Benefits and criticalities of new services of the Galileo System for Motorway operators

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Executive Summary

1. What is Galileo?

GALILEO is the European satellite navigation system which will enable each individual to know its position, thanks to a small, cheap, portable receiver, with a precision of within one meter. This technology already exists in the United States with the GPS, designed as a military no profit system. Galileo is a civilian commercial system, sponsored by the European Commission and the European Space Agency. Galileo is one of largest high-tech projects ever launched at European scale.

2. Objectives of the study

Galileo is a fundamental framework for the next years at European level. Up today the road operators, that are important subjects in this frame, did not appear to be very committed in the project. Consequently it has been decided to perform the actual study in order to provide a clear picture on the possible applications, functions, potential benefits, sources of revenues, investments and the timeframe for the development of Galileo. This study aim at give to Motorway Operators a basis of knowledge that can help them to address their choices about the use of Galileo for the development of new road applications.

3. The project phases and the budget

Galileo will be implemented through three phases:

- *The Development and In-Orbit Validation phase (2003-2006),*
  - **Cost:** € 1.1 Billion funded with budgets of the European Union and the European Space Agency. It will produce the first 2/4 satellites.
- *The Deployment Phase (2006-2008),*
  - **Cost:** will grow to € 3,25 Billion, coming from the private sector through a concession scheme, for the rollout of 30 satellites.
- *The Commercial Operations Phase (from 2008),*
  - **Cost:** € 220 million a year, funded from the private sector, to cover the maintenance expenses.
  - **Revenues:** will come from value-added services sold to operators and collected by the concession holder and from the exploitation of intellectual property rights on chipsets.
4. The market for Galileo Road Applications

The road sector is a major potential market for GALILEO applications. By 2010 there will be more than 670 million cars, 33 million buses and trucks and 200 million light commercial vehicles worldwide. Satellite navigation receivers are now commonly installed in cars as a key tool for new services such as:

- electronic Toll Collection,
- real time traffic information,
- emergency calls,
- route guidance,
- fleet management,
- advance driving assistance systems.

The market for Electronic Toll Collection equipment is expected to show rapid growth due to the unobtrusive nature of this method of toll collection and due to the ability to apply road pricing at a relatively low cost. There are still criticalities as the possibility to have an effective enforcement upon a base of all classes of vehicles.

In-car navigation systems and traffic information systems are today the two largest sectors, while fleet management is likely to be the largest sector in 2015.

Advanced Driving Assistance Systems (ADAS) is supposed be the second largest sector, growing rapidly from its present small size.

5. The public/private financing model

ESA and the EC are proposing a concession model to finance the cost of Deployment and Operation of Galileo.

The concession will be awarded to an Operating Company selected following a public procurement process. The Operating Company should build, finance and operate the system. Its shareholders would probably be the space industry, service providers and financial institutions.

The Operating Company would finance its activity from private equity and debt. There would be a formula for splitting market revenues between the Operating Company and the public sector.
6. The expected benefits

Applications: the existence of Galileo will benefit both industrialised countries and the developing world in areas such as:
- Transport by road, rail, air and sea;
- Fisheries and agriculture, oil prospecting, defence and civil protection activities, building and public works;
- Telecommunications: allied with other technologies such as GSM or UMTS, GALILEO will increase the potential to provide positioning information and Location Based Services.

Economic and social benefits - is estimated that the Galileo, for the period between 2000 and 2020, will provide:

<table>
<thead>
<tr>
<th>Benefit Type</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social benefits</td>
<td>12.000 million Euros</td>
</tr>
<tr>
<td>Economic benefits</td>
<td>62.000 million Euros</td>
</tr>
<tr>
<td>Total benefits</td>
<td>74.000 million Euros and 150.000 new jobs across Europe</td>
</tr>
</tbody>
</table>

Technological independence: GALILEO architecture is made up of components that makes the system completely autonomous and independent from the American GPS which currently has a de facto monopoly.

7. The criticalities

Delays
There are several technical and political issues that could delay the GALILEO roadmap. The risks associated with delays are critical because:
- The frequencies needed for GALILEO, obtained following difficult negotiations at the last World Radio Communications Conference, will be lost unless the first operational satellites are launched before 13 February 2006;
- All delays in the GALILEO development schedule will cause extensions of the project activities of the industrial contractors involved in the development phase, with the effect of increasing the overall costs.

Technological competition
It is vital that Galileo should come into operation in 2008, in order to be able to take up the market shares available before the possible arrival of the American GPS III. The arrival on the market of Galileo could capture those shares of market that otherwise could be occupied by the terrestrial wireless operators offering Location Based Services (LBS), using GSM and UMTS technology, that seems to be in competition with the Galileo technology.
8. The possible role of a Motorway Operator in GALILEO

Motorways Operators will have the opportunity to offer new services based on Galileo local components. With a local network of sensors and transmitters they could offer continuity of the Galileo positioning information to motorway users. Thanks to this proprietary network, the Motorway Operator could provide value added information to motorway users for free or as chargeable premium services.

9. Which services on road?

Three Galileo-based applications have been selected following a survey done with the cooperation of some Italian motorway operators: Autostrada Torino-Milano, Autostrada Torino-Alessandria Piacenza, Autostrade per l’Italia, Autovic Venete and Autostrada Brescia-Padova. The three applications are:

- Electronic Toll Collection (ETC)
- Value added services: Emergency Services and User Information
- Fleet management

Hereinafter the main survey results:

![Pie chart showing the distribution of interest in different application sectors for Galileo.](chart.png)
10. Electronic Toll Collection: the EU Directive

In April 2003, the EC issued a Proposal for a Directive on the widespread introduction and interoperability of electronic road toll systems in the Community. According to this proposal, the new European systems should be based on the use of the following technologies: the GNSS/GSM combination, together with microwave, which is already widespread use in the Union. There are no plans in the Member States to introduce new toll systems using any technology other than that based on microwaves or the GPS/GSM combination.

Thanks to the dissemination of a large number of the a.m. on-board units, a critical mass could be achieved and the manufacturing cost should become lower than today (i.e. € 500-600).

The vast presence of Toll Collection terminals will help the development of the information society in road transport: these terminals will allow value-added telematic services and safety systems for travelers (automatic emergency services, traffic information, hazardous goods monitoring, basic and premium information services, …).

Critical areas when introducing ETC via Galileo are: definition of effective enforcement strategies, digital cartography standards and actual quality, investments payback, migration to new technology, interoperability, definition of technical standards and operation criteria.
11. ETC system with Galileo: a reference scenario

![Diagram of ETC system with Galileo]

12. Costs estimated for an ETC system with Galileo

According to the existing experiences, the cost elements that a Motorway Operator will be likely sustaining for developing a satellite-based Toll Collection applications can be classified as follows:

- Development costs, including such elements as:
  - Design of processes for manual and automatic toll collection and enforcement techniques
  - System Functional design
Benefits and criticalities for the use of Galileo – the road operator point of view

- Technical architecture definition
- Hardware and software components design and development
- Billing and customer care systems design and implementation
- Enforcement systems

- Operating costs, including such elements as:
  - Manpower costs
  - Assets amortization (Hardware, software, Enforcement equipment …)
  - Enforcement operations costs
  - Telecommunications costs
  - Customer care costs

In the case of the German Toll Collect System, the development costs have been of the order of € 160 million, while the operating costs amount about € 1 billion/year against an expected revenue of about € 4/5 billion/year.

13. SOS emergency call systems

GALILEO services will improve the assistance and safety services by better positioning vehicles and events. Consequently the Motorway Operator and the drivers can draw some benefits, i.e.:

- the automatic sending of the emergency call could reduce the time for the accident handling and consequently reduce the circulation problems on the motorway network;
- reduced travel time to the accident by the rescuers: accuracy of the location data speeds up the search for the scene of the accident avoiding mistakes in routing. It is also possible for the traffic control centre to propose the fastest (and most traffic free) route to the scene. The advantages of the actual bullet are certainly more important in case of a complex road network, less important in case of motorways;
- on the scene rescue time: the availability of data on the type of accident allow the operations centre to know whether more than one emergency service is involved (e.g. fire service, police, ambulance), to co-ordinate the rescue and reduce the handling time and consequently the traffic congestion;
- transport time to hospital: the call system could be an additional channel to transmit clinical data through the on-road device and the correct information could help the rescue agent to transfer the patient to the most suitable hospital or trauma centre. In addition, information can be received from the to traffic control centre that can ensure the fastest route is taken;
- no dependence on road-site infrastructure as telephone boxes or SOS-telephones.
As a reference, the costs for developing the SOS emergency system E-Calls could be roughly estimated as follows:

- User needs and design of processes  500.000 Euro
- System architecture design, infrastructure technical specs, vehicles technical specs definition  500.000 Euro
- Infrastructure hardware and software, vehicles system development costs  2.200.000 Euro
- Infrastructures and vehicles tests, analysis of results  900.000 Euro

Total development cost  4.100.000 Euro

Beyond the production and operation costs, it seems self-evident that the commercial costs to promote to the wide public the application are certainly between main costs of development.

14. Fleet Management systems

These systems integrate a positioning device, GPS today or, in the future, Galileo with a communications mechanism such as GSM or UMTS. Major applications for fleet management systems are:
- Traffic monitoring, control and management;
- Locating and tracking vehicles world-wide;
- Monitoring of the vehicle and its cargo conditions;
- Additional functions as in board alarms, journey plans, message management (text and data) between fleet operator and vehicle;
- In car location / navigation;
- Fleet monitoring and control;
- Hazardous cargo tracking.

Fleet Management Systems aim at improving traffic conditions to the fleet and at reducing accidents, with longer-term goals of reducing the workload on drivers and co-ordinating different transportation systems for freight and passenger use.

Moreover, motorway operators can adopt fleet management of their service vehicles: by knowing the position of vehicles, it is possible to address them in the place where a problem is, reducing intervention times, costs and optimising then the quality of service.
As a reference, the costs for developing and operating the Italian Fleetrunner system (source: MIZAR) have been of the order of:

<table>
<thead>
<tr>
<th>Development costs, including such elements as:</th>
<th>~1.000.000 Euro</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Hardware and software development costs</td>
<td>(central and on board software development; no hardware development)</td>
</tr>
<tr>
<td>• Design of processes, technical architecture definition, system integration</td>
<td>~200.000 Euro</td>
</tr>
<tr>
<td>• Operations center setup (procedures design, hardware and software components)</td>
<td>~50.000 Euro</td>
</tr>
<tr>
<td>• Total development cost</td>
<td>~1.250.000 Euro</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operating costs, including such elements as:</th>
<th>~1000 ÷2000 Euro/device</th>
</tr>
</thead>
<tbody>
<tr>
<td>• GSM data transmitters/receivers to be installed on board service vehicle</td>
<td>(GSM/GPRS unit)</td>
</tr>
<tr>
<td>• Operations center /Service providers manpower and operating costs</td>
<td>~900 Euro/Year</td>
</tr>
<tr>
<td>• Telecommunications operator costs</td>
<td>~60 Euro/Year</td>
</tr>
</tbody>
</table>

15. Open issues and next steps

The result of this research has permitted to provide a picture of what Galileo is and what benefits, criticalities and business opportunity it would bring to Motorway Operators. They have now a basis of knowledge that can help them to focus their choices and investments regarding the use of Galileo for developing new road applications.

Major Italian Motorways Operators expressed interest in Electronic Toll Collection via satellite, although a number of open issues on the evolution of the state of the art have been pointed out.

Further investigation and dedicated studies should be carried out indeed, in particular on:
Compatibility with EU directives: Motorway Operators that have invested in microwave technology should further discuss their position with respect to the EC directive on Electronic Toll Collection.

Definition of standards: Motorway Operators shall study and define standards with respect to information interchange, operational procedures, billing, since the quality of services shall be guaranteed across Europe.

Interoperability: Further investigations should be carried to define the interoperability of systems across different countries and their integration with satellite functionality, avoiding non compatible satellite systems to be developed in different Countries, by standardizing satellite services and technologies.

