the GNSS applications and services markets, an excellent basis exists for understanding the users requirements of today and those of tomorrow.

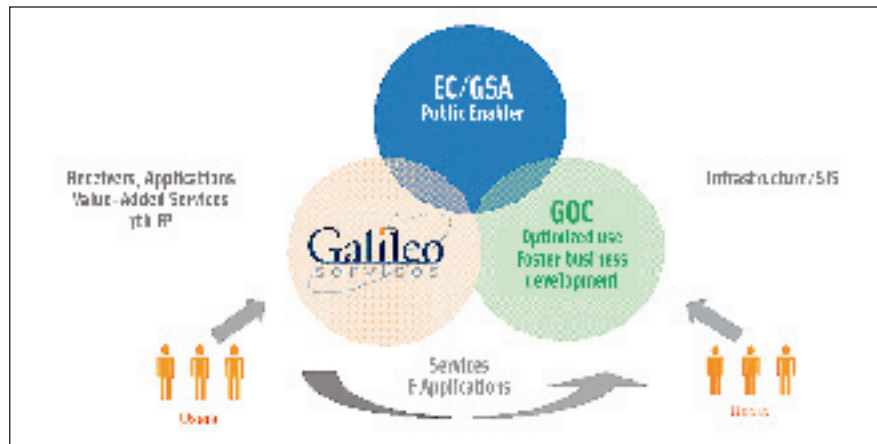


FIGURE 8 Galileo Services, a key partner for the Galileo Supervisory Authority and the future Galileo Concessionaire

To further enhance this position Galileo Services has also adopted new statutes to enable the expansion of the association towards an ever broader representation of GNSS downstream industry and service providers and a wider coverage of markets in the different regions of the world. This means that non-European companies that have interests in GNSS and Galileo downstream applications are also welcome to join the association. The role of Galileo Services is illustrated in **Figure 8**.

In this new context the mission of the Galileo concessionaire will be to transform the ESA/Galileo Industries system design of Galileo’s space and ground infrastructure into a tool for creating business. Meanwhile, the Galileo Supervisory Authority will consolidate the full public engagement and expectations whilst enabling the regulatory environment to enable and facilitate the downstream business development.

Galileo Services has the ambition to continue its role as a key partner regarding services and applications for system’s users. In that capacity the association will propose areas of market/business development, innovative business models, and service level agreements; promote the use of Galileo worldwide; stimulate R&D (including recommendations for the EU 7th Framework Programme (FP7); assist the program implementation; contribute to standardization and certification process; propose EGNOS/Galileo Systems’ improvements; and

foster user-driven performance of the infrastructures.

One of the main tasks of the association since its foundation has been to take the position of the users and contribute counsel and advocacy to ensure that Galileo will be in line with users’ needs. This process is ongoing and will also be highly relevant as the concessionaire details its suite of services. With this in mind, Galileo Services aims at establishing a close dialog with the concessionaire and the GSA.

An important incentive for developing early applications and services for Galileo are the EU Framework Programs. Within FP7, which starts next year, funds will be allocated for a period of seven years specifically for the development of Galileo applications and services. In addition to the continuation of key Galileo application developments initiated under FP6, in cooperation with the concessionaire, FP7 is expected to focus on a range of activities including specific applications and services of Galileo enabling technologies, technology integration, signal processing, public interest applications, standardization/certification, system evolution, user awareness, demonstrations and promotion, regulated and certified applications, support framework for applications and services, and projects oriented toward small and medium-sized enterprises.

Most of the projects carried out as part of the framework programs have

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a substantial financial contribution from the industry. For the industry to invest in these projects it needs to see a potential return on investment. This approach ensures that the development is well founded within the core business activities of the participating companies and is a good insurance that the initiatives are on the right track.

The involvement of Galileo Services shows that the downstream industry is highly committed to contributing to the development of Galileo, both of the system and its applications and services. The association is ready to take advantage of the opportunities presented by Galileo as early as possible in order to develop competitive and sustainable solutions for users worldwide.

Manufacturers

The ARMAS Geodetic GPS (GGPS) used 4000 SSE receivers from **Trimble**, Sunnyvale, California, USA, and corresponding post-processing software. The

ARMAS In-Car System (ICS) incorporated a PolaRx2 single-frequency GNSS/SBAS receiver from **Septentrio**, Leuven, Belgium. The ICS inertial sensors were MTi inertial measurement units from **Xsens**, Enschede The Netherlands.

Additional Resources

For further information on Galileo Services:

Visit us at our booth in the ION GNSS 2006 exhibition (September 26-29, 2006, Fort Worth, Texas, USA, booth number 909) Contact: Marie-Laure Mathieu, Galileo Services Permanent Representative, e-mail: marie-laure.mathieu@galileo-services.org Website: www.galileo-services.org

For information on the eSafety Forum's digital maps activities, see: http://europa.eu.int/information_society/activities/esafety/forum/digital_maps/index_en.htm

European Commission, "European transport policy for 2010: time to decide" (white paper), http://ec.europa.eu/transport/white_paper/index_en.htm

Authors


Sergio Barbedo is director of Skysoft Portugal, responsible for business development of the mobility, IT, and Defence areas.

Miguel Ángel Martínez Olagüe holds the position of director of corporate business development at GMV group with particular focus in supporting GNSS strategy.

Rob van Essen holds the position of director of strategic research at Tele Atlas and is an expert in the development of new technologies and markets related to digital map data.

Liévin Quoidbach is vice-president, government marketing & strategy Europe, at Navteq. He is particularly involved in ITS projects, eContent, and map applications in Galileo environment.

Jean-Pierre Barboux left his position as Thales Navigation's director of strategy & business development in January 2006 to join the Thales corporate task force on the Galileo concession as an expert for the downstream GNSS industry (receivers and applications).

Gard Ueland is vice-president of research and development with Kongsberg Seatex AS in Norway and holds the position of president of the Galileo Services Association. 



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