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Mission High Level Definition

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CHANGE RECORDS

ISSUE	REVISION	DATE	CHANGE OF RECORD
1		13 February 2001	First issue
2		3 April 2001	Following Consultation Process
3		23 September 2002	Following 4th, 5th and 6th CCB, Users' Fora comments, EC comments, bilateral contacts on PRS and Consultation Process

Abstract

Introduction

The High Level Definition (HLD) document presents a picture of the main characteristics of the Galileo programme and describes the services and performances offered in this way. It is used as the framework for the Galileo programme and is applicable to the Mission Requirement Document. This issue of the document prepared by the Galileo Interim Support Structure (GISS), results from a consultation process with European Commission, European Space Agency, Member States, Users and prospective investors and takes into account the latest results of studies performed so far.

Political and programmatic aspects.

The European objective of full autonomy in satellite navigation will be achieved in a two-step approach, starting with the EGNOS system in 2004 and then with the Galileo system, which is aimed at full operational capability by 2008. Galileo will be the first civil satellite positioning and navigation system, designed and operated under public control. Galileo will be interoperable with other systems to facilitate their combined use. For safety of life and commercial applications, the navigation services will offer a guarantee, which is an important differentiator with respect to the current GNSS systems.
Special attention has been given to the security aspect of Galileo, to protect its infrastructure and to avoid the potential misuse of its signals.

Galileo Services

Four navigation services and one service to support Search and Rescue operations have been identified to cover the widest range of users needs, including professional users, scientists, mass-market users, safety of life and public regulated domains. The following Galileo Satellite-only services will be provided worldwide and independently from other systems by combining the Galileo's Signals in Space:

i. *The Open Service (OS)* results from a combination of open signals, free of user charge, and provides position and timing performances competitive with other GNSS systems.

ii. *The Safety of Life Service (SoL)* improves the open service performances through the provision of timely warnings to the user when it fails to meet certain margins of accuracy (integrity). It is envisaged that a service guarantee will be provided for this service

iii. *The Commercial Service (CS)* provides access to two additional signals, to allow for a higher data rate throughput and to enable users to improve accuracy. It is envisaged that a service guarantee will be provided for this service.

iv. *The Public Regulated Service (PRS)* provides position and timing to specific users requiring a high continuity of service, with controlled access. Two PRS navigation signals with encrypted ranging codes and data will be available.

v. *The Search and Rescue Service (SAR)* broadcast globally the alert messages received from distress emitting beacons. It will contribute to enhance the performances of the international COSPAS-SARSAT Search and Rescue system.

The Galileo satellite-only services can be enhanced on a local basis through combination with local elements for applications with more demanding requirements.

EGNOS will be an early tool for the development of future Galileo applications. It will provide ranging service, wide area differential corrections and integrity. The EGNOS services will be combined with the Galileo satellite-only services. This will allow higher performance levels to be met by using different sources of integrity and navigation information.

Combination of Galileo signals with other GNSS system or non-GNSS systems (e.g. GSM and UMTS), will allow enhanced services at users level and the development of a wide range of applications.

Galileo System

A service-oriented approach has been used to design the Galileo architecture. The Galileo global component, comprising the constellation of 27 active satellites + 3 spare satellites in Medium Earth Orbit and its associated ground segment, will broadcast the Signal in Space required to achieve the satellite-only services. The local service enhancements will be facilitated, as the global component will be designed to easily interface with local elements. In the same way, the interoperability between Galileo and external components will be a major driver of the Galileo design to allow the development of applications combining Galileo services and external systems services (navigation or communication systems).

Development plan.

The infrastructure is being implemented in three phases:

- Development and in-Orbit validation (2001-2005).
- Deployment (2006-2007).
- Commercial operations (from 2008).

1 Introduction

Galileo will be the European contribution to the Global Navigation Satellite System (GNSS). Galileo is a global infrastructure comprising a constellation of satellites in Medium Earth Orbit (MEO) and its associated ground segment. The Galileo Programme also includes the development of user equipment, applications and services. Galileo is designed to be interoperable with other existing global radio-navigation systems. It is a civil system, operated under public control.
The Galileo Programme is at present jointly managed and financed by the EC and ESA under a mandate from their Member States.

1.1 Scope and Objective of the Document

The Galileo Mission High Level Definition document (HLD) is a programme reference document providing the main characteristics and performances of the Galileo Mission, as they are determined at the time of its publication.
The Galileo HLD is applicable to the Galileo Mission Requirements Document (MRD). The Galileo Mission Requirements Document is applicable to the elaboration of the Galileo System Requirements Document (SRD) and to the Galileo Signal In Space Interface Control Documents (ICD), which are the applicable documents for development activities.
A Hierarchy Flow diagram (Figure 1) is given below to depict logic of major Galileo programme documents.