Operations: Further studies shall be focused on the impact coming from the adoption of Satellite Electronic Toll Collection on motorway operations, in terms of traffic management, security, legal and regulatory issues, impacts on drivers, procedures to be followed in case of exception, misfunctioning, fraud, enforcement.

Many applications such as Fleet Management and SOS emergency call systems have been already developed based on the GPS signal and are in a more mature stage of progress with respect to Electronic Toll Collection.

These and other GNSS-based services will have a major boost when Galileo terminals will be extensively adopted in Europe.

However, this shall occur when the most important Galileo road application, i.e. Electronic Toll Collection, will open the market and drive its growth.
0. Introduction

0.1. Objectives and methodology

Galileo is an important framework for the future transport systems at European level. Up to day today the road operators, that are supposed to be one important subject active in this frame, did not appear to be very involved in the project. Consequently it has been decided to start the development of a study that could accomplish the following main objectives:

- To gather and synthesize the existing documentation about Galileo and the main application related in order to deliver a paper to the decision makers of the road operators in Italy (and possibly at SERTI area level) who maybe are not so familiar with the whole initiative. This work of synthesis has been performed in the Part 1 of the actual study and aim at providing a clear picture of the possible applications, the functions, the potential benefits, the sources of revenues, the investments forecast, the timeframe of development of Galileo.

- To collect direct information from actors involved in the development of satellite technology and to verify the requirements from Motorway Operators. The Second Part of the study has been based on the information gathered thank to the cooperation of the EC – DG-TREN, the ASI (the Italian Space Agency), the GISS (Galileo Interim Support Structure, today renamed Galileo Joint Undertaking), the Italian “Ministry of Infrastructures an Transports” and the German Company Toll Collect. Interviews have been carried out then with Motorways Operators. They expressed interest in specific future Galileo applications, that have been therefore discussed in terms of a costs-benefits analysis.
0.2. Relationship with other SERTI studies

The SERTI project was started in 1996 to improve traffic conditions on the TERN (Trans European Road Network) by implementing telematics services on the following countries of the southern Euro-region: France (south-east regions), Germany (Baden-Württemberg Länder), Italy (north-west regions) and Spain (bordering northeastern regions and Catalunya) with the cooperation of Switzerland and Andorra as associated members of the project.

In order to manage heavy traffic flows on the 5,000 km of motorways and main roads in the TERN between France, Germany, Switzerland, Italy and Spain according the most effective and sustainable way, the SERTI partners are currently developing traffic management and user information services in the above mentioned regions of southern Europe using Intelligent Transport Systems (ITS).

The SERTI project is led by the French Ministry of Transport (MELT), which, together with the Ministries of the other countries and main road operators, compose the Steering Committee of the Project. The Italian member of the Steering Committee is the Ministry of Infrastructures and Transports (formerly Ministry of Public Works), which is charged with the co-ordination of the Italian participants.

The work of the project is co-ordinated to ensure that services are implemented both at regional, national and international level. The aim is the maintaining of the continuity and quality of the services available to the road users of the Trans-European-Network for Transport (TEN-T) in the southern European region.

SERTI Project activities

The SERTI Euro-regional Project has grouped its activities in the following domains:

- Road monitoring infrastructure
- European network of traffic centers
- Traffic management and control
- Traveler information services
- Incident and emergency handling
- Freight and Fleet management
The SERTI partners that are working on projects related to GALILEO or similar areas are Adf/SINELEC (Italy) and DSCR/ASFA (France) on areas such as:

- Identification of needs for LCD users and study of different kind of services addressed to different type of travelers (such as transport/logistics HGV/Buses fleets versus holiday vehicles);
- Study of services homogenization within SERTI countries.
1.  PART 1 – The Galileo System

1.1.  Framework of the Galileo System

GALILEO is the European satellite radio-navigation programme which will enable each individual to know its position to a precision of within one metre, thanks to a receiver designed in order to be small, cheap and portable.

A similar technology already exists in the United States with the GPS system and in Russia with the GLONASS system. Both the mentioned systems were designed as military systems. Since the Russian system seems to have not succeeded in generating any significant civil applications, GALILEO is deemed to offer a real alternative to the establishment of the current “de facto” monopoly in favour of GPS and the American industry.

Galileo is an initiative jointly sponsored by the European Commission and the European Space Agency and it is one of largest high tech projects ever launched at European scale.

Galileo will offer several services, both with open and restricted access:

- An open, free basic service, mainly involving applications for the general public and services of general interest. This service is comparable to that provided by civil GPS, which is free of charge for these applications, but with improved quality and reliability.

- A commercial service facilitating the development of professional applications and offering enhanced performance compared with the basic service, particularly in terms of service guarantee.

- A "vital" service (Safety of Life Service) of a very high quality and integrity for safety-critical applications, such as aviation and shipping.

- A search and rescue service that will greatly improve existing relief and rescue services.

- A public regulated service (PRS), encrypted and resistant to jamming and interference, reserved principally for the public authorities responsible for civil protection, national security and law enforcement which demand a high level of
continuity. It will enable secured applications to be developed in the European Union, and could prove, in particular, to be an important tool toward the improving of the instruments used by the European Union to contrast illegal exports and illegal immigration.

1.1.1. **Galileo advantages and complementarity with respect to GPS**

GALILEO is designed in order to offer a number of advantages over GPS, namely:

- GALILEO has been designed and developed as a non-military application, while nonetheless incorporating all the necessary protective security features. Unlike GPS, which was essentially designed for military use, GALILEO therefore provides, for some of the services offered, a very high level of continuity required by modern business, in particular with regard to contractual responsibility;

- It is based on the same technology as GPS and provides a similar - and possibly higher - degree of precision, thanks to the structure of the constellation of satellites and the ground-based control and management systems planned;

- GALILEO is supposed to be more reliable as it includes a signal "integrity message" informing the user immediately of any errors. In addition, unlike GPS, it will be possible to receive GALILEO in towns and in regions located in extreme latitudes;

- It represents a real public service and, as such, guarantees that continuity of service, provision for specific applications. GPS signals, on the other hand, in recent years have on several occasions become unavailable on a planned or unplanned basis, sometimes without prior warning.

GALILEO also complements GPS insofar as:

- Using both infrastructures in a coordinated fashion (double sourcing), it offers real advantages in terms of precision and in terms of security, should one of the two systems become unavailable;

- The existence of two independent systems is a benefit for all users since they will be able to use the same receiver for both GPS and GALILEO signals.
The European Commission and the European Space Agency attach great importance to the complementary and interoperable relationship between Galileo and GPS in order to provide improved and safer services to the world-wide users.

1.1.2. **EGNOS: the Galileo forerunner**

EGNOS, the European Geo-stationary Navigation Overlay Service, is the European contribution to the first step of the Global Navigation Satellite System (GNSS1). ESA together with the EC and Eurocontrol are currently implementing the programme. It will augment both the existing American military-run GPS and the Russian GLONASS satellite systems by providing various transport communities such as civil aviation and maritime, with new services such as guaranteed availability, accuracy, integrity and continuity service levels.

Egnos will be the Europe’s contribution to the first stage of the Global Navigation Satellite System aiming at providing regional satellite-based augmentation services to aviation, maritime and land users in Europe. GNSS1 also includes similar enhancements under development in the US (WAAS) and Japan (MSAS).

EGNOS, which has been developing since 1993, increases the number of GPS signals, applies a differential correction and adds an integrity message. EGNOS is also set to be incorporated into GALILEO, that will be Europe’s contribution to the second stage of the Global navigation Satellite System (GNSS2).

1.1.3. **The financial framework**

The Galileo project total budget will be € 1.1 Billion for the first phase that will bring the building of the first constellation of 2/4 satellites within 2006.

The budget will increase to a total of € 3,25 Billion for the rollout of 30 satellites within 2008. During operations, the maintenance expenses are estimated to reach about € 220 million a year. This includes an operations and maintenance cost of 70 million € per year as well as the cost of satellite replacement.

The organization of GALILEO at EU and ESA level is depicted in the following chart:
The budget will be issued through the following organizations:

EC Navigation Unit: it will manage activities mostly concerned with the definition/design of the services and applications for the Galileo customers. The projects will be funded through VI Frame Program of the CEU that is started in Q2/Q3 2003 and will last for approximately 3 years.

ESA Galileo Project Office: this structure will manage ESA plus EC funds to develop the In-Orbit Validation Phase. It includes a Space Segment (four demonstrative satellites) and the Ground Segment (ground station and relevant services). The projects will be issued through public tenders managed by ESA.

Joint Undertaking: this is an organization controlled by ESA and the EC which role will be:

- to manage the EC funds coming from the VI Frame Programme through the issuing of public tenders for the development of applications, standards/certifications, Galileo terminals prototypes, etc.
- to issue a public tender to let an Operating Company obtain the concession for the future commercial exploitation of Galileo in the Full Development & Operations phase. The funding will be partly public, partly private from banks and shareholders that will have the right to the commercial exploitation of the system.

ESA Navigation Applications Office. It will provide tenders for the development of the applications (theoretically in coordination with the EC Navigation Unit). It is a new structure that will develop through the years. The projects will be issued via public tenders managed by ESA.
The European suppliers are organized mainly into two Industrial Consortia created to access the funds of Galileo project:

- **Galileo Industries**, composed by a large group of suppliers, which main players are Astrium (UK and D subsidiaries), Alenia (I), Alcatel (F). It puts together European manufacturers of space systems and its aim is to obtain ESA funds for the Space Segment and the Ground Segment and to get to the future concession for the Operations Phase.

- **Galileo Services** was formed more recently by service companies. The main players are Thales (ex Thomson CSF, French), Telespazio, Eutelsat. Its main scope is to obtain the CEU funds and it wants to challenge Galileo Industries for the future concession for the Operational Phase.

### 1.1.4. The timeframe and the project phases

The main infrastructure will be implemented through three phases:

1. **The Development and In-Orbit Validation phase** (2003-2006), that will be funded with public financing already programmed within the budgets of the European Union and the European Space Agency. During this phase, the activities will mainly be focused on the consolidation of the mission requirements, the development of 2-4 satellites and ground-based components and the validation of the system in orbit.

2. **The Deployment Phase** (2006-2007), in which a predominant economical contribution will come from the private sector through a concession scheme. During this timeframe, the focus will be on the construction and launch of the remaining 26-28 satellites and the installation of the complete ground segment.

3. **The Commercial Operations Phase** (from 2008), also funded mainly from the private sector with the concession scheme. In that phase, the development and validation of the space segment and related ground segment will be carried out by ESA. During the Commercial 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 on chipsets. By 2015, the revenues to the concessionaire will allow the public availability payments to be reduced to zero.
1.1.5. The value chain and revenue sources

The Galileo satellite constellation and ground control stations will be built and operated by a signal operator, the Galileo Operating Company. During operations, the revenues for the Operating Company will come from:

- Royalties on chipset sales, paid by equipment providers who incorporate a GPS/Galileo enabled chip in their products to allow users to get the Open Access Service;
- Income from Service Providers who want to use the specialized encrypted signals to offer other services, for example assisted navigation integrating Galileo and terrestrial GSM signals from wireless telecommunication operators;
- Authentication services, i.e. exact determination of users or signal identity thanks to a time-dependent location signature paid by chipset manufacturers or directly by the end users.

The GALILEO revenue model

In 2000, there were approximately 6 million civilian GNSS receivers in use in Europe, however this market is expected to grow rapidly over the coming years and it is estimated that there will be around 100 million receivers in use in Europe in 2010, increasing to 250 million by 2020.
The global revenues from GALILEO product sales is predicted to grow rapidly from around 14 billion € in 2000 to 50 billion € in 2010 and to 155 billion € in 2020. The total revenues start flattening out after 2017 as the market for GNSS receivers starts becoming saturated.

The global revenues arising from the sale of GALILEO products were derived from the number of receivers multiplied by the full price of the GALILEO terminal product offered on the market and bought by the end user (i.e. the entire car navigation system, mobile phone, surveying system or stand-alone receiver).

The global market for GNSS is predicted to grow to 800 million users by 2020. The European market is initially smaller than the North American market but will grow to a similar size by 2020, representing about 30% of the total market for GNSS.

