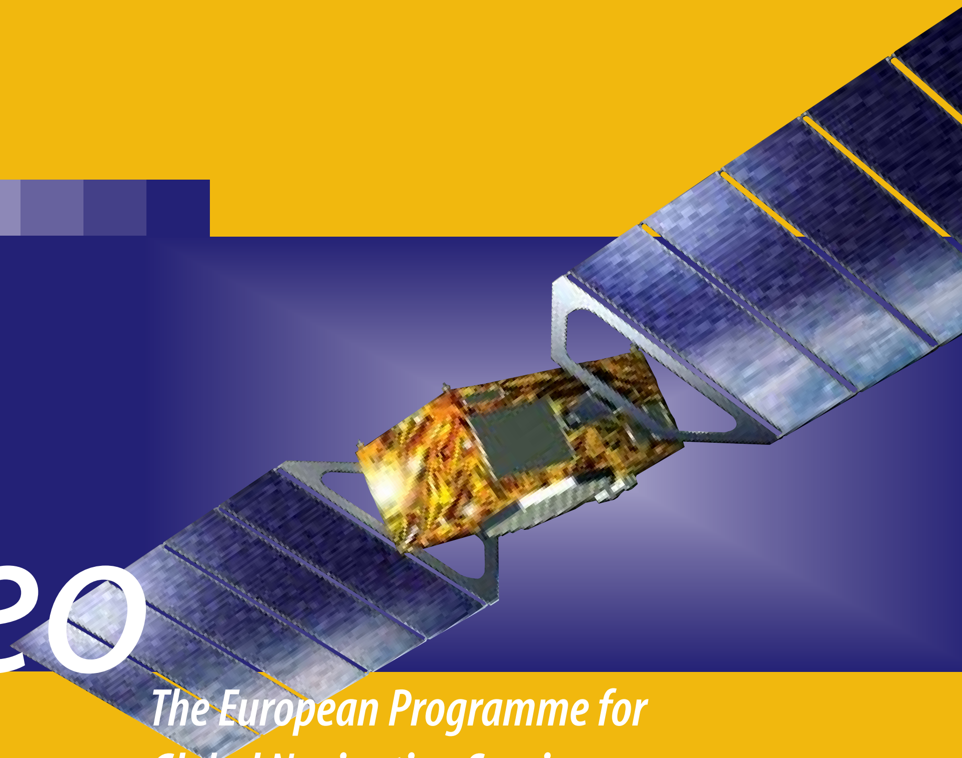
Galileo



The European Programme for Global Navigation Services

esa

European
Commission

Galileo

The European Programme for Global Navigation Services

BR-186 (2nd edition; English)
January 2005

ISBN 92-9092-738-0
ISSN 0250-1589

Coordinator: Muriel Simon, Galileo Joint Undertaking

Editor: Andrew Wilson, ESA Publications Division

Design & layout: Carel Haakman & Andrew Wilson, ESA Publications Division

Published by: ESA Publications Division, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands

Price: EUR 10

Printed in The Netherlands

Contents

Galileo

Galileo, the first satellite positioning and navigation system specifically designed for civil purposes, will offer state-of-the-art services with outstanding performance in accuracy, continuity and availability. It will be more advanced, more efficient and more reliable than the current US GPS monopoly.

Galileo: a Technical, Economic and Political Challenge

Galileo will provide the first satellite positioning and navigation system specifically for civil purposes. Its profitable applications will spread into many areas of all our lives – starting with safe and efficient transport. Using only small receivers, we will all be able to determine our locations to within a few metres.

Galileo is vital for the future of Europe's high-technology industries. It will generate new, large markets and provide the critical advance in technology for Europe and its partners.

It is crucial for Europe to have a choice independent of the current US Global Positioning System (GPS). In addition, the scale of future navigation needs and the requirement for global coverage cannot be satisfied by a single system alone.

A recent agreement with the US will ensure interoperability of Galileo with GPS. Galileo is thus becoming the *de facto* world standard for open signals in the GNSS mass market.

The Galileo programme has been launched. The cost of deploying the system is some EUR 3.4 billion. The system will create more than 100 000 new jobs and a market for equipment and services worth some EUR 200 billion per annum by 2013.

Galileo

Getting the Most from Satellite Navigation

Satellite Navigation and Timing

Satellite navigation pinpoints a location by measuring the distances to at least three known locations – the Galileo satellites. The distance to one satellite defines a sphere of possible solutions. Combining three spheres defines a single, common area containing the unknown position. The accuracy of the distance measurements determines how small the common area is and thus the accuracy of the final location. In practice, a receiver captures time signals from the satellites and converts them into the respective distances.

The position accuracy depends on the accuracy of the time measurement. Only atomic clocks provide the required accuracy, of the order of nanoseconds (10^{-9} s), and the necessary stability, of the order of 10 nanoseconds per day for Rubidium Atomic frequency standard and 1 nanosecond per day for hydrogen-maser atomic clocks. Such clocks are a major technology element aboard the Galileo satellites and contribute to the definition of international time standards. The time measurement is improved by including the signal from a fourth satellite, so special care is being taken in selecting the numbers of satellites and their orbits.

The Advent of Galileo

Galileo comprises a constellation of 30 satellites divided between three circular orbits at an altitude of around 23 000 km to cover the Earth's entire surface. They are supported by a worldwide network of ground stations. At present, there are two radio navigation satellite networks: the US GPS and the Russian Glonass systems, both designed during the Cold War for military purposes, although the Russian system is not yet fully deployed. Galileo circumvents the vulnerabilities of a single infrastructure (GPS), and offers the possibility of making satellite navigation services more robust, more reliable and safer.

GPS is used to a large extent for civil purposes but it does have several major shortcomings:

- a varying position accuracy (sometimes to only several dozen metres), depending on place and time;
- the reliability leaves something to be desired. Regions at high latitudes, crossed by many aviation routes, do not have dependable coverage. Signal penetration in dense areas and town centres is unreliable. Furthermore, the predominantly military character of GPS means there is always a risk of civil users being cut off in the event of a crisis.

Whether intentional or otherwise, signal interruptions of existing navigation systems can have disastrous consequences, especially as there is no warning and no immediate information about errors to users. For example, a Canadian research body highlighted the case of an aircraft affected by an unannounced signal interruption of more than 80 minutes, aggravated by an initial positioning error of 200 km when contact was

reestablished. The Icelandic aviation authorities reported several transatlantic flights in their control zone similarly disturbed. Civil aircraft suffered 20-minute signal interruptions in three mid-US states, and airline captains have reported the same phenomenon over the Mediterranean.

In August 2001, the report of the Volpe National Transportation Centre commissioned by the US Government clearly stressed a number of such shortcomings. Even the advent of the improved GPS III, which the US is considering, would not resolve all of them. There is a total absence of service guarantee and accountability – as these are incompatible with the system's military objectives – with all the implications that can be envisaged in the event of an aviation accident or an oil tanker wreck.

The European Union (EU) therefore decided, in close cooperation with the European Space Agency (ESA), to develop a system of its own that meets the criteria for accuracy, reliability and security.

Galileo offers superior and constant accuracy thanks in particular to the structure of its satellite constellation and ground control system. Guaranteed accuracy to better than 1 metre is necessary for certain applications such as entering a seaport or guiding a vehicle into a parking space.

Galileo offers superior reliability because it includes an integrity message that immediately informs users of possible errors, and because it covers difficult areas such as northern Europe.

Recognising the importance of Galileo, an agreement has been reached between Europe and the United States on the interoperability and compatibility of the two systems, leading to Galileo to become the world standard for satellite navigation services.

Galileo will provide the very high level of continuity required by today's business, particularly for satisfying contractual responsibility.