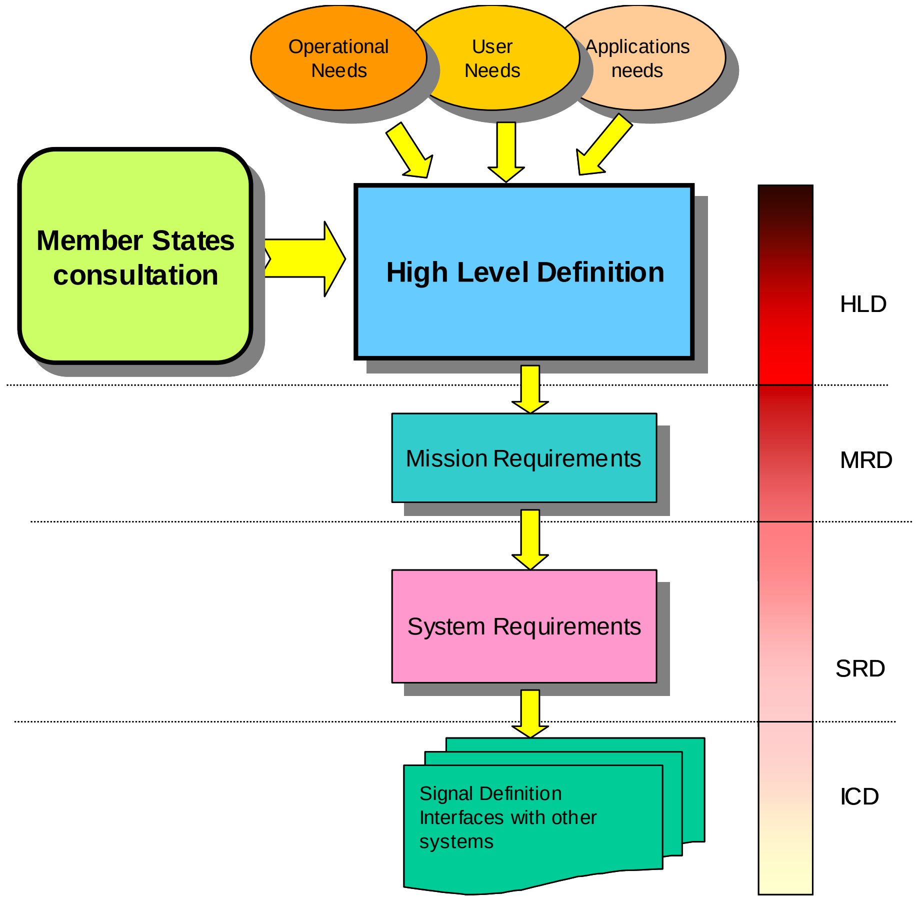

Figure 1 Hierarchy of Galileo programmatic documents

1.2 History of the Document

The first issue of the HLD, defining the Galileo mission and as a consequence the associated services, was set up at the beginning of 2001. It was largely distributed and commented by users' groups and Member States during a special session of the Galileo Steering Committee and of the Program Board for Navigation, held in ESTEC on March 22nd and 23rd 2001.

The second issue of the Document, made available to everyone at the Galileo web site in April 2001, took into consideration most of the expressed remarks.

Following the Council decision of March 2002 and the evolution of the technical concepts coming from industrial activities and the definition phase, a new version has been issued and has already been proposed to Users' Fora (such as "Safety of Life" and "Location-based Services"). This final version will allow having a clear vision of the characteristics of the offered services, which is an indispensable element to initiating the infrastructure and the international negotiations. Moreover, it will facilitate the decision of industrial and financial groups to submit a concession offer with full knowledge of the facts. Finally, it will allow manufacturers to start up their activities of development of receivers and systems, in view of preparing the applications market.

1.3 Approval and Management of the Document

The Galileo HLD is elaborated by GISS. It takes into account the remarks and the resulting suggestions from Member States, user communities and industry consultation.

1.4 Activities supporting the mission consolidation

Following the preparatory activities of previous years, the Galileo Definition Phase was undertaken by EC and ESA during the year 2000. This led to the European Commission Communication on Galileo in November 2000, the ESA Council Resolution in December 2000 and to the EU Transport Council decision of April 2001.