It is estimated that over the next 20 years, 70-80% of all GNSS receivers sold in Europe will be for personal use.

On the assumption that there will be convergence between in-car and personal navigation equipment by 2020, it can be predicted that over 65% of the population in Europe will rely on GNSS while going about their business and daily lives.

1.1.6. The services foreseen and the expected market for Road Applications

The road sector seems to be a major potential market for GALILEO applications. Satellite navigation receivers are now commonly installed in cars as a key tool for proving new services to people on the move such as electronic charging, real time traffic information, emergency calls, route guidance, fleet management or advance driving assistance systems. By 2010, there will be more than 670 million cars, 33 million buses and trucks and 200 million light commercial vehicles worldwide.

At present, traffic congestion places enormous constraints on our day-to-day mobility with over 10% of the network blocked, representing enormous costs. Improving road transport systems calls for systematic recourse to information about vehicle position and speed. A driver using a GALILEO receiver will receive a constant supply of information to enable him or her to determine their location and find the best route. The system will therefore make for better vehicle fleet management (e.g. taxis, trucks, buses), optimum route finding and traffic
optimization. Advanced Driver Assistance will include also functions for safety and mobility improvements in road traffic, such as collision warning, vision enhancement, low speed maneuvering aid, etc.

Some examples of practical uses of positioning information from Galileo:

- **In-Car Navigation Systems**
  
  Route guidance using satellite navigation is already a well-established product offered by car manufacturers. The majority of these systems are based on satellite navigation systems and onboard sensors (odometer and gyros) to compute optimal routes in real-time. However, GPS does not offer sufficient coverage in urban areas to be used alone. Galileo with its 30 satellites will increase the coverage and accuracy. This will enable manufacturers to use cheaper sensors to fill the satellite navigation gaps (tunnels, narrow streets).

- **Traffic Management Systems**
  
  One of the main aims of a Traffic Management System is to speed the flow of traffic along a given transport system and reduce environment effects caused by stoppages. This will be significantly facilitated when a great number of cars are equipped with satellite navigation receivers. Two interesting applications of traffic management systems are Electronic Toll Collection (ETC) and Position Reporting Systems.

  ETC enable payment to be made automatically without the need to stop at booths for the use of roads.

  Position Reporting Systems allow vehicles to transmit their position and identity to monitoring stations. The uses for this are varied and include Fleet Management Systems and Emergency Services.

  Taxi, bus and train fleet management are crucial and complex tasks for operators. Companies have already equipped more than 500,000 vehicles in Europe with sensors to identify the location of each to a control center. GALILEO offers the guarantee that the service will be continuous. Knowing the exact location of their buses, operators can inform
travelers on the expected time of arrival of the next bus. Electronic displays are displaying this information at bus stops.

Emergency Services are a very important applications that will allow tracking and managing emergency and rescue vehicles. Combined with dynamic traffic information, an ambulance (Europe has 60,000) with a GALILEO receiver and communication link will be able to reach its destination much faster. Traffic lights could be controlled to speed the arrival of an emergency vehicle. More than 50% of emergency calls now come from mobile phones, so integral GALILEO receivers (as planned by the European E-112 project) will dramatically shorten the rescue chain, gaining time and saving lives.

- **Advanced Driving Assistance Systems (ADAS)**

Advanced Driving Assistance Systems (ADAS) combine vehicle capabilities to improve mobility and active safety. GALILEO will provide important additional data to ADAS on the vehicle's environment. ADAS then warns the driver of imminent danger or takes full or partial control over the vehicle. For instance, the speed could be reduced by ADAS under bad visibility conditions if the car approaches a tight turn too fast.

This function will be possible only with accurate position data of guaranteed integrity furnished by GALILEO and local elements. It is expected that half of the vehicles operating in Europe by 2020 will carry ADAS.

- **Traffic Information Systems**

Traffic Information Systems provide motorist with immediate congestion information using link with traffic monitoring system. The main communications system in Europe is RDS-TMC (Radio Data System – Traffic Message Channel) and the capabilities of this system are covered. This new system has an European-wide standard, which means that the message format will be the same across all European countries. Furthermore, as the digital messages are standardized, software can be used to translate them into any language and they are available for use by in-car navigation software to display hazard information visually. Traffic
information is also given to drivers by the use of variable-message displays (VMS) sited alongside major roads.

A summary of the road applications market, relevant to ITS equipment, is shown in following tables (an estimation of TTS Italia and Politecnico di Torino of the total world ITS market, including services is 3-4 times larger that the one of equipment only).

### Total Market for ITS equipment (US $m)

<table>
<thead>
<tr>
<th>By sector</th>
<th>Year 2005</th>
<th>Year 2010</th>
<th>Year 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Information Systems</td>
<td>4.640,60</td>
<td>9.818,30</td>
<td>31.361,00</td>
</tr>
<tr>
<td>RDS-TMC</td>
<td>108,40</td>
<td>434,80</td>
<td>2.181,40</td>
</tr>
<tr>
<td>Electronic Toll Collection</td>
<td>930,20</td>
<td>3.113,59</td>
<td>4.387,44</td>
</tr>
<tr>
<td>Fleet Management Systems</td>
<td>889,80</td>
<td>992,62</td>
<td>1.330,73</td>
</tr>
<tr>
<td>Emergency Services</td>
<td>852,80</td>
<td>934,56</td>
<td>1.197,67</td>
</tr>
<tr>
<td>In-car Navigation</td>
<td>6.604,00</td>
<td>7.798,16</td>
<td>11.557,49</td>
</tr>
<tr>
<td>ADAS</td>
<td>697,30</td>
<td>873,75</td>
<td>1.258,98</td>
</tr>
<tr>
<td>Total Road Applications</td>
<td>14.723,10</td>
<td>23.965,78</td>
<td>53.274,71</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>By Region</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>2.909,70</td>
<td>7.343,88</td>
<td>20.120,20</td>
</tr>
<tr>
<td>Japan</td>
<td>8.059,30</td>
<td>8.455,95</td>
<td>12.338,72</td>
</tr>
<tr>
<td>EU</td>
<td>2.482,10</td>
<td>5.655,08</td>
<td>15.272,72</td>
</tr>
<tr>
<td>Rest of world</td>
<td>1.272,00</td>
<td>2.510,87</td>
<td>5.543,07</td>
</tr>
<tr>
<td>TOTAL</td>
<td>14.723,10</td>
<td>23.965,78</td>
<td>53.274,71</td>
</tr>
</tbody>
</table>
### Total Market for ITS equipment in UE (US $m)

<table>
<thead>
<tr>
<th>Service</th>
<th>2001</th>
<th>2006</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Information Systems</td>
<td>788.90</td>
<td>2,258.21</td>
<td>9,094.69</td>
</tr>
<tr>
<td>RDS-TMC</td>
<td>18.43</td>
<td>100.00</td>
<td>632.61</td>
</tr>
<tr>
<td>Electronic Toll Collection</td>
<td>158.13</td>
<td>716.13</td>
<td>1,272.36</td>
</tr>
<tr>
<td>Fleet Management Systems</td>
<td>151.27</td>
<td>228.30</td>
<td>385.91</td>
</tr>
<tr>
<td>Emergency Services</td>
<td>144.98</td>
<td>214.95</td>
<td>347.32</td>
</tr>
<tr>
<td>In-car Navigation</td>
<td>1,122.68</td>
<td>1,793.58</td>
<td>3,351.67</td>
</tr>
<tr>
<td>ADAS</td>
<td>118.54</td>
<td>200.96</td>
<td>365.10</td>
</tr>
</tbody>
</table>


**Fleet Management** is likely to be largest sector in 2015, with growth being driven by easily identifiable commercial benefits. At present, fleet management is one of the smallest sectors.

**ADAS** will be the second largest sector, again growing rapidly from its present small size as manufacturers develop collision avoidance systems that become standard fittings on new vehicles.

**In-car navigation systems** and traffic information systems are the two largest sectors at present, and their growth is expected to be more subdued, although steady.

The market for **Electronic Toll Collection** equipment is expected to show rapid growth due to the unobtrusive nature of this method of toll collection and due to the ability to apply road pricing at a relatively low cost.

**RDS-TMC** figures are included and show a good potential for aftermarket sales.

In terms of geographic regions, Japan will lose its dominant lead in ITS spend after 2010, with the US taking first position, followed by the UE. Spending on ITS in the rest of the world is expected to start in earnest after 2010.
1.1.7. The public/private financing model and the role of private companies

ESA and the EC are proposing a concession model to finance the cost of Deployment and Operation of Galileo.

The concession will be awarded to an Operating Company selected following a public procurement process.

The Operating Company should build, finance and operate the system. Its shareholders would probably be the space industry, service providers and financial institutions.

The Operating Company would finance its activity from private equity and debt.

The private sector would be able to finance a significant proportion of the Deployment and Operation costs under the sort of structure used for Private Finance Initiative (PFI) projects, with up to 90% senior debt and 10% equity/quasi equity.

This assumes our proposed contractual arrangements and that the counterpart to the concession would be the EC or another body with a sovereign credit. In practice, The Operating Company would contract with the Joint Undertaking and then the EC to provide a level of service in return for an availability payment. There would be a formula for splitting market revenues between the Operating Company and the public sector.

The following picture depicts the economic model of the Operating Company.

---

1 Inception study to support the development of a business plan for the GALILEO programme TREN /B5/23-2001.
The key characteristics of the Concession would be:

- A Concession term of up to 20 years, under which the EC would pay the operator and availability payment from commencement of commercial operations.

- The availability payment would be intended to supplement market revenue to give the company enough expected income to cover:
  - operating costs;
  - debt service payments and tax;
  - provide a degree of return to shareholders.

However this would not be guaranteed. The company would only deliver a return if it earned its projected commercial revenue by achieving the expected market penetration, and met performance requirements. It would also be exposed to capital and operating expenditure risk.

There would be a mechanism for sharing upside in commercial revenues with the public sector. This could partially offset the public sector availability payment.

There would be a break mechanism for re-negotiation of terms when the satellite constellation has to be replaced.
The public sector would provide cover for the product liability risks above the level which could be insured commercially.

1.2. The expected benefits

1.2.1. Creation of new services

Although transport by road, rail, air and sea is the example most frequently quoted, satellite radio navigation is also increasingly of benefit to fisheries and agriculture, oil prospecting, defense and civil protection activities, building and public works, etc. In the field of telecommunications, allied with other new technologies such as GSM or UMTS, GALILEO will increase the potential to provide positioning information as well as to provide combined services of a very high level.

Energy
The design, construction and operation of energy networks for electricity, oil and gas require accurate localisation systems. Galileo offers new possibilities for energy transport and distribution.

Some examples of practical uses of Galileo are: Network synchronisation for power generation and distribution, Infrastructure mapping, Rig anchoring and marine seismic exploration.

Telecommunications
The integration of Galileo receivers with mobile phones will generate a multitude of combined uses in positioning, direction finding, real-time traffic information and many others.

Some examples of practical uses of Galileo are: Exact localisation of mobile telephones, LBS: Location Based Services, Communication network monitoring, Location billing.

Finance, Banking, Insurance
Security, data integrity, authenticity and confidentiality have emerged as major issues in the electronic exchange of documents and Galileo can play a key role in these applications.

Some examples of practical uses of Galileo are: Secure electronic documents, Data encryption, E-commerce, Insurance.
Civil Engineering
Accuracy and reliability are well-known requirements in civil engineering. Combined with digital mapping, Galileo offers a powerful tool for improving productivity while preserving standards in all areas.

Some examples of practical uses of Galileo: Structure monitoring, Machinery guidance, Construction site management and logistics, Road/rail infrastructure maintenance.

Agriculture
Farmers strive to improve quality, while respecting the environment.

Some examples of practical uses of Galileo are: Chemical spraying, Crop yield monitoring, Crop acreage and livestock tracking.

Fisheries
The needs of the fishing sector range from day-to-day operational support to the navigation and positioning of fishing vessels.

Some examples of practical uses of Galileo are: Navigation and monitoring of fishing vessels, Monitoring fishing applications.