Applications Markets

Satellite transmission is now a fact of life in telephony, television, computer networks, aviation and shipping and many other areas. The range of applications open to the Galileo system is extremely varied and the number of potential spin-offs immense.

The benefits to future driving systems are of vital importance. At present, road accidents (including 40 000 fatal ones) generate social and economic costs corresponding to 1.5-2.5% of the gross national product (GNP) of the European Union. Road congestion entails additional estimated costs of around 2% of the European GNP. A significant reduction in these figures as a result of Galileo will therefore have enormous socio-economic benefits, quite apart from the number of lives saved.

The number of inland transport applications is expanding. Motor vehicle makers now offer their customers navigation units that combine satellite location and road data to avoid traffic jams and reduce travel time, fuel consumption and therefore pollution. Road and rail transport operators will be able to monitor the movements of their lorries, wagons and containers more efficiently, and combat theft and fraud more effectively. Taxi companies now use these systems to offer a faster and more reliable service to their customers. Road tolling based on Galileo will be a reality.

The aviation market will also benefit largely from the safe services offered by Galileo; By 2020, at least 120 000 aircraft (from civil transport, general aviation, helicopters, etc.) will use satellite navigation in conformity with international aviation standards.

The value of Galileo is not limited to the economy and companies. It will also clearly be a valuable tool for the emergency services (fire brigade, police, paramedics, sea and mountain rescue), who will respond more rapidly to those in danger. Galileo can guide the blind, monitor Alzheimer's sufferers with memory loss, and guide explorers, hikers and sailing enthusiasts.

Many other sectors will also benefit from Galileo. It will be used as a surveying tool for urban development and large public works, for geographical information systems, for managing agricultural land more efficiently, and helping to protect the environment. It will be a means towards developing third-generation mobile phones with Internet-linked applications. It will facilitate the interconnection of telecom-munications, electricity and banking networks and systems via the extreme precision of its atomic clocks. It will also be of paramount importance to help developing countries preserve their scarce natural resources and develop their international trade.

The applications prospects are enormous. As with the microcomputer 20 years ago or the Internet 10 years ago, it is highly likely that at the moment we can only see the tip of the iceberg.

To meet all these demands, Galileo will offer several levels of service:

– a basic level free of direct charge for the final user, emphasising consumer applications and general-interest services. GPS is also free for these applications but Galileo offers better quality and reliability;
– restricted-access service levels for commercial and professional applications that require superior performance to generate value-added services. These levels range up to a highly restricted service for applications that must in no event be disturbed.

The paid-for services will contribute to the economics of the system.

Crucial Issues

Crucial issues are at stake for the future of Europe. Galileo will enable Europe to acquire technological independence, as it did with the Ariane and Airbus initiatives. It is vital that Europe should be included in one of the main industrial sectors of the 21st century, an area that is already widely recognised in the US. Without Galileo, the development or even the survival of European new technology sectors would be under very serious threat. The technological advance from Galileo will give the participating European industries a considerable competitive advantage in this sector and in the many ensuing applications.

The equipment and services market resulting from the programme is estimated at around EUR 10 billion per annum, with the creation in Europe of more than 100 000 highly skilled jobs. Conversely, if Europe misses out on these new developments, many electronics and aerospace jobs would ultimately disappear.

In terms of international cooperation, leading-edge technologies are prime assets for Europe's standing in the world.

The EU has clearly stated that it is willing to involve interested non-member countries in Galileo's research, development and industrial commissioning activities. The EU has clearly stated that it is willing to involve interested non-member countries in the Galileo's research, development and industrial commissioning activities; China and Israel are already involved. This can only strengthen our links and common interests, quite apart from the choice that will be offered to the entire world.

International Cooperation

Galileo is a global system and requires global partners for developing its full potential. Consequently, Galileo will not just be the result of cooperation between European countries, but it will embrace the involvement of a rapidly increasing number of other countries. Cooperation with those countries will result in a better technical harmonisation with the other satellite navigation systems in the world, strengthen the worldwide infrastructure needed to operate the system, and develop and stimulate the markets worldwide.

The European Union has recently concluded cooperation agreements with a number of countries with a view to meeting such objectives:

– with the US in order to assure the interoperability and compatibility with GPS;
– with China and Israel, in order to create a framework for cooperation on a wide scale for industrial, research and scientific activities (standardisation in particular), regional integrity monitoring and financial participation in Galileo;
– discussions with the Russian Federation are under way with a view to creating the cooperation mechanism that will allow Galileo to benefit from the experience of the

development and operation of Glonass.

The number of countries wishing to participate actively in Galileo is growing. The European Commission is holding discussions with Ukraine, India, Brazil, South Korea, Mexico and Australia.

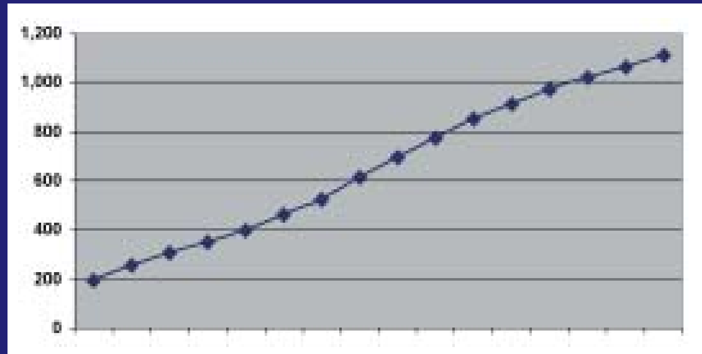
Within the scope of the political cooperation agreements that are being concluded with the European Union, and indeed as one of the underlying objectives, a number of entities of these countries are establishing active participation in the Galileo Joint Undertaking. Thus, in October 2004 the National Remote Sensing Centre of China became the first new member of the Joint Undertaking, joining the founding members, the European Union and the European Space Agency. Through the agreement, China has committed an investment of EUR 200 million in order to finance specific activities in the development and deployment phases. The development-phase activities, to be designed to meet the specific needs in China, are complementing the established work programme for this phase and focus on infrastructural and related areas (such as local elements and local augmentations, ranging station, sensor stations, SAR-payload), as well as on applications and market development (multi-modal, user segment, standardisation and certification, frequency coordination, joint workshops and research activities).

Like China, Israel has also indicated its aim of investing soon in Galileo by joining the Galileo Joint Undertaking, through the Israel Export and International Cooperation Institute.

Investment and Economic Viability

Galileo is not expensive. Its development and deployment cost, including the launching of 30 satellites and the installation of ground equipment, is EUR 3.4 billion. This is equivalent to the cost of building

Projected Worldwide GNSS Unit Sales (millions)





150 km of semi-urban motorway or a main tunnel for the future high-speed rail link between Lyon and Turin. This is less than the Øresund link between Denmark and Sweden, or the fifth terminal now being built at Heathrow airport. It is roughly two-thirds the cost of the high-speed rail link between Liège, Cologne and Frankfurt, or the 160 km Betuwe rail infrastructure project for container transport in The Netherlands.

The Galileo infrastructure is economically viable. PricewaterhouseCoopers, based on projections over a period of 20 years, indicated a cost/benefit ratio of 4.6 – higher than for any other infrastructure project in Europe. This figure was obtained through conservative estimates, and the benefits calculated took into account only a few transport sectors.

The economic viability has been confirmed by all candidate consortia for the Galileo concession.

An Original and Innovative Structure

Galileo is adopting an original and innovative legal structure to encourage public-private partnership. To complete the development and validation phase, and pave the way for the deployment phase, an original form of company provided for in Article 171 of the Treaty establishing the European Community has been set up: a Joint Undertaking. Its founder members are the EU and ESA. In addition, the European Investment bank and, at a later stage, firms subscribing a minimum of EUR 5 million (EUR 250 000 for Small- and Medium-sized Enterprises subscribing individually or collectively) can also become members.