Based on the Definition Phase, the Galileo Mission High Level Definition (Issue 2, 3rd of April 2001) was written and consolidated through a consultation process involving Member States, user communities and potential private investors.

As a result of Member States having recognised the importance of concentrating efforts on services and signal definition, EC and ESA established a Task Force on Signal definition.

In June 2001, new studies were incepted by ESA and EC consolidating the Definition Phase and paving the way for preparing the launch of the Development and Validation Phase. ESA B2 Phase study (the Galileo system architectural study) started in June 2001 and EC started the Galilei study in August 2001, which comprises of a set of complementary studies to B2 Phase Study, covering aspects such as the local components, frequency issues, interoperability issues, legal issues, and detailed market analysis.

Specific User Fora and consultations have been organised in 2002 in order to ensure that the updated services definition covers the user needs properly. This consultation process has allowed the feedback from different user communities to be taken into consideration.

The outcome of all the above-mentioned activities have assisted in the consolidation of the Galileo services, as defined in Section 3, and the Galileo architecture, as defined in Section 4. Some evolutions of the Galileo services performances are foreseen, but the flexibility and scalability of the system design will minimize the impact that the refinement at mission level could have on the system architecture and its associated cost.

2 Political and Programmatic aspects

2.1 The European Satellite Navigation Strategy

As a result of the quality of service offered, satellite navigation is now set to become the primary means of navigation for most of civil applications, worldwide. Satellite navigation, positioning and timing have already found widespread application in a large variety of fields and will be an integral part of the Trans European Network[1]. Many safety-critical services, in areas of transport and numerous commercial applications will depend on this infrastructure.

The European Commission White Book on transport policy has highlighted the importance of decoupling economic growth and transport needs: this will be achieved by shifting the balance of transport modes, the elimination of bottlenecks and by placing users at the heart of transport policy. Galileo has been highlighted as a promising instrument to reach these goals.

Existing terrestrial Radio Navigation aids are widespread in number and technology all over Europe. Different types of systems are used by each transport community but without a coordinated policy at the European level. A potential ERNP (European Radio-Navigation Plan) is under elaboration to encourage a common European approach to radio navigation, positioning and timing means across all modes of transport. Aviation and maritime communities are already well organised on a global level in this respect but other communities support various national standards. In this context, Satellite Navigation is a key element of the ERNP because of its multimodal and supranational character.

One major concern for the current Satellite Navigation users is the reliability and vulnerability of the navigation signal. Several cases of Satellite Navigation service disruption have been reported over the past years, which had many different origins, including unintentional interference, satellite failure, signal denial or degradation. In this context, Galileo will contribute significantly to reduce these shortcomings by providing independently additional navigation signals broadcast in different bands.

Recognising the strategic importance of satellite navigation, its potential applications and the current GNSS systems shortcomings, Europe decided to develop its own GNSS capability in a two-step approach:

- EGNOS (European Geostationary Navigation Overlay Service) is the first European step in satellite navigation that will be operational by 2004. Europe is building EGNOS as a complement to GPS and the Russian GLONASS (GLObal NAvigation Satellite System) to provide a civil service. EGNOS implements a warning of system malfunction (integrity) of the GPS and GLONASS constellations. The provision of this quality control service is essential for safety critical applications. EGNOS will also improve the accuracy of GPS and GLONASS by means of differential corrections. Similar initiatives are being developed in US (WAAS system) and Japan (MSAS system). The ICAO (International Civil Aviation Organization) international SBAS (Satellite Based Augmentation System) standards guarantee the interoperability of all these systems at user level. Besides its own specific operational objective as the European SBAS, EGNOS is a unique instrument to gain

[1] TEN guidelines Decision Council /EP 1996

experience not only in the development of GNSS technology but also, most importantly, in the operational introduction of Galileo services.

- Galileo is the second step. EGNOS provides Europe with early benefits but does not provide Europe with a sufficient level of control over GNSS. The introduction of satellite navigation services on a very large scale and the implementation of European regulations cannot be envisaged if users become fully dependant on a single system, outside European control. Galileo represents the European objective of autonomy for such a strategic and crucial technology. It will provide the required stability for European investments in this area and elevate European industries in innovative market segments. Galileo will also offer, alongside an open service similar to the GPS civilian service, new features to improve and guarantee services, thereby creating the conditions for responding to obligations imposed by critical, safety of life, or commercial applications. Galileo services are required to be fully compatible and interoperable at user level with other GNSS services, with no common failure mode between systems. This combined use of Galileo and other GNSS systems will offer better performances for all kinds of user communities all over the world.