Environment
Galileo will contribute to tracking pollutants, dangerous goods and icebergs, mapping the oceans and cryosphere, and studying the tides, currents and sea levels. It will help to monitor the atmosphere, water vapor for weather forecasting and climate studies, and the ionosphere for radio communications, space science and even earthquake prediction. In nature, the movements of wild animals can be tracked to help preserve their habitats.

Some examples of practical uses of Galileo are: Environment monitoring, Natural sciences, Protection of Marine Resources, Environment safety.

Civil Protection
In major disasters like earthquakes, floods, landslides and forest fires, the transport and communications infrastructures are probably unavailable, while roads, power lines and water distribution may be damaged or even destroyed.

Galileo will be a valuable tool in such situations. Its high reliability, even under difficult conditions, and independence from a substantial ground infrastructure are of paramount importance to the civil protection authorities in managing disasters.
Some examples of practical uses of Galileo are: Disaster Monitoring and Prediction, Optimizing Disaster Relief Operations, Emergency Calls and Incident Management, Facilitating Humanitarian Aid Operations.

**Science**

The science community will be significantly impacted by the use of GALILEO. In the area of environment monitoring, GALILEO could for example be used for oceanographic and cryospheric mapping, including the determination of the extent of polluted areas, studies of tides, currents and sea levels, and tracking of icebergs. It could help in the monitoring of the atmosphere, including analysis of water vapor (for weather forecast and climate studies), or ionospheric measurement (for radio communication, space science, and even earthquake forecasting).

1.2.2. **The economical and work-related fallbacks**

Useful applications of Galileo will benefit both industrialised countries and the developing world.

The existence of Galileo, therefore, will provide considerable amount economic and social fallbacks to the world in general, and to Europe in particular.

An estimate of all benefits for the period 2000 and 2020 is illustrated below:

- Social benefits = 12,000 million Euros
- Economic benefits = 62,000 million Euros
- Total benefits = 74,000 million Euros
- 150,000 new jobs

**Social benefits**

Social benefits are those that will improve the quality of life for the citizens of Europe in general terms. These will be facilitated by advanced integrated service based on GALILEO for road applications. Such social benefits can have a huge value, but conversion of these into a monetary value is not always straightforward.
A summary of the annual social benefits of GALILEO are as follows:

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</thead>
<tbody>
<tr>
<td><strong>Annual averages</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced congestion</td>
<td>0</td>
<td>0</td>
<td>200</td>
<td>650</td>
<td>1425</td>
</tr>
<tr>
<td>Decreasing environmental</td>
<td>0</td>
<td>0</td>
<td>70</td>
<td>175</td>
<td>400</td>
</tr>
<tr>
<td>Increased safety</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Reuse of radio spectrum</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td><strong>TOTAL Social Benefits</strong></td>
<td>0</td>
<td>0</td>
<td>300</td>
<td>1000</td>
<td>2000</td>
</tr>
</tbody>
</table>

Average annual social benefit for Europe (million €)

*Value of reduced congestion across Europe*

Reduced congestion will decrease travel times which will also save money and increase economic efficiency. The benefits have been estimated for four sectors: aviation, car, lorries and buses, light commercial vehicles.

For the land transport sectors, the estimates are based on the efficiency savings brought about by automated route guidance and information systems. The timesaving estimated for each user type for urban and inter-urban travel are:

<table>
<thead>
<tr>
<th>Mode</th>
<th>Saving for vehicle for year</th>
</tr>
</thead>
<tbody>
<tr>
<td>cars</td>
<td>55 hours</td>
</tr>
<tr>
<td>Lorries and buses</td>
<td>193 hours</td>
</tr>
<tr>
<td>Light commercial</td>
<td>96 hours</td>
</tr>
</tbody>
</table>
These estimates are multiplied by the operating costs of each commercial vehicle and the estimated value of time for the driver of each car. These are then multiplied by the number of expected GALILEO users on an annual basis.

For aviation, the estimate is based upon the contribution of GALILEO to increase air traffic capacity. Eurocontrol is putting in place plans to increase capacity by 100% by 2017 using a range of measures. It is assumed that 5% of this capacity increase can be attributed to the GALILEO specific contribution.

*Value of decreasing environmental pollution*

One of the indirect benefits of improved efficiency in European transportation that GALILEO could bring about is a reduction of pollution and specifically emissions of greenhouse gases.

The impact of this is both political and economic. The EU has committed under the Kyoto Protocol to reduce its overall emissions to 8% below 1990 levels by 2012. It is estimated that the reductions from emissions in the transport sector due to GALILEO by 2015 could account for 0.2% of this 8% reduction.

For the land transport sectors, efficiency gains are based on time travel saving per user, which are then translated into fuel savings and multiplied by the number of users (cars, lorries or buses, vans) each year.

**Economic benefits to producers (supply side)**

The total benefit of GALILEO attributable to producers has been calculated. This includes firms across the entire value chain – space industry developing the space and ground network for GALILEO and also those that will deliver products (equipment manufactures) and services (service providers) based on the signal after Full Operational Capability. The calculation also includes the benefits to suppliers of these firms, who will see an increase of their level of turnover (this is an indirect effect).

The calculations have been made on annual basis, for specific time periods and performed specifically for European firms (including business activity within Europe and exports to the rest of the world). The results are shown below.
Economic benefits accrued to producers (million €) in Europe

<table>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Space sector firms and the GALILEO operator</strong></td>
<td>190</td>
<td>930</td>
<td>190</td>
<td>190</td>
<td>190</td>
</tr>
<tr>
<td><strong>Producers of integrated products &amp; services</strong></td>
<td></td>
<td></td>
<td>20</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td><strong>Total Benefits suppliers</strong></td>
<td>190</td>
<td>930</td>
<td>210</td>
<td>260</td>
<td>270</td>
</tr>
</tbody>
</table>

Economic benefits to users (demand side)

These include the direct benefits of new services that will be offered by GALILEO that cannot be offered by GPS as well as improved services that are possible because interoperability of GALILEO and GPS mean that some applications are more beneficial to users.

The benefit of each new service or improved service has been uniquely assessed and multiplied by the number of European users envisaged. The calculation relies heavily upon the description of the various satellite navigation applications made through the GALILEO architecture definition phase, view of potential user groups, the services levels available from potential alternative suppliers and expert opinion.

<table>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Net user benefits</strong></td>
<td>0</td>
<td>0</td>
<td>1990</td>
<td>4740</td>
<td>7630</td>
</tr>
</tbody>
</table>

Average annual net user benefits (million €) in Europe
1.2.3. The independence from the US technology

GALILEO architecture is made up of four principal components that makes the system completely autonomous and independent from the American GPS which currently has a monopoly:

- Global component
- Regional components
- Local components
- User receivers and terminals

Global component

The central component will be the **global constellation of thirty satellites**, distributed over three planes in Medium Earth Orbit. Within each plane, one satellite is an active spare, able to be moved to any of the other satellite positions within its plane, for replacement of a failed satellite.

The **control of the satellite constellation**, the synchronization of the satellite atomic clocks, processing of the integrity signal, and data handling of all internal and external elements is performed by two redundant **GALILEO Control Centers**. Both of which will be located on European ground.

**Data transfer** to and from the satellites is performed through a global network of GALILEO **Up-link Stations**, each of which combines a Telemetry, Telecommand & Tracking Station and a Mission Up-link Station.

**GALILEO Sensor Stations** distributed around the globe **sense the quality of the satellite navigation signal**. The information on the Signal In Space quality, also called integrity information, is the major differentiator of GALILEO compared to other GNSS and thus allows the GALILEO system to be certified for Safety-of-Life applications.
Regional components

A regional component is made up of an additional network of stations to oversee the integrity of the signals and a processing centre to provide this service.

The design of the GALILEO system is such as to permit the introduction of data from regional service providers using authorised integrity up-link channels provided by GALILEO, thereby making it possible to "personalise" integrity under partnership agreements with the relevant countries. The cost of this component will be borne by the region in question.

Local components

For some specific applications in given areas, more demanding levels of positioning performance will be necessary or, alternatively, integration with other functions, e.g. local communications, will confer added value on the basic service.

It will be possible to adapt local elements to specific requirements: airports, ports, rail, roads, urban areas, etc. Furthermore, each application will need to make provision for specific cases: road tunnels, urban buildings, underground parking complexes, etc.

Data may be transmitted to the user's receiver either via a specific link or by means of external systems, eg. mobile communication networks (using GSM or UMTS standards).

User receivers and terminals

Receivers will be the crucial link in the GALILEO chain and to be successful will need to satisfy market requirements:

- Competitive performance and costs compared with the existing systems;
- Adequate tailoring to the needs of users (general public and the professional market);
- Potential for change and integration of the services (e.g. communications);
- Possibility of multi-modal use.
A wide range of GALILEO receivers is forecast in order to provide the various types of satellite radio navigation services on offer, whether or not combined with other functions, for example:

An in-vehicle navigation platform offering the driver combined positioning and traffic information monitoring facilities;

Mini-terminals for use by the general public, or the incorporation of a positioning function as an integral feature in mobile telephones, providing value-added services or position location facilities;

The integration of a navigation service certified under aircraft industry standards in the operational support system for aircraft pilots;

- The challenge of the market in GALILEO receivers represents one of the major factors that will determine whether the European industry successfully takes off in this area.

1.3. The criticalities

1.3.1. The political issues within and outside Europe

After the agreement between Germany and Italy in March 2003 and the agreement between ESA countries in May 2003, GALILEO Project has been unlocked. In fact, in December 2002, there has been a stop because Spain and Germany didn’t accept a solution that should take GALILEO to the final phase.

It has been a delicate phase because the countries involved in GALILEO were discussing several aspects of project. The agreement among the 15 countries has not been easy and it is needed to find compromise solutions. In particular, the question was in which country should rise the control navigation system Agency. The most probable candidates were Germany and Italy and they both offered wide guarantee of success. The decision has been hard because no one of the two countries intended to renounce. To be the country that will give hospitality to GALILEO Agency, means to acquire a leader position at European level.

In the end Germany was awarded the principal legal center of GALILEO Industries and the nomination of the managing director. Italy got a national branch center and the nomination
of the vice managing director that will have the task to manage the four principal agreements of GALILEO project:

- realization of satellite equipment
- mission activity
- customer services
- ground services

In May 2003 in Paris, the ESA Countries found a financial agreement that satisfied everybody and in particular Madrid, that had requested an increase of its own participation share, important for the industrial return of the operation.

Spanish government has, therefore, obtained the share of 10% instead of 9% supposed in a first phase of GALILEO project, while the four major “shareholders” (Italy, Germany, France and United Kingdom) have accepted a reduction of own share from 17.50% to 17.38%. This has been an important compromise that has shown at last the European capacity to conciliate economic interests in order to make an industrialial wide-breath project take off.

Out of Europe, the major criticisms to GALILEO come from the United States. In fact:

The United States emphasises that the GPS is free of charge while GALILEO’s services will be charged. Actually, according to plans, GALILEO will be free of charge for basic applications; the applications for which a charge will be made will be those which require a very high quality of service which the GPS cannot provide.

Frequencies have been earmarked by the International telecommunications Union for all radio navigation systems. The United States is disputing the right of Europeans to use some of them which might, according to the United States, interfere with the GPS signal. The Europeans are aware of the need to avoid any risk of disturbing that system, and have come up with solutions which is supposed to give every possible guarantee in this connection.

The United States, finally, claims the right to jam GALILEO’s Public Regulated Service signal since it believes that it could be hijacked for hostile purposes.
The Europeans claim that they don’t intend to adopt a protectionist and monopolistic approach and they are willing to co-operate actively in all areas with the United States, as well as with Russia or China. An agreement with China has recently been performed.

1.3.2. Concerns about the real time and cost of implementation

There are several issues and criticisms, in Europe and in the world that can delay the GALILEO roadmap. The risks associated with delays in the GALILEO are critical because: The frequencies needed for GALILEO, obtained following difficult negotiations at the last World Radio Communications Conference, will be lost unless the first operational satellites are launched before 13 February 2006 – which presupposes successful completion of the successive preliminary technical stages as part of a precise and tight timetable.