In addition to the space sector, which is accustomed to benefiting from the EU's research programmes, the foundations for public-private partnership is laid with a wide range of firms. By contributing to the capital of the Joint Undertaking, firms will take their share of the normal risks inherent in industrial activities. Public funds cannot be expected to cover all of the costs involved.

While it is the responsibility of the public sector to carry out forward analyses, detect future emerging markets, encourage their development and prepare the required technologies – as with Ariane and Airbus – it is also necessary for large firms, which in some cases have until recently been featherbedded by the public authorities, to look themselves beyond the short term if they want to survive in the face of world competition.

Public Private Partnership

The Galileo system will be managed and operated in the form of a concession as part of a public-private partnership (PPP), a structure that allows the project to be financed by both public and private funds. The principle objective of a PPP is to achieve best value for money for the public sector by minimising the whole life cost of the project while maximising the benefits and revenues.

While the private-sector concessionaire will be responsible for managing the deployment and operational phase – and thus making a substantial contribution to the financing of the project – a limited public contribution is foreseen for the deployment phase and the first years of the commercial operating phase.

The Concession Process

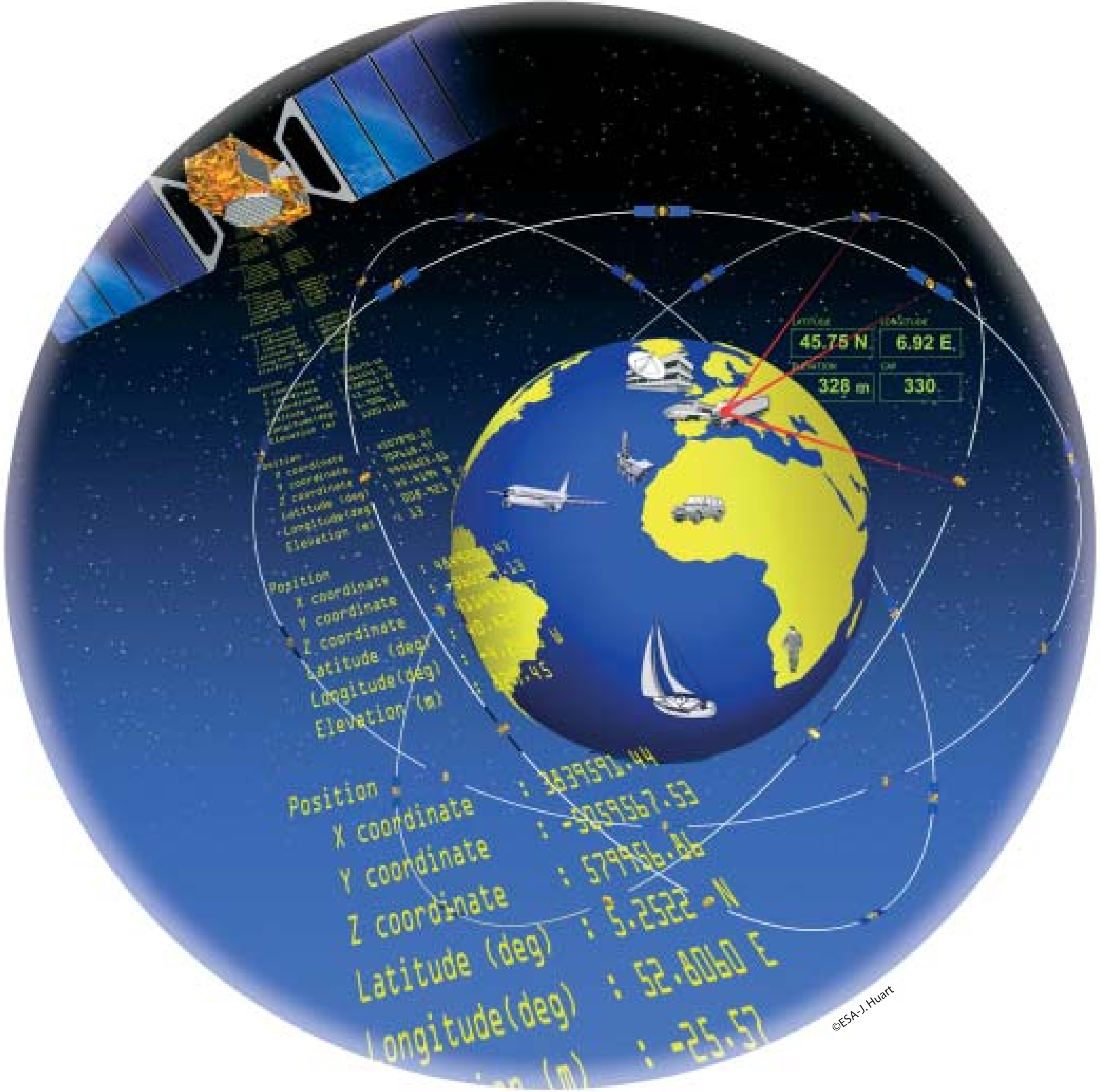
The Galileo deployment phase will be financed in PPP. The Galileo Joint Undertaking is to help mobilise the public and private sector funds required to complete the various phases of the programme.

In achieving this goal, the Galileo Joint Undertaking plays a key role by managing a competitive tendering process aimed at negotiating an overall PPP contract for financing the deployment and exploitation phases of the programme. The contract clearly sets out the responsibilities, roles and risks to be shared between the public and private sectors.

The Galileo Joint Undertaking manages the Concession process. It addresses the various technical, legal, commercial and financial issues related to the development of the Galileo business plan, the fund-raising and risk allocation and the integration of EGNOS with Galileo.

The Concession process will be successfully concluded through the establishment of the Galileo Concession Contract. The public counterpart (i.e. the conceding authority), representing the interest of the public partners, is the Galileo Supervisory Authority.

Galileo



©ESA-J.Huart

Applications: Opening New Horizons

Galileo is conceived as a core infrastructure upon which applications will be built. It will form part of society's greater technical infrastructure, including communications and broadcasting systems, on which we will all rely heavily. The applications made possible by Galileo stretch beyond the determination of a user's position and time, and instead integrate new technologies to satisfy coming user needs.

Applications underpin and foster European innovation in industry, research and small- and medium-sized enterprises. In some areas, they can produce direct benefits for citizens and their social environment by improving system efficiency and economic return, or simply by facilitating everyday activities.

Galileo applications will rely on integrated services: navigation data are combined with additional information layers. The numerous domains range from transport (air, rail, maritime, road, pedestrian) to timing, surveying, law enforcement, engineering, science, environment, search and rescue, and even recreation. These in turn directly affect business areas such as oil and gas, banking, insurance, telecommunication, tourism and agriculture.

Some applications require the system to have special features. These features do not exist in the current positioning systems and will constitute added value for Galileo as a civil system. They may include service guarantee, authentication of the signal, integrity of the signal, liability of the service operator, traceability of past performance, operation transparency, availability of raw and processed data from the core system, certification and competitive service performance in terms of accuracy, continuity and availability. In addition to all these features, the Galileo Supervisory Authority and the Galileo Concessionaire will provide an institutional, regulatory and commercial framework to facilitate and regulate the exploitation of the downstream worldwide market. New applications are appearing every day in this huge market, which is projected to reach 3 billion users in 2020.

Transport

The transport applications are the user category par excellence for Galileo. The system's services will be used in every transport domain – aviation, maritime, road, rail and even pedestrian. Each user segment has its own characteristic needs, and Galileo is designed to satisfy them all.

In civil aviation, Galileo can be used in the various phases of flight: en route navigation, airport approach, landing and ground guidance. In particular, Galileo local elements will allow for applications like precision approach in conditions of limited visibility. Galileo will enable the transition to a GNSS service concept in aviation that finally leads to a reduction of the current ground infrastructure.