It is vital that GALILEO should come into operation in 2008 in order to be able to take up the market shares available before the possible arrival of the America GPS III.

The costs of implementation of GALILEO project actually include systems engineering and management costs, satellite costs, launch costs, ground segment costs, system operations and validation costs, and costs of a support programme for the user segment and critical technology. The costs of integrating EGNOS are also included in order to provide a total cost estimate.

All delays in the GALILEO development schedule will cause extensions of the project activities of the industrial contractors involved in the development phase, with the effect of increasing the overall costs, especially the systems engineering and management costs and the technology support program costs, described hereafter.

Satellite costs

The satellite cost estimation assumes that GALILEO will comprise a constellation of 30 satellites when Full Operation Capability is achieved in early 2008.

In addition to the costs of the operational constellation, the total satellite costs include design, development and qualification costs and also an allowance for 2 experiment spacecraft to be launched during the development and validation phase.
Maintenance of full operational capability after 2008 will require the launch of a further 45 satellites over a 20 year period to 2028 based on the present satellite lifetime assumption (15 years).

**Launch costs**

The launch cost estimate assumes that 2 preliminary satellites will be launched separately. Launch costs are conservatively estimated at 40 M€ per launch. It is assumed that the 30 satellites in the operational constellation will be launched in batches of 5. The average cost per launch is estimated at 110 M€ giving a total of 660 M€ for the launches required during the deployment phase. No allowance has been made for the additional satellite procurement costs that would result from a launch failure.

**Ground segment**

The ground segment cost estimate covers all elements needed to implement the GALILEO global component. There are no separate costs for a European regional component. EGNOS integration costs are separately accounted for (see note below). A first estimate for a regional overlay is in the order of 90 to 150 M€, depending to a large extent on definition of the region. It is similarly assumed that the costs of deploying and operating the local components needed to provide specialised services over localised areas will be borne by various local service providers, some typical figures for the recurrent cost of ground infrastructures can be listed:

- Mass market application: 5-20 K€
- Professional market application: 50-70 K€
- Safety of life application:
  - Maritime: 130-200 K€
  - Aviation: 230-700 K€
**Operations and validation costs**

Cost will be incurred due to the need to validate the GALILEO system prior to the achievement of FOC. These costs are estimated at 70 M€ during the development and validation phase.

**Technology support program**

The cost of manufacturing user terminal equipment is not included in the GALILEO cost estimate as this will be borne by industry. However a need is foreseen for a technology support programme to support the development of critical units such as onboard clocks or user segment equipment (terminals, receive, etc.) which might otherwise be regarded as too high risk for the programme planning or to attract industry investment. The costs of such a programme have been estimated at 70 M€ in the development and validation phase to 2005 and a further 60 M€ in the deployment phase, i.e. a total of 130 M€ up to FOC.

**Systems engineering and management**

Systems engineering and management costs include the costs that will be incurred by the “system contractor“ responsible for procurement, operation and maintenance of the GALILEO infrastructure together with all other management costs of the GALILEO Operating Company. The latter includes general business management, delivery of the GALILEO services including collection of revenues, safety management, marketing and promotion of GALILEO services and the costs of raising finance for the business venture.

The management costs of the public sector GALILEO Agency also need to be considered but are likely to be small compared to the other management costs identified.

Total systems engineering and management costs up to “Full Operational Capability” in 2008 are estimated at 290 M€ of which 160 M€ will be incurred in the development and validation phase and 130 M€ in the deployment phase.

**EGNOS integration**

The costs of the EGNOS development and implementation activities currently underway are not included in the GALILEO cost estimate as EGNOS is considered a separate programme.
Integration of EGNOS into the GALILEO system architecture will however incur some costs due to the need for modifications to the GALILEO ground segment. These costs are estimated at 50 M€ and will be incurred in the development phase and in the validation phase between 2001 and 2007.

A summary of estimated costs is shown in following table:

<table>
<thead>
<tr>
<th></th>
<th>Cumulative Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems engineering and management</td>
<td>160</td>
</tr>
<tr>
<td>Satellites and launches</td>
<td>320</td>
</tr>
<tr>
<td>Ground segment</td>
<td>480</td>
</tr>
<tr>
<td>EGNOS integration</td>
<td>0</td>
</tr>
<tr>
<td>User segment technology support programme</td>
<td>70</td>
</tr>
<tr>
<td>Operations (and replacements after 2008)</td>
<td>70</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1,100</td>
</tr>
</tbody>
</table>

Breakdown of estimated costs of the GALILEO system (million €)

1.3.3. The technical standards

Galileo will provide 10 navigation signals in Right Hand Circular Polarization (RHCP) in the frequency ranges 1164-1215 MHz (E5a and E5b), 1215-1300 MHz (E6) and 1559-1592 MHz (E2-L1-E1 1), which are part of the Radio Navigation Satellite Service (RNSS) allocation.

All the Galileo satellites will share the same nominal frequency, making use of Code Division Multiple Access (CDMA) compatible with the GPS approach. Six signals are accessible to all Galileo users for Open Services (OS) and Safety-of-life Services (SoL). Two signals with encrypted ranging codes are accessible only to some dedicated users that gain access through a given Commercial Service (CS) provider. Finally, two signals with encrypted ranging codes and data are accessible to authorized users of the Public Regulated Service (PRS).

Recent results of interference studies:

The use of the frequency range 960-1215 MHz by aeronautical radio-navigation services is reserved on a worldwide basis to airborne electronic aids to air navigation and any directly associated ground-based facilities and, on a primary basis, to radio-navigation satellite services. This multiple allocation causes interference, which has to be assessed carefully to allow the usage of GPS/Galileo navigation signals for safety critical applications.
Interference due to these ground-based sources increases with altitude since more interfering signals are received.

Compatibility/Interoperability of GALILEO-GPS:
Galileo shall be designed and developed using time, geodesy and signal structure standards interoperable and compatible with civil GPS and its augmentations.
Compatibility is in this context understood as the assurance that Galileo or GPS will not degrade the stand-alone service of the other system. Interoperability is the ability for the combined use of both GNSS to improve upon accuracy, integrity, availability and reliability through the use of a single common receiver design.

1.3.4. The competition from the terrestrial wireless operators
Location Based Services (LBS) based on GSM and UMTS technology, represent a large potentiality in competition with GALILEO technology to which they could subtract market shares as already happened in recent past with GPS technology.
This kind of competition could resemble the one that caused in the recent past the commercial failure of the satellite mobile phone operators Iridium, Globalstar and ICO. The satellite technology was unique at the time that it was conceived, but it became obsolete when the system started the operations after several years. The service was, in fact, comparable with the one offered by GSM operators with similar coverage and at a much lowest cost.
Examples of existing GSM location-based applications are described hereafter:

- The NIMBLE localization system from Telecom Italia Lab, launched in February 2003 has achieved a platform that uses a new localization technique, conceived and developed in its own laboratories. This technology allows the customer to be localized with a precision of 100-150 metres in urban areas. The NIMBLE localization system uses data gathered from the mobile phone localization cell that are sent, through SMS, to the localization platform. The server that receives the SMS, reads the SMS information and determines mobile phone position.
• Since February 2003, customers from Wind (the third Italian mobile phone operator) can consult, while moving, map services. It’s sufficient to point out an address to show the particular topographic map of an area. This service allows:
  o Finding companies in the area of localization;
  o Knowing traffic information;
  o Calculating the optimum route between two places while providing detailed information on the lay-out and on the directions.

• Oberthur Card System, a company operating in the smart card sector, and Alcatel have introduced a demonstration of the “Guardian Angel” system at the 3GSM World Congress of Cannes 2003. The system allows the parents of monitoring the position of their children when they come home from school. In order to start the service, the parents must follow the child on the usually road for coming home using an application of their son’s mobile phone. Child’s real route is compared with that standard one. If the routes don’t coincide, the “Guardian Angel” will send a SMS to the parents’ phone, who so can call their son to control if there is some problem. An alarm message is sent also if the child doesn’t come home on time.

• In September 2002, H3G and Tele Atlas have achieved in Italy and United Kingdom, a system for developing information services and geographic localization. The agreement implies that Tele Atlas realizes to H3G the road digitalized maps of 30.000 Europe cities, information on interesting points: post office, shopping centres, restaurants, train stations, gas stations, etc).

1.4. The present project framework

1.4.1. ESA and EU existing studies

During the definition phase, the European Commission and the European Space Agency have activated a very large part of the European space industry as well as a large number of potential service providers with a view to defining the basic elements of this project.

A number of projects and comprehensive studies have contributed to this phase:

• GALA, for the overall architecture definition;
• **GEMINUS**, to support the GALILEO service definition;
• **INTEG**, for EGNOS integration into Galileo;
• **SAGA**, to support the GALILEO Standardisation process;
• **GalileoSat**, for the space segment architecture definition;
• **GUST**, related to GALILEO receivers pre-specification and certification;
• **SARGAL**, related to potential SAR (Search and Rescue) applications of Galileo.

Currently, two major activities related to the definition phase are going on:

• Phase B2 of the GalileoSat study led by ESA focusses on the consolidation of mission and system requirements, system architecture and finalisation of phase B activities leading to the Preliminary System Design Review (PSDR).

• **GALILEI** is an activity funded by the European Commission. It has the purpose of defining the overall service and user approach for GALILEO, complementing the studies performed by ESA in the frame of the GALILEO definition phase, in particular on following topics:
  - architecture of GALILEO Local Components and customisation for some key applications;
  - interoperability between GALILEO and other systems (GNSS, GSM/UMTS, etc.);
  - co-ordination and protection of frequencies used by GALILEO;
  - standardisation and certification aspects;
  - market observatory of applications using GALILEO;
  - definition of the legal, regulatory and institutional framework of GALILEO.

Moreover, the following Pilot Projects are going on under the Growth thematic programme of the 5th RTD Framework Programme of the European Union, managed by the Commission's Directorate-General for Energy and Transport:
1. **GADEROS - Galileo Demonstrator for Railway Operation Systems** (December 2001 - June 2004), it will demonstrate the use of GNSS safety-of-life features for defining a satellite-based system to perform train location for safe railway applications that will be integrated into the European Rail Traffic Management System (ERTMS) / European Train Control System (ETCS). The system will offer another technological approach for train location, mainly for conventional and low-density traffic lines.

2. **GALLANT - GALileo for safety of Life Application of driver assistaNce in road Transport** (January 2002 - December 2003), is the follow-on to the “GALILEO Application for Road Safety and Mobility” GALA pilot project, which focused on specifying the technical needs of an Advanced Driver Assistant System (ADAS) for the road environment. It is a significant important improvement over the prototype system developed in recent years within different national and international initiatives, using GPS integrated with ADAS.

3. **INSTANT - Infomobility services for safety-critical applications** (July 2002 - March 2004), it addresses sustainable mobility and intermodality and focuses on the management of large-scale events and emergency situations. In particular, it is targeting the 2004 Olympic Games, as a case-study, and proposes safety-of-life applications in two different environments (sea and land) and in different land surroundings (urban, semi-urban). Applications will make extensive use of up-to-date GNSS receivers in close integration with other emerging technologies such as geo-information, mobile satellite communications, personal digital assistants, and mobile mapping software.

4. **NAUPLIOS - Improving safety in maritime navigation** (July 2002 - March 2004, it will demonstrate the added value of the Galileo positioning and SAR services for commercial shipping. It will make use of the EGNOS Test Bed and six vessels equipped with autonomous terminals - an EGNOS receiver, a satellite telecom link and an Automatic Identification System (AIS). NAUPLIOS Control Centres will monitor results, which will be adapted in a geographical information system and formatted prior to being transmitted to several kinds of end users. NAUPLIOS will demonstrate how monitoring and surveillance of European waters can be improved such that risks can be identified at an early stage and measures can be taken to avoid major pollution incidents.
5. **POLARIS - A navigation system performance-analysis tool** (January 2002 - December 2003), it will allow the assessment of navigation performances using Galileo alone or combined with various Global Navigation Satellite Systems (GNSS) and a wide variety of systems and sensors. A powerful simulation tool for users with a range of satellite navigation experience and needs, Polaris will provide clear results that can be translated into Galileo system requirements.