Galileo will also be an efficient tool for the implementation of the Single European Sky.

In maritime navigation, Galileo will be used for onboard navigation for all forms of transport, including ocean and coastal navigation, port approach and port manoeuvres. Galileo's characteristics, which make it suitable even for today's most demanding applications, will permit the definition and development of new applications, such as the Automated Identification System (AIS), to improve safety in navigation. Inland waterway navigation, even in critical environments, will also benefit from Galileo and its interoperability with other systems and sensors. The River Information System (RIS) will benefit even more in general.

Road applications include in-car navigation, fleet management of taxis, lorries and buses, road tolling and driver assistance. Road operators will be able to exploit their network efficiently, basing the electronic fee-collection systems – currently being developed – on the reliable and accurate Galileo position. Information services for road users can also be based on Galileo. Traffic behaviour can be monitored via onboard navigation recorders to generate useful information for other road users. Vehicle data can be stored together with exact time stamps and precise position information for liability purposes in case of accident. In order for the recorded data to be usable in court and for insurance companies, they need to be highly reliable, guaranteed and derived from a certified system. Galileo meets these requirements.

Galileo performance levels – often supported locally by terrestrial components – and its enhanced reliability (guaranteed continuity and integrity) will improve safety and mobility in road traffic. Advanced Driver Assistance Systems combined with Galileo receivers will include features such as collision warning, vision enhancement and low-speed manoeuvring aids.

The rail community will also benefit, from train control, train supervision, fleet management, track survey and passenger information services. Railway operations are a safety-of-life application, where Galileo can help to reduce the number of accidents, which may involve hundreds of victims. To control such risks as hazardous materials travelling through densely populated areas, a high level of accuracy is required together with high levels of integrity, availability and guarantee of service. Galileo-based automatic level crossing systems will be a safer alternative to today's many unattended level crossings in rural areas. Certification of the service is a *sine qua non* for deploying a system meeting the safety needs of rail applications.

Satellite navigation will play a role in improving border controls. Physical controls could be restricted to goods or persons not monitored via this technique. Increased efficiency will benefit customs authorities as well as the public.

Galileo will have a primary role in all of the above applications because of its core characteristics of certification, operations transparency and service guarantee derived from its civil nature. In addition, the integrity monitoring feature (real-time 'integrity flags') of the navigation performance over the whole service area makes Galileo suitable for all the safety-of-life applications.

Energy

The very precise timing obtainable via Galileo will help to optimise the transfer of electricity along power lines. Galileo could also help in the maintenance of the electricity-distribution infrastructure. Power grids are continuously monitored by a range of instruments spread around the system. Information from these instruments is used to repair the

system when a power line breaks or weaknesses appear in the grid. Galileo will improve the instruments' time synchronisation to provide a speedier return to full service. The 'trustubility' and 'traceability' of the Galileo time stamp will facilitate the contractual and commercial agreements for the power distribution contract between public and private contractor/s.

The oil and gas sector can benefit from Galileo in a large number of areas. For instance, marine seismic exploration will use the positioning service both for the seismic acquisition vessel as well as for the seismic streamer arrays and gun arrays. This will enhance the safety of drilling activities, by enabling high-resolution surveys of the new sites and the identification of any geomorphological or geophysical risks.

The positioning of the rig and its anchor-handling vessel will be improved through Galileo. Accurate positioning information will be provided during transit and final positioning of tow tugs relative to the rig, the anchoring of semi-submersibles and any independent drilling rigs. The final position of the drilling facility will be determined as well as the final orientation of the platform to a high degree of accuracy.

The trend in the oil and gas sector is to move away from established finds towards remote sites without any local infrastructure. In these areas, satellite positioning and communications are of vital importance. Real-time data transmission combined with position determination enables oil companies to make real-time decisions on drilling operations. Integrity information, provided by Galileo, is of paramount importance when approaching the target and preparing to anchor or lower the drilling platform legs.

Finance, Banking and Insurance

As online financial transactions become an increasingly common part of daily life, the integrity, authenticity and security of transmitted data have emerged as major issues in the electronic exchange of documents. For example, one of the biggest concerns in e-commerce is the security of information provided by the customer in the purchasing process. This usually calls for a dedicated encryption system. Similarly, e-banking suffers from risks such as falsified transactions and unauthorised access to documents, accounts and credit cards. Stock exchange activities are subject to similar risks. Data-stamping based on a legally traceable time reference will reduce these risks.

Online systems have created the need for accurate and legally accepted documentation that provides detailed information on the user and the type and size of transaction. Electronic signatures are currently used, but time-stamping will dramatically enhance the security of these systems. A Galileo-based trusted-time signal could be used for a reliable encryption system, offering the additional value of traceability and liability of the time information.

In the insurance sector, Galileo provides an effective way of controlling and monitoring valuable goods. This includes the transportation of gold bullion between national banks, works of art, and large numbers of banknotes for distribution to banks or for destruction. Continuous tracking reduces the risks and thus benefits the insurance companies and their customers.

The certified services offered by Galileo not only provide legally-accepted information, but also enable a great number of services related to car and property insurance. This is expected to generate significant return for the insurance sector as well as for the end users, as it could bring about innovative prime and policy conditions based on 'pay per use' and increased confidence on insurance-associated risks.

Agriculture and Fisheries

With food security climbing ever higher up the decision-makers' agenda, together with food risks and consumer concerns, achieving traditional productivity targets at all costs is no longer the main driver in agriculture. On the contrary, farmers aim for better quality agricultural products, while respecting the environment and maintaining acceptable income.

Navigation can contribute to yield monitoring and the spraying of fertilisers, herbicides and insecticides to replenish low-yield areas and control of weeds and pests. Galileo receivers can be installed easily on harvesters, tractors and self-propelled sprayers.

Proper yield monitoring entails not only effective resource management and consequently significant return, but also contributes to safeguarding the agri-environment, which, in turn, is often regulated by a series of rules. There might be a legal requirement for farmers to provide map evidence showing the exact areas where chemicals were sprayed.

Another application in the agriculture domain is based on Galileo terminals performing 'certified' agriculture parcel measurements to provide cost-effective solutions for both users and controllers.

The fisheries sector will similarly benefit from Galileo. Apart from the day-to-day navigation and positioning of vessels, Galileo can help to monitor fish resources. This can be enhanced with data from the sea and environs.

Certified Galileo services will allow authorities to confirm that fishing vessels operate only in designated areas. This applies all the more at the international level, where there are strict rules governing the invasion of national water boundaries.

Similarly, Galileo will provide the means to establish or improve land registries. This will help to create legal security where cadastral information today is often inaccurate or even unavailable.

Personal Navigation

Galileo opens the door to several location-based services by integrating positioning with communications, typically in handheld terminals. A handset will determinine its position using either Galileo alone or in conjunction with other systems.

Location-based services depend on service providers or network operators knowing the position of the mobile caller in order to provide appropriate information. Data sent to a user's handset can be automatically customised to provide on-demand services such as information about nearby restaurants, hotels and theatres, and weather forecasts.

This technique is particularly important in emergency situations for identifying callers with only vague ideas – or none whatsoever – of their locations. The locations can be automatically determined and reported to the nearest emergency services. This concept is part of the development, in Europe, of the E-112 emergency call programme.

People-tracking is another application, where external staff could be coordinated more efficiently: medical and welfare employees visiting patients; policemen; fire engines; commercial workers. This service can be used generally to control and coordinate the activities of a group. The same technique can improve the safety of children on their way to school.

The billing systems of mobile communications networks could be improved. Today, mobile network operators vary their call charges depending on the time of day. Soon, by pinpointing handsets, they could also charge on the basis of location, allowing corporate tariffs in small areas. Location-based billing could extend to services such as road tolling and automated tourist guides.

Emergency and Crisis Management

Crisis and emergency management require fast response times and the most efficient use of resources. An effective response to forest fires, for

example, calls for early alert and reliable and accurate position information about the location of the fire. Police and emergency services need reliable and accurate knowledge of the location of deployed forces in order to coordinate them efficiently. This issue is particularly critical when the 'traditional' infrastructures (electricity, water, roads, communications, etc) are not available because of the emergency conditions. The speed of implementing temporary backups then becomes critical. Galileo, with its reliable signal, can play a fundamental role in this situation.

Other crisis situations include floods, maritime emergencies, oil spills, earthquakes and humanitarian aid operations.

Environmental Management

Galileo is expected to play an important role for the scientific community. The availability of new frequencies and different signals will increase the possibilities of analysing data for different purposes. For example, the continuous collection of data will allow new experiments in various research areas. Galileo can contribute to ocean and cryosphere mapping, including the determination of the extent of polluted areas (and tracking offending tankers to their origins), studies of tides, currents and sea levels, and tracking of icebergs. It will help to monitor the atmosphere, including the analysis of water vapour for weather-forecasting and climate studies, and ionospheric measurements for radio communications, space science and even earthquake prediction. In nature, the movements of wild animals can be tracked to help preserve their habitats.

Surveying

The surveying sector covers a very wide and heterogeneous set of users: land and maritime survey for cartography, mapping, cadastral survey, hydrography, natural resources, geodesy, marine seismic exploration, etc. All these users have a common need: the high accuracy in positioning for professional business. Today, some of these users are using Differential GPS (D-GPS) techniques that are constrained by the availability of stations in the area of interest. They are also very expensive for the final users.

Galileo will open new opportunities in this market by offering a global world-wide service, with sub-metre accuracy thanks to the additional dissemination of encrypted navigation-related data, ranging and timing – all with a service guarantee. Moreover, the service guarantee will open new scenarios for business situations involving third parties with commercial and contractual relations. For example, there might be contracts between public authorities and private companies to provide 'certified' surveys for public applications.

Recreation

The leisure market will see a tremendous surge in developments that we cannot even imagine today. GPS services are already established for recreational flying and sailing, but Galileo will extend them to personal navigation via handsets with map displays and secondary communication functions. Integration with mobile communications technology will open up new scenarios and applications for personal mobility.

Attractive tourist packages can be based on Galileo coupled with interactive multimedia communications linked to local information providers.

The key advantage of Galileo is its focus on interoperability, which will easily allow its integration – at system and user levels – with existing and future systems, such as GSM and UMTS.

In the same way that no-one nowadays can ignore the time of day, everyone in the future will need to know their precise location.

Galileo

Services: Bringing Space to the User

Satellite navigation positioning and timing services are becoming an indispensable element in many activities. Managing and controlling the various modes of transport, and their related safety-of-life aspects, communications networks and many other utilities are expected to rely heavily on satellite navigation. Mass-market applications, including combined mobile communications and navigation systems, are growing rapidly, with their own needs. Galileo is designed to satisfy the requirements of such a wide range of applications.

The Galileo Services Approach

In contrast to GPS, Galileo will broadcast integrity information for some critical applications, assuring the quality of positioning accuracy. Users will receive a timely warning whenever the system fails to meet its stated accuracy. The Galileo system guarantees that this warning is sent out quickly enough even for the most demanding of applications, such as aircraft landing.

Guaranteeing signal accuracy and integrity provides a competitive edge for the swift introduction of Galileo's services in the presence of the existing GPS system. Galileo will give service providers and users alike the necessary confidence in their investments.

Guaranteed accuracy and integrity calls for a scheme defining the roles of the public and private partners. Globally recognised signal standards are essential for the worldwide acceptance of satellite navigation and will permit speedier adoption of the system by all user communities. Certification of system elements or functions that are mandatory for safety-critical applications will assure other users that the system is reliable.

This framework will be defined in consultation with international organisations such as those dealing with air and maritime navigation, and with national authorities regulating specific applications.

Galileo as a Global and Open System

It is clear that Galileo needs to serve all parts of the world, not only to provide a seamless service to maritime and civil aviation users but also to allow European equipment-makers and operators to sell their products globally. The synergies between navigation and communications are obvious and need to be fostered right from the beginning. There are immediate opportunities in conjunction with mobile terrestrial networks such as GSM and UMTS, with satellite communications networks providing the extensions where needed.

To guarantee European independence, Galileo needs to be a standalone infrastructure, yet it must be compatible and interoperable with systems such as GPS, not only to achieve the highest possible availability but also to ease the introduction of its services. Moreover, Galileo is able to accommodate the later integration of regional components.

User Needs and Services Mapping

The need for several service categories, in terms of accuracy, service guarantees, integrity and other parameters, has been identified. Most requirements will be met solely with the satellite signal, in many cases in combination with auxiliary sensors that can, for instance, be in the user's vehicle. Improved service requirements can be satisfied most effectively by local components, offered as value-added services by private operators. The various service requirements and their associated performance level and security aspects can be rationalised into five distinct service groups, as described below.

The Galileo ***Open Service*** (OS) is defined for mass-market applications. It provides signals for timing and positioning, free of direct user charge. The Open Service will be accessible to any user equipped with a receiver. While up to three separate signal frequencies are offered within the Open Service, cheap single-frequency receivers will be used for applications requiring only reduced accuracy. In general, Open Service applications will use a combination of Galileo and GPS signals, which will improve performance in severe environments such as urban areas.

The Open Service does not offer integrity information, and the determination of the quality of the signals will be left entirely to the users. There will be no service guarantee or liability from the Galileo Operating Company on the Open Service.

The ***Safety-of-Life Service*** (SoL) will be used for most transport applications where lives could be endangered if the performance of the navigation system is degraded without real-time notice. The Safety-of-Life Service will provide the same accuracy in position and timing as the Open Service. The main difference is the worldwide high-integrity level for safety-critical applications, such as maritime, aviation and rail, where guaranteed accuracy is essential.

This service will increase safety, especially where there are no traditional ground infrastructure services. This worldwide seamless service will increase the efficiency of companies operating on a global basis – airlines and transoceanic maritime companies. The EGNOS regional European enhancement of the GPS system will be optimally integrated with the Galileo Safety-of-Life Service to have independent and complementary integrity information (with no common mode of failure) on the GPS and Glonass constellations.

The Safety-of-Life Service will be certified and its performances will be obtained by using certified dual-frequency receivers. Under such conditions, the future Galileo Operating Company will guarantee SoL. To benefit from the required level of protection, Safety-of-Life is implemented in the frequency bands reserved for the Aeronautical Radio-Navigation Services (L1 and E5).

The ***Commercial Service*** (CS) is aimed at market applications requiring higher performance than offered by the Open Service. It provides added value services on payment of a fee. CS is based on adding two signals to the open access signals. This pair of signals is protected through commercial encryption, which is managed by the service providers and the future GOC. Access is controlled at the receiver level, using access-protection keys.

The uses foreseen for the Commercial Service include data broadcasting and resolving ambiguities in differential applications. These will be developed by service providers, who will buy the right to use the two commercial signals from the Galileo operator.

Developing commercial applications either by using the commercial signals alone, or by combining them with other Galileo signals or external communications systems, opens a wide range of possibilities. The worldwide

coverage brings a strong advantage for applications requiring global data broadcast.

Typical value-added services include service guarantees; precise timing services; the provision of ionosphere delay models; local differential correction signals for extreme-precision position determination; and other services based on the broadcast of system information data.

Galileo is a civil system that includes a robust and access-controlled service for government-authorised applications. The ***Public Regulated Service*** (PRS) will be used by groups such as the police, coastguard and customs. Civil institutions will control access to the encrypted Public Regulated Service. Access by region or user group will follow the security policy rules applicable in Europe.