### 1.4.2. Expected development program of the Galileo project

The GALILEO program comprises the following phases:

- Definition of the system.
- Development of the system.
- Deployment and commercial operation.

During the definition phase, the Commission and the European Space Agency (ESA) have mobilised a very large part of the European space industry as well as a large number of potential service providers with a view to defining the basic elements of this project.

The development and validation phase (2002 – 2005) covers the detailed definition and subsequent manufacture of the various system components: satellites, ground components, user receivers.

This validation will require the putting into orbit of prototype satellites from 2004 and the creation of a minimal ground infrastructure. It will allow the necessary adjustments to be made to the ground sector with a view to its global deployment and the launching, if necessary, of operational prototypes manufactured in parallel. During this phase it will also be possible to develop the receivers and local elements and to verify the frequency allocation conditions imposed by the International Telecommunication Union.

The constellation deployment phase will consist in gradually putting all the operational satellites into orbit from 2006 and in ensuring the full deployment of the ground infrastructure so as to be able to offer an operational service from 2008 onwards.
1.4.3. **Future financial framework**

The start-up costs through to 2008 for this system are estimated at 3.25 billion euro. Much of the financing will be raised through an open public-private partnership scheme.

**Study phase**

Almost € 80 million from European funds have already been allocated for this study phase, now nearing completion.

**Development phase (2001-2005)**

A joint (European Union/ESA) public funding of € 1.1 billion is budgeted. On March 2001, a group of industrialists (service providers, operators, space system and parts manufacturers) agreed to set up a joint company with an investment of € 200 million. They will play an active role in defining the services offered by Galileo.

**Deployment phase (2006-2007)**

The satellite deployment phase should be achieved with a financing of € 2.15 billion, most of which will be raised by the private sector.

**Operational phase (2008)**

Maintenance costs are estimated at € 20 million a year.

For further more information, see par. 1.1.4.
2. PART 2 – Motorway operators and new services

2.1 The possible role of a Motorway operator in GALILEO

2.1.1 Developing GALILEO local components
Motorways Operators will have the opportunity to offer new services based on GALILEO local components.
Along some motorways elements such as tunnels, canyons or other closed or underground environments (e.g. parking complexes) the GALILEO basic services might not be reachable.
In such areas, the Motorway Operator has the opportunity to build a local network of sensors and transmitters that would offer continuity to the GALILEO positioning information to motorway users, the so called Local Area Augmentation Services (LAAS).
Thanks to this proprietary network, the Motorway Operator could provide value added information to motorway users for free or as chargeable premium services.
The information may be transmitted to the user's receiver by means of mobile communication networks using GSM or UMTS standards, RDS/radio, DAB, wi-fi, etc. Commercial agreements shall be made between the Motorway Operator and the mobile network operator and for these transmission services.

Service Providers will access GALILEO services under contractual agreements. They will take market risk and recover their own costs, possibly through reselling to national / regional / local service providers supported by retailers and after sales networks.
The European guidelines regarding mobility take basically into account two important wording: interoperability and intermodality. The medium-long term future will be likely featured by devices gathering different technologies and standards inside, in order to respond to the service field of new applications and to geographic coverage for existing ones.

2.1.2 The most Interesting applications according to Motorway Operators
Three applications have been selected following a survey with the Italian motorway operators: Autostrada Torino-Milano, Autostrada Torino-Alessandria Piacenza, Autostrade Group, Autovie Venete and Autostrada Brescia-Padova.
The survey has been based on a questionnaire structured with questions relevant to those applications considered more interesting using GPS and EGNOS in the short-medium term (2003-2008) and using GALILEO starting from 2008. The questionnaire and aggregated results are attached to this study as Annex 1.

The satellite-based applications considered most interesting in the survey have been:

- Automatic Toll Collection
- Value added services: Emergency Services and User Information
- Fleet management

The road tolling based on satellite localization and mobile communication GSM/UMTS has been deemed interesting according to five operators, starting from 2008; this application is not considered among the services that the motorway operators want to implement before 2008 because the DSRC technology based on Telepass results still reliable.

Moreover, no operator deemed interesting the use of a Services Agency for the collection of the road toll.

In the short-medium term (2003-2008), for every motorway operator, the development of applications for Fleet Management applied to People Transport Monitoring is considered quite interesting; while from 2008, also the Goods Transport Monitoring, especially the hazardous freight transport, will be considered for implementation.

The sample does not appear particularly interested in guaranteeing the continuity of the satellite signal through local components, for the lack of tunnels according to few operators and because it is not a priority for the other.

Moreover, the sample considers of interest the development of value-added services, in particular Emergency Services and User Information.

Finally, all the motorway operators showed interest in the Working Groups on GALILEO in order to provide active contribution on Standards, development applications, etc.

In the following paragraphs the three applications Automatic Toll Collection, Emergency Call Systems and Fleet Management are discussed in terms of criticalities/benefits, cost elements and analysis of similar existing experiences in Italy and Europe based on the GPS signal.
2.1.2.1. Automatic Toll Collection

The main objective of such systems is to speed up toll collection process, thereby reducing the cost of the congestion. Various systems were introduced, first at local and then at national level, but these systems are not compatible.

Italy, Portugal, France, Switzerland, Slovenia and Norway have national systems, but they are mutually incompatible. In view of the growth of the international traffic, it is now desirable for these systems to be interoperable at European level.

In April 2003, the EC issued a Proposal for a Directive on the widespread introduction and interoperability of electronic road toll systems in the Community\(^2\).

According to this directive, the new systems should be based on the use of technologies that are already available: the GNSS/GSM combination, together with microwave, which is already in widespread use in the Union. There are no plans in the Member States to introduce new toll systems using any technology other than that based on microwaves or the GPS/GSM combination.

Criticalities

According to the EC Proposal of Directive, all motorway operators should adopt by 2012 the satellite technology, facing a number of open issues, namely:

**Complexity of the Systems:** Satellite Based toll collection systems are very complex in architecture and operating procedures. The first operational system is Toll Collect in Germany which is facing delays and technical difficulties for the commercial startup (see following description of Toll Collect).

**Cartography:** Digital cartography is presently developed by two vendors, no one of them native of Europe: Navtech and Teleatlas, whom standards are technically non-interoperable. The precisions of the cartography of both vendors could be in some sections not accurate enough in order to allow a reliable European toll system, ensuring with high precision that the vehicles are on the toll roads and not, maybe, in a side free road. In perspective, the detailed

cartography should be downloaded by the drivers in mobility. The lack of standards should be addressed since European Motorway Operators adopting Satellite Road Tolling should be free to choose cartographic data from those vendors that will provide reliable and accurate cartography.

**Investments payback**: Motorway operating companies have already invested large sums of money (several hundred million euros per network) to install systems on their networks. Account must be taken of these investments and their payback (in economical and technical terms) so as to migrate progressively towards interoperable systems as part of the "European service".

**Migration to new technology**: it will be possible for existing national and local systems to be maintained alongside the European service for local or National use until they are eventually decommissioned. Microwave systems which are still in service may continue to be used. In such areas where Galileo-based Road Tolling systems will be adopted, a migration strategy will have to be drawn.

**Interoperability**: many Motorway Operators spent huge efforts to achieve the tolling interoperability along a seamless national network (especially Italy that has today the largest interoperable network in Europe). AISCAT issued a paper where considers necessary to adopt a careful approach at European Level and with the adoption of satellite-based Electronic Tolling Systems, since a loss of interoperability could eventually result in a loss of revenues. Italian operators have been working for a long time with their ASECAP colleagues, within EU co-funded projects (TARDIS, CASH, MOVE-IT, CESARE, PISTA) and in bi-lateral activities (Italy-France, Italy-Austria), developing also specific on-board devices aimed to permit the coexistence between different microwave applications.

**Definition of standards**: since the quality of services shall be guaranteed across Europe, Motorway Operators shall study and define standards with respect to classification of vehicles, data interchange and financial procedures for cross-country billing, common signaling, equal treatment between natives and foreigners, etc.

**Operations**: the adoption of Satellite Electronic Toll Collection on motorway operations shall avoid impacts in terms of traffic congestion at gateways, security, legal and regulatory issues, effects on drivers (e.g. interoperability with installed on-board microwave systems, cost and
installation of new On Board Units, ...), procedures to be followed in case of exception and malfunctioning, etc.

**Enforcement**: an area of criticality comes from the implementation of enforcement systems and the recognition of their efficiency by the motorway users. The existing enforcement system implemented at the motorway gates for DSRC systems is today considered very efficient and it could be adapted to a new satellite-based system. In areas where no existing enforcement systems exist (e.g. in countries with no motorway gates), they shall be implemented and their effectiveness has still to be proven and consequently accepted by users.

**Benefits**
The use of satellite positioning and mobile communications technologies is sponsored by the EC for:

- the deployment of the European electronic toll service;
- all new national systems;

in fact location based technologies appear more flexible and better suited to roads that today are not subject to toll; moreover the satellite technology could be better suited to the new EU charging policies.

Satellite positioning in conjunction with mobile communications is a solution that allows uniform tolling applied to vehicles entering or leaving a given geographic area, both locally (e.g. a conurbation) and at European level.

According to the EC, electronic toll shall be the application that could allow the massive diffusion of on-board Galileo-enabled vehicle terminals that can provide also other services for safety and information of the users.

Thanks to the dissemination of a large number of such on-board units, a critical mass shall be achieved and their manufacturing cost should become considerably lower than today (presently the cost of such terminals is in the order of € 500-600).

- The vast presence of Galileo-enabled terminals for Toll Collection is consequently the potential key to develop the information society in road transport, as the same equipment installed in vehicles will allow value-added telematic services and safety
systems to be deployed for travelers: automatic emergency services, traffic information, hazardous goods monitoring, basic and premium information services, …

2.1.2.2. Existing systems in Europe

*Toll Collect in Germany*

Its geographical position in the center of Europe makes Germany the hub of international commercial trucking. The continual growth in the volume of freight transport had a significant impact on German motorways, requiring high investment for maintenance and construction.

The German Federal Government has decided the introduction of new road charging system for the use of its 12,000 Km of motorways by heavy goods vehicles over 12 ton. It was planned to replace in 2003 the Eurovignette system by an automatic system, which will take into account the number of km traveled and the class of the vehicle.

Two modes of payment will be offered by the German authorities:

1. an automatic system for frequent users, who will have to install in their vehicles an On Board Unit (OBU) which is made of combination of GPS/GSM for vehicle location and transmission of the transactions to the billing center. In addition, a DSRC module will allow the enforcement process and, in prospective, the interoperability of road tolling with the other European countries.

2. The non-frequent users will be required to make a reservation before entering on the motorway. The reservation can be made either by telephone, via the Internet or on Kiosks, which will be installed in many service areas and commercial centers.

To avoid frauds, several methods of enforcement will be implemented. Has to be verified if this is or not the weak point of the system, being the final enforcement done manually or free flowing vehicles after an automated screening.

The steps of the automatic toll collection are the following:

- Vehicle detection;
Vehicle classification (without stopping the vehicle);

Verification of the correct functioning of the toll collection system through:

- the verification of the correct transmission of the radio frequency or infrared signal of the on-board device to the Central System;
- the verification of the car plate which should be automatically detected after the taking of the photo.

Toll Collect performs this kind of Control (automatic, stationary or mobile) thank to some Control Stations installed on motorway sections. They are constituted of infrared sensors, Communication Interfaces (DSRC) and cameras reading car plates.

The system implies an open platform that can evolve so allowing new mobility services. In particular, it could allow advanced fleet management functions, route optimization, localization, information useful to move from one place to another.

**Delays in starting the Toll Collect service:** Originally scheduled to start in August 2003 and then delayed to November 2003, the project has been plagued by series of administrative and technical difficulties and it is not expected to be up and running before the first or second quarter of 2004. Various reasons are the cause of the delay, for example: not enough trucks equipped with the devices (only 80,000 of the necessary 450,000 trucks equipped - and only half those installed actually work), the on-board-units that do work don't register the correct toll (the same route registers with different prices on different days), route-registration via the Internet application takes a 40 minutes, …

The German government will lose 156 million euros in revenue for every month the toll system is delayed. The Toll Collect consortium is obliged to pay the state 7.5 million euros per month if the delay lasts more than three months. One of the consequences of the delay is that the sum of around 990 million Euros will be lost. Money that the German government has already spent.