The PRS is operational at all times and in all circumstances, including during periods of crisis. A major PRS driver is the robustness of its signal, which protects it against jamming and spoofing.

The ***Search and Rescue Service*** (SAR) is Europe's contribution to the international cooperative effort on humanitarian search and rescue. It will allow important improvements in the existing system, including: near real-time reception of distress messages from anywhere on Earth (the average waiting time is currently an hour); precise location of alerts (a few metres, instead of the currently specified 5 km); multiple satellite detection to overcome terrain blockage in severe conditions; increased availability of the space segment (30 Medium Earth Orbit satellites in addition to the four Low Earth Orbit and the three geostationary satellites in the current COSPAS-SARSAT system). Galileo will introduce new SAR functions such as the return link (from the SAR operator to the distress beacon), thereby facilitating the rescue operations and helping to reduce the rate of false alerts. The service is being defined in cooperation with COSPAS-SARSAT, and its characteristics and operations are regulated under the auspices of the International Maritime Organisation and the International Civil Aviation Organisation.

Galileo

Infrastructure: From Space to Ground

Space and Ground Segment

The core of the Galileo system is the global constellation of 30 satellites in medium Earth orbit, three planes inclined at 56° to the equator at about 23 222 km altitude. Nine satellites will be spread evenly around each plane, with each taking about 14 hours to orbit the Earth. Each plane has one additional dormant spare, able to provide cover for any failed satellite in that plane.

The satellites will use largely proven technologies. The body will rotate around its Earth-pointing (yaw) axis for its solar wings to rotate and point towards the Sun (generating peak power of 1600 W). A basic box structure will group the payload and platform elements. The launch mass is about 700 kg each.

After the initial constellation is established, further launches will replace failed satellites and replenish the system as the original satellites reach their ends of life. The baseline for creating the constellation is to carry multiple satellites on a single rocket, with a dispenser able to deliver up to six spacecraft simultaneously into medium Earth orbit. Smaller launchers will be used for the early in-orbit validation missions and for replenishments.

A network of ground stations consisting of sensor stations, control centres and uplink stations will support satellite operations. A worldwide network of Galileo Sensor Stations will continuously monitor the satellites. Its precise measurements of the navigation signals will be sent to the two Galileo Control Centres, in Europe, for further processing. There, sophisticated software will determine the satellite orbits and the time synchronisation error of the satellites' atomic clocks with respect to the Galileo system time maintained on the ground. The orbits and clock data will be uploaded to the satellites about every 2 hours for dissemination to the users, who will use them in their position-calculation algorithms. Such a frequent update rate will achieve the high level of positioning accuracy demanded of the system. The Control Centres will also compute the integrity data, which are provided as part of the Safety-of-Life service. The integrity data will be uploaded to the satellites for dissemination to the users even more frequently than the orbit and clock data. In the case of alarms (e.g. malfunctioning signals), the system will be able to alert the users with a delay of only 6-10 seconds.

Data transfer to and from the satellites will be performed through a global network of Telemetry, Telecommunications and Tracking Stations (satellite control and monitoring data) and Mission Uplink Stations (uplinking navigation data: orbits, clock errors, integrity).

The integrity data computed at the Galileo Control Centres will be usable by any users worldwide because they are based on the measurements from the global network of sensor stations.

However, it will also be possible for regional service providers to deploy their own networks of sensor stations to compute the integrity of the Galileo signals over their region. Those regional integrity data can be made available to the users via authorised integrity uplink channels provided in the Galileo satellites. Alternatively, those data can also be sent to the Galileo Control Centres for integration with the integrity data computed centrally.

Local components will enhance the above with local data distribution via terrestrial radio links or existing communication networks, in order to provide extra accuracy, integrity or extended coverage around airports, harbours, railways and in urban areas. Local components will also be deployed to extend navigation services to indoor users.

Frequencies and Signal Design

Galileo will transmit 10 signals: six serve open and safety-of-life services (although part may also be used for the commercial service), two are for commercial services and two are for public regulated services. They will be broadcast in the following frequency bands:

- E5A-E5B (1164-1215 MHz) and E6 (1260-1300 MHz), allocated to RNSS at WRC-2000 in Istanbul;
- E2-L1-E1 (1559-1591 MHz) were allocated to RNSS before WRC-2000 and arealready used by GPS. Sharing this band with GPS will be on a non-interference basis, in order to avoid affecting current GPS services while offering users simultaneous access to GPS and Galileo at minimal increases in terminal cost and complexity.

Galileo navigation signals will comprise ranging codes and data messages. The data messages will include satellite clock, ephemeris, space vehicle identity and status flag and constellation almanac information. Moreover, they will also include a Signal-In-Space Accuracy parameter providing the users with a prediction of the satellite clock and ephemeris accuracy over time. The data messages will also include the integrity data as determined centrally from the measurements by the network of global sensor stations monitoring the Galileo constellation and, when available, regional integrity data.

An important aspect of the Galileo concept is the provision of revenue-generating services, of which data broadcast will be an important element. A range of data message rates, up to 1000 symbols per sec, is being considered, maximising the potential for value-added services such as weather alerts, accident warnings, traffic information and map updates.

EGNOS: Paving the Way for Galileo

EGNOS, the European Geostationary Navigation Overlay Service, is Europe's first venture into satellite navigation. A joint project of ESA, the EC and EUROCONTROL (European Organisation for the Safety of Air Navigation), EGNOS is the first step in the European satellite navigation strategy, paving the way for Galileo and offering early Galileo services. EGNOS is Europe's Satellite-Based Augmentation System (SBAS) and is being deployed to provide regional satellite-based augmentation services to aviation, maritime and land users in Europe. It augments the GPS and GLONASS systems, making them suitable for safety-critical applications such as flying aircraft or navigating ships through narrow channels. EGNOS is designed to meet the extremely challenging performance requirements for landing aircraft, so it naturally meets most other user requirements:

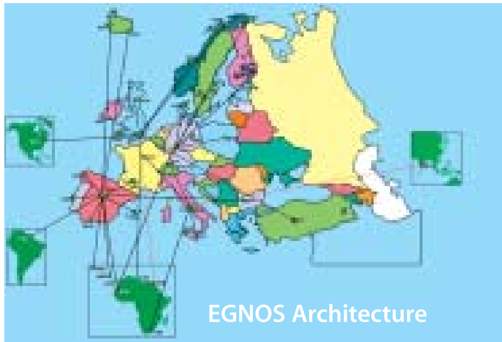
- availability is improved by broadcasting GPS look-alike signals from up to three geostationary satellites;
- accuracy is improved to 1-2 m horizontally (previously about 20 m) and 3-5 m vertically;
- integrity and safety are improved by alerting users within 6 s if a GPS malfunction occurs.

GPS has revolutionised navigation and positioning over the last two decades, but there are shortfalls: some users need firm commitments on civil control, others need much better accuracy than GPS alone can provide, and many need improved system 'health warnings' to support safety-critical applications. Satellite-based augmentation systems such as EGNOS do all this and more, preparing the way for Galileo services, and improving positioning solutions and increasing safety. Everything done before with GPS is now improved and much more easily achievable. Today, when a GPS satellite malfunctions, it can take up to 3 hours for the satellite to be declared 'unhealthy' and, during that time, positional accuracy can be much worse than 100 m. Each SBAS provides an alert message within 6 s when GPS malfunctions, helping to maintain performance.

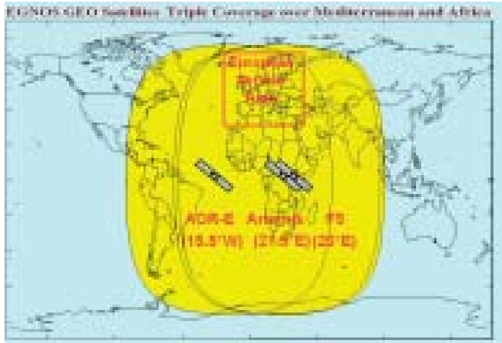
EGNOS services are being provided in Western Europe and the Mediterranean from 2005 for non-safety-critical applications. EGNOS may be extended to cover other areas, including Africa, South America and Asia. EGNOS is one of several similar systems in operation or under construction worldwide, as in the US (WAAS), Japan (MSAS) and India (GAGAN). As it is built upon common international standards, EGNOS will provide interoperability with these other systems so that a user with a GNSS receiver can use the EGNOS, WAAS, MSAS and GAGAN augmentation signal in the appropriate regions.

The financing, construction, deployment and validation of the EGNOS system is supported by public entities and the European Air Traffic Service Providers. Operation and services exploitation will be licensed to the EGNOS Economic Operator (EEO) and managed within the Galileo Concession. EGNOS is the first stimulus for European-led navigation services and, paving the way for Galileo services. For civil aviation use, EGNOS complies with ICAO global standards. It also covers multi-modal transport and many other non-transport applications. It will be integrated into Galileo as part of the concession.

The EGNOS infrastructure will be available in 2005 with provision of services for non-Safety-of-Life applications. Civil aviation will be able to make operational use of EGNOS in 2006 when the Safety-of-Life Service is certified.



EGNOS Architecture



Galileo

Excelling in Technology Development

The Galileo system depends on a number of novel technologies, ranging from signal-generation and time-keeping in the space segment to accurate control and secure operations in the ground segment. ESA began developing the most critical technologies at the inception of the Galileo programme, covering almost all areas of Galileo, including simulation tools.

Payload

The satellite payload consists of the Timing, Signal Generation and Transmit Sections. There will also be dedicated antennas for the search and rescue (COSPAS SARSAT) service, plus the frequency conversion and transmission and reception stages.

The *Timing Section* is the very heart of the payload, with the atomic clock providing the very accurate time reference. The ranging error from this clock is of the order of 30 cm. Two different clocks have been developed. The small Rubidium Atomic Frequency Standard (3.3 kg) is derived from a commercial design used in communication networks. This clock oscillates at optical frequencies (laser-pumped) with a microwave beat frequency of about 6.2 GHz. Upload of clock corrections for this clock are foreseen every 2 hours The development of the more challenging but more precise Passive Hydrogen Maser started in 2001. It is larger than the Rubidium clock but still compact enough (18 kg) for accommodation without difficulty in the satellites. The clock oscillates directly at 1.4 GHz. The stability of this clock is such that ground intervention will be necessary only once every orbit.

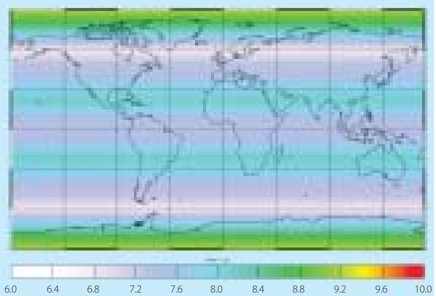
The *Signal Generation Section* delivers the navigation signals. These consist of a set of ranging codes that are first combined with the relevant navigation messages and then up-converted before delivery to the output transmit section. The navigation messages contain information about the satellite orbit (ephemeris) and the clock references.

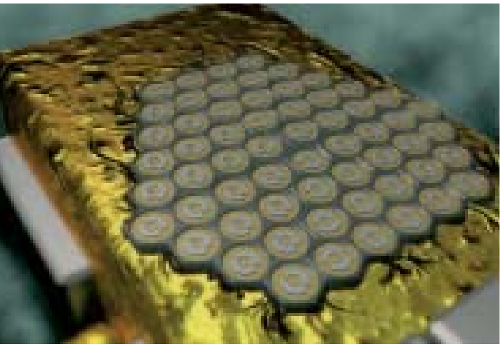
Two developments helped to demonstrate the feasibility of the Galileo signal design: Navigation Signal Generation, and Frequency Generation and Up-Conversion.

The *Transmit Section* amplifies the four navigation signal carriers up to about 50 W each. These signals are then combined in an output multiplexer and delivered to the transmit antenna. Two power amplifiers have been developed for the low and high bands of the Galileo frequency spectrum.

The Navigation Antenna was the subject of two parallel activities. The challenge with these antennas is to illuminate the Earth's surface with a quasi-isoflux power level, independent of whether a receiver is directly below the satellite (shortest signal propagation path) or seeing the satellite at very low elevation angle (longest signal propagation path). This is required to minimise signal interference between satellites.

Average vertical accuracy (m) for Open Service.





As for the Search and Rescue payload, special attention has been paid to the antenna unit, which combines transmission and reception at two different frequency bands, one of them very close to the navigation band.

Platform

The spacecraft platform will largely use existing technologies. However, the telecommunication and telemetry functions will be supported by two different modes: the standard mode that is used for Tracking, Telemetry & Command (TT&C) operations of most ESA missions, and a new mode based on spread-spectrum signals. The new mode is envisaged mainly for nominal operations of the constellation and is intended to provide increased system robustness and security.

There are stringent safety and operational requirements for the TT&C transponders, together with a variety of flexibility requirements. It will be possible to change the telecommand/telemetry (TC/TM) operating frequencies within a limited range to accommodate the multiple launches, reduction in interference levels, security aspects and the evolution of frequency allocation throughout the mission life. In addition, the system requires the increased signal robustness provided by spread-spectrum techniques and the increased security of the TT&C link by data encryption and authentication.

The S-band transponder will receive telecommands, ranging and other signals, and transmit telemetry and the transposed ranging. The transponder can be driven by internal and external clock references. Additionally, the ranging capability can support time-transfer and clock synchronisation functions using a highly stable ground clock reference.

Predevelopment of the TT&C transponder began in 2000 with the goal of producing an engineering model. The activity is concentrating on a flexible design with optimised mass and power consumption, and high reliability.

Simulation Tools

The Galileo System Simulation Facility (GSSF) is an end-to-end simulation tool of the Galileo system. It provides high-level models of the Galileo space, user and ground segments, and of the environmental effects on the navigation performance. The models can be run in real-time and allow the analysis of specific figures of merit, including integrity analyses and navigation accuracy for Galileo, GPS and hybrid (Galileo/GPS) receivers. The flexibility of the GSSF architecture allows user-defined models and algorithms to be plugged into the overall GSSF models. Future Galileo users can also use GSSF to design their navigation systems efficiently in a realistic environment.

The Galileo Signal Validation Facility (GSVF) allows the generation of the Galileo signal as received at the output

of a user antenna. This signal includes up to 16 satellite sources, and takes account of the propagation effects between the satellites and the user. As opposed to the GSSF, where the user receiver is modelled by software, the GSVF allows it to be plugged directly to the simulation by replacing the receiver antenna with the GSVF output. The receiver 'believes' that is receiving the real satellite signals and behaves as it would if mounted on a car, ship or aircraft, for example, depending on the kind of user profile being simulated. GSVF includes very sophisticated models that allow high-fidelity realistic simulations. GSVF will be used as a reference tool for testing Galileo receivers.

Galileo System Test Bed

In parallel with developing the satellite technologies, an overall testbed has been developed to address critical ground-segment technologies, and an experimental satellite is being built for launch in advance of the in-orbit validation satellites.