**Telepass 3G**
Autostrade per l’Italia has been studying a new concept of On Board Equipment (OBE) for three years with the cooperation of the Italian/French industry ST-Microelectronics. This
OBE, named provisionally *Telepass 3G Project*, has the aim to help realising an integrated system based upon:

- Satellite technology to determine the position of vehicles;
- GSM/GPRS technologies capable to provide a channel to exchange text, audio and video files;
- DSRC 5.8 GHz;
- Intranet/Internet technologies for the information management via the traffic Information Center of the involved transport operators.

One of the main features of the system will be the detection of the position of vehicles along the supervision area in order to use this information and take profit of added value services. In general, they could have the following application services to motorway users:

- *Fees payment facility* by means of an integrated DSRC module capable to communicate with the Road Side Equipments for the electronic toll collection;
- *Assistance to drivers*, following SOS calls (made by some function keys placed on the Telepass 3G) or automatically after an accident with direct allocation of calls to competent bodies;
- *Traffic information* related to the stretches the vehicle is going to ride on.

**The European Space Agency (ESA)**

ESA is funding the Irish provider of location technology products Mapflow to undertake a feasibility study to look into the possibility of implementing a pan-European road tolling system. The research aims to establish whether satellite technology can be used to calculate the cost of motoring.

A plan exists to complement this activity with a real demonstration of the virtual tolling concept in the greater area of Lisbon. Also under ESA funding, the project is being conducted by the Portuguese company Skysoft in close cooperation with the Portuguese motorway authority. The demonstration is planned for the end of 2004.

The research commissioned by ESA on behalf of the European Union will evaluate the feasibility of a standard tolling approach throughout Europe. The study will look at the effects of such a system on Europe’s road infrastructure as well as associated technology impacts.
Cost elements

According to the existing experiences, the cost elements that a Motorway Operator will be likely sustaining for developing a satellite-based Toll Collection applications can be classified as follows:

- Development costs, including such elements as:
  - Design of processes for manual and automatic toll collection and enforcement techniques;
  - System Functional design;
  - Technical architecture definition;
  - Hardware and software components design and development;
  - Billing and customer care systems design and implementation;
  - Enforcement systems;

- Operating costs, including such elements as:
  - Manpower costs;
  - Assets amortization (Hardware, software, Enforcement equipment …);
  - Enforcement operations costs;
  - Telecommunications costs;
  - Customer care costs.

In the case of the German Toll Collect System, according to information given by the winning consortium, the development costs have been of the order of € 160 Million, while the operating costs amount about € 1 Billion/year against an expected revenue of about € 4/5 Billion/year.
2.1.2.2 SOS emergency call system

The existence of a direct relationship between the rescue time and the probability of survival, explains why the realisation of an emergency services for road accidents can contribute significantly to the saving of lives. Recent European analyses have estimated that the use of telematics can reduce the reaction time in response to the emergency call by as much as 30%. It has been calculated that automatically generated calls from vehicles can increase the probability of survival in road accidents by 15%.

Emergency and rescue services based on telematics are divided into:

- **In-vehicle systems**, where the call is initiated automatically (e.g. on airbag deployment) or by the driver, and then the call is routed (via the network operator) to a service provider, who can decide how to take the call, either relaying it to the national emergency call operator or passing it directly to the nearest emergency service; In this case, both voice and data links are needed. The data link can send the vehicle identity, position, status and other details to the service provider, while a voice link is needed between the operator and the driver, to clarify the nature of and response to the emergency.

- **Emergency call originating from a mobile phone**. In this case, the call must be dialled manually (e.g. to the Motorway Operator Rescue Service) by the driver/passenger, it passes via the network operator to a special network of emergency call operators, who take the call orally and relay it to the appropriate emergency agency. The network operator has the responsibility to locate the caller before passing on the call.

Examples currently seen in Europe include ADAC, Passo and Tegaron in Germany, and Viasat and Movitrack services in Italy. These services are increasingly being built into vehicles from now as standard equipment, e.g. Opel OnStar and Volkswagen Telematik.

GALILEO services will improve the Assistance and Security Services by better positioning and consequently their benefit to the user, i.e.:

- assistance call with automatic localisation of the vehicle;
- release of calls also in case of heavy injuries of the drivers;
- faster arrival of rescue and service vehicles due to exact position;
- prepared and informed rescue service staff a arrival;
Benefits

Emergency and rescue services based on telematics can help reduce the rescue time and the traffic on the Motorway Network by applying automated processes:

- the automatic sending of the emergency call (just a few seconds are needed instead of several minutes or even longer time lapse between crash and notification) permits to resolve the accident in a shortest time and could reduce the impact on the circulation on the motorway network;
- reduced travel time to the accident by the rescuers: accuracy of the location data speeds up the search for the scene of the accident avoiding mistakes in routing. It is also possible for the traffic control centre to propose the fastest (and most traffic free) route to the scene. The advantages of the actual bullet are certainly more important in the case of a complex road network, rather than in the case of motorways;
- on the scene rescue time: the availability of data on the type of accident allow the operations centre to know whether more than one emergency service is involved (e.g. fire service, police, ambulance) and to co-ordinate the rescue;
- transport time to hospital: the clinical data transmitted by the on-road device could allows the rescue agency to transport the patient to the most suitable hospital or trauma centre. In addition, information can be received from the operation centre to ensure the fastest route is taken.

Criticalities

Decisive factors for the successful deployment of the service Emergency Call that uses the GNSS for localisation are:

- reasonable price for the service;
- possibility of an immediate release of the alarm, by the driver or automatically through sensors (airbag) and direct information of the emergency service;
- knowledge of actual position;
Benefits and criticalities for the use of Galileo – the road operator point of view

- simple handling of the service;
- no dependence on infrastructure (mobile/fixed telephone line, SOS-telephone).

**Experiences and existing systems in Europe**

Italy is carrying out the pilot project “E-Calls”, an initiative promoted by the Italian Ministry of Infrastructure and Transport. This pilot project will adopt the European Standard Protocol for Emergency Calls defined by the European Project E-MERGE.

The architecture is structured on six main levels, or functional groups, relating to the actors involved in the pilot project: Vehicle, Service Providers, Public Safety Answering Points (PSAP), Info Providers, Rescue Centres, GSM Operator.

The Vehicle involved in the project will be provided with on-board devices and several sensors to monitor the vehicle status and, in some cases, the driver status too. These devices have to be able to communicate to the PSAP the emergency details such as the Calling Line Identification of the device, time stamp, location (actual and last three vehicle positions), how the e-call has been generated and the language spoken by the driver.

The Service Providers involved in the E-Calls project, will be responsible for sending a copy of the message to the PSAP. Currently, they will only fulfil the function of message forwarders.

The Public Safety Answering Points (PSAP) are the core of the system and must and be equipped with an adequate information system and qualified personnel. The PSAP has the following principal functions: emergency call entry, activation of hands free communication, emergency classification and localisation, forwarding of the request to rescue centres, coordination of the rescue operations.

The E-Calls pilot project has identified 2 PSAPs (one in Milan and one in Turin) to test the communication between them.

The task of the Info Providers is to supply real-time traffic data to the PSAP, that will fulfil the additional function of route planning in order to provide optimised routes to rescue vehicles.

The GSM Operator has the duty of making available localisation data obtained with the latest technologies, and the Calling Line Identification.
Cost elements

According to the existing experiences, the cost elements that a Motorway Operator will be likely sustaining for developing a satellite-based SOS emergency Calls system can be classified as follows:

- Development costs, including elements such as:
  - Design of processes for managing manual and automatic emergency calls.
  - Rescue operations center setup for teleassistance (hardware and software components, manpower costs)
  - Technical architecture definition and system integration.

- Operating costs, including such elements as:
  - GSM data transmitters/receivers to be installed on board service vehicle
    - Rescue operations center /Service providers manpower and operating costs
    - Telecommunications operator costs

As a reference, the estimated costs for developing and operating E-Calls are:

<table>
<thead>
<tr>
<th>Development costs, including such elements as:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• User needs and design of processes</td>
<td>500.000 Euro</td>
</tr>
<tr>
<td>• System architecture design, infrastructure technical specs, vehicles technical specs definition</td>
<td>500.000 Euro</td>
</tr>
<tr>
<td>• Infrastructure hardware and software, vehicles system development costs</td>
<td>2.200.000 Euro</td>
</tr>
<tr>
<td>• Infrastructures and vehicles tests, analysis of results</td>
<td>900.000 Euro</td>
</tr>
<tr>
<td>Total development cost</td>
<td>4.100.000 Euro</td>
</tr>
</tbody>
</table>
2.1.2.3. **Fleet Management Systems**

These systems integrate a positioning device, GPS today and Galileo in the future, with a communications mechanism such as GSM or UMTS.

Two elements are at the core of a fleet management system: the tracking devices on board the vehicles and a central computer at the dispatching centre.

There may also be an in-vehicle interface that permits the driver to access information and send messages. In addition, some systems are equipped to monitor vehicle parameters, such as sensing whether or not the doors of the trailer are open, closed, or locked or what the temperature level is inside the trailer. Other sensors could detect, for example, extraordinary or violent movements, unscheduled stops (possible hijacking), or unsafe temperatures in trailers for perishable goods.

This system can also be integrated with an automated company management system that includes operational planning, statistical data from the operation management system, staff data (salaries, leave, etc.) financial and accounting information and other details, providing a complete business management tool.

Major applications for fleet management systems are:

- Locating and tracking vehicles world-wide;
- Monitoring of the vehicle and its cargo conditions;
- Additional functions as in board alarms, journey plans, message management (text and data) between fleet operator and vehicle;
- In car location / navigation;
- Information services based on GPS/GSM combined services;
- Fleet monitoring and control;
- Traffic monitoring, control and management;
- Hazardous cargo tracking;
- Theft identification;
- Police & rescue services.
Benefits

Traffic Management Systems aim at improving traffic flows and reduced accidents, with longer-term aims of reducing the workload on drivers and co-ordinating different transportation systems for freight and passenger use. These systems can help to improve vehicle utilisation by 15%, reduce fuel costs by 10% and then environment pollution. For motorway operators, the main benefit is related to service vehicles fleet management. Indeed, by knowing the position of their vehicles, it is possible to address them in the place where there is the problem, reducing intervention times and costs, consequently optimising the quality of service.

Criticalities

The most critical issues for this application are:

- Price of user terminal;
- Accuracy of data;
- Cost of acquiring this data;
- Percentage of data lost due to no signal;
- Integrity of the data.

Experiences and existing systems in Europe

ESA-Telespazio (Italy)

Telespazio has developed, in the EGNOS-TRAN program (European Geostationary Navigation Overlay Service - Terrestrial Regional Augmentation Networks) promoted by ESA, an innovative solution for using of EGNOS navigation services in multimodal context (hazardous freight transport, personal security, GIS applications, air traffic control and airport vehicles management). At practical level, it has been implemented dangerous goods transport management, in particular the authorization of travels, route monitoring and control, and the automatic emergency calls.
Mobiloc (France)

Mobiloc, a fully owned subsidiary of TDF (Telediffusion de France) developed a solution that uses on-board terminals that transmit location and other data via its radio network to and from the vehicles and managers. This is combined with the control centre processing software that display fleet position on a roadmap updated every 20 seconds. Representative symbols identify the vehicles (type, speed, availability, etc.), with clickable window display providing corresponding information (name, last known position and time, nearest location, etc.).

Mizar Automazione (Italy)

Mizar offers a fleet management system, Fleetunner, a modular system based on satellite navigation, palmotop computers and the internet. It enables continuous monitoring of current location of fleet vehicles on detailed digital maps and communications to and from the vehicles. It permits monitoring of important parameters on the vehicle, driver and delivery task as well as offering an alarm system that alerts managers of incidents, safety problems and expiry of driving time. In addition, it can define the best route with detailed directions for the driver and provide real-time information on traffic and road conditions. There are also tools for automatic analysis of operations and vehicles as well as printing reports.

Autostrada dei Fiori (Italy)

Autostrada dei Fiori (AdF) carried out in 2002 the preliminary design of a system capable of positioning a certain vehicle by means of satellite GPS technology and exchanging information with a control centre using GMS devices. At present, AdF plans to carry on the study with the experimentation of a set of prototypes installed on probe vehicles, putting more efforts in the GSM message server and in the optimisation of the on board device; a preliminary study will also be started to begin exploring the GALILEO facility for satellite positioning.

Cost elements

The cost elements that a Motorway Operator will be likely sustaining for developing service vehicles fleet management are:
• Development costs, including such elements as:
  o Design of processes for the handling of data of the Operations Center
  o Operations center setup (hardware and software components, manpower costs)
  o Technical architecture definition and system integration

• Operating costs, including such elements as:
  o GSM data transmitters/receivers to be installed on board service vehicle.
  o Operations center /Service providers manpower and operating costs.
  o Telecommunications operator costs.

As a reference, the costs for developing and operating the above mentioned Fleetrunner system by MIZAR have been of the order of:

<table>
<thead>
<tr>
<th>Development costs, including such elements as:</th>
<th>~1,000,000 Euro</th>
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<tbody>
<tr>
<td>• Hardware and software development costs</td>
<td></td>
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<tr>
<td></td>
<td>(central and on board software development; no hardware development)</td>
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<tr>
<td>• Design of processes, technical architecture definition, system integration</td>
<td>~200,000 Euro</td>
</tr>
<tr>
<td>Operations center setup (procedures design, hardware and software components)</td>
<td>~50,000 Euro</td>
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<tr>
<td>Total development cost</td>
<td>~1,250,000 Euro</td>
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<tr>
<th>Operating costs, including such elements as:</th>
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2.2 The Market of “Car Telematics” services based on the commercial exploitation of GPS and wireless networks in USA

Though still immature, telematics represents a large potential market of 87 million new vehicles issued in the period between 2002 and 2006 in USA. Despite a small base of telematics subscribers in the US today, less than 2.5 million, telematics presents a highly contextualized environment in which to reach consumers.

In a survey performed by Jupiter/The NPD Group, Inc. in 2002 in USA, (see charts below), consumers expressed a willingness to pay—44 percent for basic services, 50 percent for premium services, and 32 percent for luxury services—in spite of a $400 up-front fee.

While nearly 80 percent of drivers showed interest in at least one telematics service, consumers’ preferences focused on vehicle and driving services (i.e. navigation) and they exhibited a clear propensity for services that enhanced driving and vehicle ownership.

By incorporating contextual information (e.g., speed, location, mileage, and parts integrity), these services address consumer demand for enhanced control and security and improve owners’ ability to maintain their vehicle. Consumers expressed significantly less interest in personal (or generic wireless) services for which voice was the enabling technology.
While telematics is important for original equipment manufacturers (OEMs) and wireless operators, companies in industries such as travel, financial services, media, and consumer packaged goods (CPGs) also stand to benefit from an evolved market.

The following charts shows the consumers demand of Car Telematic services as mapped in the Jupiter/The NPD Group 2002 survey.
This demand has lead a number of companies to offer Car Telematics/Navigation services based on GPS/wireless integrated signal. Some commercial services operating in the US are: OnStar/General Motors.

With two million subscribers, OnStar is the leading provider of telematics services in the US. OnStar’s in-vehicle safety, security, and information services use GPS satellite and cellular technology to link vehicles and drivers to the OnStar Center. At the OnStar Center, advisors offer real-time personalized help, 24 hours per day, 365 days per year.

_Wingcast_

Wingcast is building a network that will deliver a variety of telematics services and applications to end-users.

Services include safety and security applications such as automatic air bag notification, roadside assistance, SOS/emergency assistance, and stolen-vehicle tracking; communication services such as handsfree, voice-activated calling; convenience services such as navigation, traffic, concierge, and location-based services as well as personalized content such as news, sports, and stocks.

All services are delivered via a GPS-enabled device embedded into vehicles.

_Networkcar_

Networkcar is a provider of around-the-clock services for monitoring the performance, location, and security of consumer and fleet vehicles.

Advanced performance monitoring technology and satellite location systems allow Networkcar to provide the most advanced solution for car maintenance and operation on the market today.

The Networkcar service includes real-time car performance updates, smart roadside assistance, stolen-vehicle recovery services, and a Car Guardian feature that allows car owners to find their cars by accessing a secure Web page. With the Networkcar service, car owners increase safety and security, save time, and reduce costs with advanced preventive maintenance and early problem detection.
3. Conclusions

The result of this research has permitted to provide a first picture of what Galileo is and what benefits, criticalities and business opportunity it would bring to Motorway Operators. This paper could be a base of knowledge that can help them to focus their choices and investments regarding the use of Galileo for developing new road applications.

Major Italian Motorways Operators expressed interest in Electronic Toll Collection via satellite, although a number of open issues on the complexity of the system and on the evolution of the state of the art have been pointed out.

Further investigation and dedicated studies could be carried out indeed, in particular on:

- **Compatibility with EU directives:** While performing the co-decision process the European Institutions have to evaluate the existing investments relevant to microwave technology and should consequently focus their position with respect to the EC directive on Electronic Toll Collection: the actual proposal of directive recommends indeed the coexistence of GNSS/GPRS and Microwave technologies until 2008. It is presently under discussion what will be the position of the EU after that date regarding the migration and/or co-existence of microwave and satellite technologies for Electronic Toll Collection across Europe.

- **Complexity of the Systems:** Satellite Based toll collection systems are very complex and the lessons learned from delays in starting Toll Collect in Germany (the first commercial system of this kind) shall be well understood when deploying a service at European scale.

- **Cartography:** A suitable cartography, at European scale, should be defined and developed.

- **Definition of standards:** Motorway Operators shall study and define standards with respect to information interchange, operational procedures, billing, since the quality of services shall be guaranteed across Europe.

- **Interoperability:** Further investigations should be carried to define the interoperability of systems across different countries and their integration with satellite functionality, avoiding non compatible satellite systems to be developed in different Countries, by standardizing satellite services and technologies.
Operations: further studies shall be focused on the impact coming from the adoption of Satellite Electronic Toll Collection on motorway operations, in terms of traffic management, security, legal and regulatory issues, impacts on drivers, procedures to be followed in case of exception, malfunctioning, fraud, enforcement.

Many applications such as Fleet Management and SOS emergency call systems have been already developed based on the GPS signal and are in a more mature stage of progress with respect to Electronic Toll Collection.

These and other GNSS-based services will have a major boost when Galileo terminals will be extensively adopted in Europe.

However, this shall occur when the most important Galileo road application, i.e. Electronic Toll Collection, will open the market and drive its growth.
Annex 1: Questionnaire and results

SURVEY ON POSSIBLE IMPLICATIONS OF SATELLITE APPLICATIONS FOR AN ITALIAN MOTORWAY OPERATOR

Questionnaire structure
The questionnaire is structured with questions relevant to those applications considered more interesting in the short-medium term (2003-2008) using GPS and EGNOS and using GALILEO starting from 2008.

Date       __________________________________
Motorway Operator     __________________________________
Name       __________________________________
Contact person     __________________________________
___________________________________________________________________________

1. To provide your services, are you estimating the opportunity to invest on GALILEO localization systems?
   □ YES       □ NO

2. Which GALILEO application sectors are more interesting?
   □ Traffic management systems (road tolling, etc.)
   □ Goods and fleet management systems (emergency services)
   □ Traffic information systems (RDS-TMC, VMS, in-car navigation, etc)
   □ Other .........................

3. On which services/applications based on satellite technology are planning to invest in the next future?

<table>
<thead>
<tr>
<th>2003-2008</th>
<th>After 2008</th>
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☐ **Road Tolling** based on satellite localization and mobile communication GSM/UMTS

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☐ **Vehicles Traffic Monitoring**

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☐ **Goods Traffic Monitoring, especially hazardous goods**

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☐ **Tunnels control**

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Are you interested in developing and in providing payment added-value services to travelers that will have GALILEO technologies (emergency services, user information, etc)?

☐ YES ☐ NO

If yes, which are these?

______________________________________________________________

______________________________________________________________

5. Are you estimating the opportunity to ask for Service Agencies for the road toll collection?

☐ YES ☐ NO

6. Are you interested to participate in Working Groups on GALILEO for road modal in order to provide active contribution on Standards, development of applications, etc.?

☐ YES ☐ NO
Benefits and criticalities for the use of Galileo – the road operator point of view

Which GALILEO application sectors are more interesting?

- Traffic management systems (road tolling, etc.)
- Goods and fleet management systems (emergency services)
- Traffic information systems (RDS-TMC, VMS, in-car navigation, etc)
- Other

On which services/applications based on satellite technology are planning to invest in the next future?

- Road Tolling based on satellite localization and mobile communication GSM/UMTS
On which services/applications based on satellite technology are planning to invest in the next future?

Vehicles Traffic Monitoring

On which services/applications based on satellite technology are planning to invest in the next future?

Goods Traffic Monitoring, especially hazardous goods
References

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### List of Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>ADAS</td>
<td>Advanced Driving Assistance Systems</td>
</tr>
<tr>
<td>AIS</td>
<td>Automatic Identification System</td>
</tr>
<tr>
<td>CDMA</td>
<td>Code Division Multiple Access</td>
</tr>
<tr>
<td>CS</td>
<td>Commercial Services</td>
</tr>
<tr>
<td>DSRC</td>
<td>Data short range communication</td>
</tr>
<tr>
<td>ESA</td>
<td>European Space Agency</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>EGNOS</td>
<td>European Geo-stationary Navigation Overlay Service</td>
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<tr>
<td>ERTMS</td>
<td>Rail Traffic Management System</td>
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<tr>
<td>ETC</td>
<td>Electronic Toll Collection</td>
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<tr>
<td>ETCS</td>
<td>European Train Control System</td>
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<tr>
<td>FOC</td>
<td>Full Operation Capability</td>
</tr>
<tr>
<td>GCC</td>
<td>Galileo Control Centers</td>
</tr>
<tr>
<td>GLONASS</td>
<td>GLObal NAvigation Satellite System</td>
</tr>
<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Position System</td>
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<tr>
<td>GSM</td>
<td>Global System for Mobile communication</td>
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<tr>
<td>GSS</td>
<td>Galileo Sensor Stations</td>
</tr>
<tr>
<td>GUS</td>
<td>Galileo Up-link Stations</td>
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<tr>
<td>ITS</td>
<td>Intelligent Transport Systems</td>
</tr>
<tr>
<td>LBS</td>
<td>Location Based Services</td>
</tr>
<tr>
<td>MEO</td>
<td>Medium Earth Orbit</td>
</tr>
<tr>
<td>OBE</td>
<td>On board equipment</td>
</tr>
<tr>
<td>OBU</td>
<td>On board unit</td>
</tr>
<tr>
<td>OS</td>
<td>Open Services</td>
</tr>
<tr>
<td>PFI</td>
<td>Private Finance Initiative</td>
</tr>
<tr>
<td>PPP</td>
<td>Public Private Partnership</td>
</tr>
<tr>
<td>PRS</td>
<td>Public Regulated Service</td>
</tr>
<tr>
<td>PSAP</td>
<td>Public safety answering point</td>
</tr>
<tr>
<td>PSDR</td>
<td>Preliminary System Design Review</td>
</tr>
<tr>
<td>RDS-TMC</td>
<td>Radio Data System – Traffic Message Channel</td>
</tr>
<tr>
<td>RHCP</td>
<td>Right Hand Circular Polarization</td>
</tr>
<tr>
<td>RNSS</td>
<td>Radio Navigation Satellite Service</td>
</tr>
<tr>
<td>SIS</td>
<td>Signal In Space</td>
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<tr>
<td>SMS</td>
<td>Short Message System</td>
</tr>
<tr>
<td>SoL</td>
<td>Safety of life (Services)</td>
</tr>
<tr>
<td>VMS</td>
<td>Variable Message System</td>
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</table>