The first stage of the Galileo System Test Bed (GSTB-V1) is an experimental Galileo ground segment to verify Galileo concepts for Orbit Determination & Time Synchronisation and integrity algorithms. In the absence of real Galileo satellites, GSTB-V1 uses GPS satellites. A worldwide network of GPS reference stations represents the worldwide network of Galileo sensor stations. The GPS measurements collected by the network have verified that the stringent performance requirements for Galileo are feasible. Orbit determination and time synchronisation ranging errors below the 50 cm-level have been achieved on a routine basis. The establishment of a Galileo Master Time has also been demonstrated. GSTB-V1 has been in operation since early 2004. It was established in collaboration with the scientific community, such as the International GPS Service and the UTC Time Community. The availability of data online encourages scientists to examine the results and provide feed-back to the development of Galileo.

The second stage (GSTB-V2) consists of the development and launch of an experimental satellite ahead of the launch of the first block of Galileo satellites. This satellite, to be launched at the end of 2005 into a Galileo orbit of 23 222 km altitude, will fulfil the requirements of the International Telecommunications Union (ITU) in respect of the use of frequencies reserved for Galileo. In addition, the Galileo orbit will be characterised and critical satellite technologies such as the clocks will be validated, providing important feedback to the development of the operational satellites. Owing to the criticality of this mission, two experimental satellites are being developed in parallel, with the intention of launching whichever is ready first.

Galileo

Implementation and Management

The infrastructure is being implemented in three phases:

Development and In-Orbit Validation (starting 2002)
- consolidation of mission requirements;
- launch end-2005 of the first experimental satellite;
- development of 4 satellites and ground-based components;
- validation of the system in orbit.

Deployment
- construction and launch of the remaining 26 satellites;
- installation of the complete ground segment.

Initial Service Provision (from 2008)

The Development and In-Orbit Validation Phase is mainly co-funded by ESA and the EC. The GJU oversees its implementation and prepares for the Deployment Phase. In that phase, a predominant contribution will come from the private sector through the concession scheme.

The development and validation of the space and ground segments are being carried out by ESA.

Early in the development phase, an experimental satellite will also be launched, to secure the Galileo frequency filings, to characterise the orbits to be used by the validation satellites, and to test critical technologies such as the atomic clocks. The in-orbit validation will take place before 2007.

The Development and In-Orbit Validation phase will be followed by the Full Deployment and Operations phase, which covers the manufacture and launch of the remaining satellites, completion of the ground segment and routine operations and maintenance of the system for a minimum of 20 years.

During the operations phase, private sector revenues will range from value-added services sold to operators and collected by the concession holder, to the exploitation of intellectual property rights. By 2015, the revenues to the concessionaire should allow the public availability payments to be reduced to zero. Profit-sharing mechanisms will be agreed with the concessionaire.

Key Points

The Users at the Centre of the Systen

Galileo definition has been driven by user needs. They are reflected in the mission requirements and implemented with different satellite services customised per group of users.

Not Only a Signal from Space

The Galileo users will not be alone with their receivers. The users will benefit from the Galileo framework specifically put in place to support them:

- the Galileo Supervisory Authority to monitor the quality of the provided services according to the mission requirements and public interests;
- the Galileo Concessionaire interfacing with the different users and value-added service providers via specific service centres and *ad hoc* service-level agreements;
- a network of value-added service providers with commercial exploitation agreements with the Concessionaire for a complete downstream value chain.

The System is Continuously Monitored

Galileo performance is continuously monitored and the results made available to users and customers of Galileo-based applications.

Value for Money

Galileo services will be free to end users or charged depending on the specific services. The users will be free to decide according to value-for-money criteria.

Global and Local

Galileo provides Global services with homogeneous performances worldwide. At the same time, the Galileo Local Component allows customisation and add-on improvements of services according to regional and local needs.

GPS, EGNOS and Galileo Together

Galileo, GPS and EGNOS are compatible and will not interfere with each other. More importantly from the user point of view is the GPS, EGNOS and Galileo interoperability. The performance of receivers will be improved thanks to the use of both constellations. The combined Galileo-GPS-EGNOS receiver will be the common solution for the majority of applications, especially in the mass market.

Cost-Effective Safety and Security

Galileo in safety and security-related applications will allow the investments on terrestrial infrastructures to be reduced. These infrastructures are usually expensive to deploy and maintain, and not always interoperable across different regions and states. The Galileo applications will provide cost-effective solutions while satisfying the target security and safety requirements.

More Business Opportunities

The Galileo downstream value chain does not stop at the Concessionaire level. There will be many intermediate added-value levels between it and the final customer and/or end-user. These levels offer important business opportunities for non-space industries and service providers.

High Demanding Requirements

The Galileo core system is designed to satisfy highly demanding requirements and standards from the aviation, maritime and rail sectors, where the safety-of-life applications are targeted. Certification against these demanding requirements will be an additional guarantee for other users.

The Galileo Joint Undertaking

The Galileo Joint Undertaking (GJU) was set up by the EC and ESA to manage the development phase of the Galileo programme. The main tasks of the GJU are:

the Galileo Concession: the GJU is overseeing the establishment of a public private partnership between the public and the private sector in order to manage the Galileo programme and to mobilise the required funds. A competitive tendering process is being used to select the private consortium that will be awarded the Galileo Concession;

Galileo In-Orbit Validation: the GJU will launch via ESA a first series of satellites for the large-scale demonstration of the capabilities and reliability of the Galileo system;

6FP Galileo related activities: GJU also provides technical management for Galileo-related projects launched under the EU's 6th Framework Programme for Research and Development (FP6). These projects, with a combined estimated budget of EUR 100 million, will deliver many of the key technologies required for the implementation and operation of Galileo. They are another opportunity for the private sector to participate in the development of Galileo;

EGNOS Integration: the GJU is also responsible for managing the integration of EGNOS into Galileo.

Further Information

Galileo Joint Undertaking
Rue du Luxembourg 3
B-1000 Brussels
Belgium
Tel: +32 2 507 80 00
Fax: +32 2 507 80 01
Email: info@galileoju.com
http://www.galileoju.com

European Space Agency
Directorate of European Union and Industrial Programmes
8-10 rue Mario Nikis
F-75738 Paris CEDEX 15
France
Tel: +33 1 53 69 77 26
Fax: +33 1 53 69 72 86
Email: dominique.detain@esa.int
http://www.esa.int/navigation/

European Commission
Directorate General for Energy and Transport
Unit E.4 Satellite Navigation System (Galileo), Intelligent Transport
DM28 1/64
B-1049 Brussels
Belgium
Tel: +32 2 29 56040
Fax: +32 2 296 5372
Email: tren-galileo@cec.eu.int
http://europa.eu.int/comm/dgs/energy_transport/galileo/

Acronyms

CS:	Commercial Service
EC:	European Commission
EGNOS:	European Geostationary Navigation Overlay Service
ESA:	European Space Agency
ESTB:	EGNOS System Test Bed
Eurocontrol:	European Organisation for the Safety of Air Navigation
GJU:	Galileo Joint Undertaking
GNSS:	Global Navigation Satellite System
GOC:	Galileo Operating Company
GPS:	Global Positioning System
GSFF:	Galileo System Simulation Facility
GSM:	Global System for Mobile Communications
GSTB:	Galileo System Test Bed
GSVF:	Galileo System Validation Facility
ICAO:	International Civil Aviation Organisation
IGS:	International GPS Service
IMO:	International Maritime Organisation
ITU:	International Telecommunications Union
MSAS:	MT Sat-based Augmentation System
OS:	Open Service
PRS:	Public Regulated Service
RIMS:	Ranging and Integrity Monitoring Station
RNSS:	RadioNavigation Satellite Service
SAR:	Search and Rescue
SoL:	Safety-of-Life
TAI:	Temps Atomique International
TC:	Telecommand
TM:	Telemetry
TT&C:	Tracking, Telemetry & Command
UMTS:	Universal Mobile Telecommunications System
UN:	United Nations
UTC:	Universal Time Coordinated
VSAT:	Very Small Aperture Terminal
WAAS:	Wide Area Augmentation System
WRC:	World Radio Conference