This strategy is reflected in the EC communications on Galileo[2] [3], and in the Galileo resolution of the Council of the European Union[4]. The latter adopted the resolution, highlighting the objective of European autonomy for such a strategic and crucial technology for the benefit of our society and economy. ESA Member States agreed on an integrated strategic vision for the provision of European GNSS Services by the combined use of EGNOS and Galileo services[5].

ESA Member States adopted the GalileoSat programme[6] declaration at Council level (Edinburgh November 2001) and in the Council of Heads of States and Governments of the EU (Barcelona, 13-14 march 2002) gave the political support to Galileo. The Council of the European Union (Brussels, 26 March 2002) gave financial support to the Galileo programme and approved the establishment of a Joint Undertaking for the management of the programme.

2.2 Socio-economic aspects

Previous studies, including GALA, Geminus, Galileo Cost-Benefit Analysis and the Business Plan for the Galileo Programme, have analysed future market prospects and identified potential sources of revenue. The economic aspects are a key driver of the Galileo programme and the mission consolidation activities should be steered by these elements. Only with this approach will Europe have a self-sustainable system that will bring important social and user benefits and have a significant effect on the European economy.

[2] Commission Communication, “Galileo, Involving Europe in a New Generation of Satellite Navigation Services”, COM (1999) 54 final, 10.02.1999

[3] Commission Communication on “Galileo”, COM (2000) 750 final, 22.11.2000

[4] Council Resolution on Galileo, 7918/01, 5.04.2001

[5] ESA/PB-NAV(2001)29, rev.1

[6] ESA/C (2001)117

2.3 Interoperability

Galileo is being designed as an independent system but at the same time, this design is optimised for use with other systems, notably GPS.

Key drivers for facilitating the use of Galileo with other systems are user requirements and the object of gaining access to future GNSS market. The main reasons are:

- Satellite navigation systems present some technical constraints (e.g. low power signals), which prevent them from meeting the overall identified user requirements, especially the most demanding.
- The late arrival of Galileo in the future satellite navigation market dominated by GPS applications.

Consequently, three main interoperability objectives have been identified. They are to:

- Facilitate interoperability of Galileo with other GNSS systems (most notably GPS) at receiver level. This is reflected in the study and choice of:
    a) Galileo frequencies.
    b) Signal structure.
    c) Time reference frame.
    d) Geodetic datum.
- Assess the combined use of Galileo with other non-GNSS systems, such as ground navigation systems or mobile communication networks, to enable a reduction of GNSS deficiencies through the provision of combined positioning services. Potential issues to be studied at user level are similar to those mentioned for GNSS systems;
- Facilitate the use of Galileo with telecommunication systems to provide jointly navigation/communication services. This is an additional functionality that:
    a) enables enhanced communications capabilities (e.g. higher data transfer)
    b) facilitates the generation of GNSS value-added services, such as location based services, with a strong influence in the future GNSS market.

The combined use of Galileo with all these systems will introduce interoperability requirements not only in the Galileo global components but also in the design of local components and user equipment.

- Studies on these issues are currently performed in the Signal Task Force and ESA/EC contracts. Significant results are expected by the end of 2002.

2.4 Certification and standardization

2.4.1 Certification

Certification is a process by which a mandated body will independently assess the compliance of the system with standards identified by a regulating authority. This standardisation process, mainly focusing on the signals and/or services delivered by Galileo, will not overlap or replace traditional certification schemes used by different user communities to certify specific applications. On the contrary, it is perceived as a pre-requisite whereby user communities, such as aviation or maritime, can build their own safety analysis taking into account their particular specifications in terms of environment and user equipment.

The certification scheme that will be built for Galileo will cover the whole life cycle of the system including system design, implementation and operation phases during which quality assurance shall be provided.

A certification mechanism will be proposed to Member States that involves all main actors of the Galileo project including users, regulators, system designer and service operator/providers.

The Galileo system will be designed, built and operated to perform to very high performance standards and, as mentioned above, it is the intent that a form of guarantee can be offered to user communities with special interest in such a feature. In this framework, the certification of the system will increase user confidence in the performance delivered by the system and will set the basis for a guarantee scheme.

2.4.2 Standardisation

The introduction of an ambitious system such as Galileo that will offer a worldwide service to many different kinds of users requires significant activity in the standardisation domain.

Europe is already very active regarding the standardisation of Galileo and will maintain a pro-active attitude to support the development of standards having regard to the motivations of different user communities (safety, interoperability, commercial considerations).

The work undertaken will be pursued to identify the actors involved and set-up specific action plans to support the development of standards on a case-by-case basis. In general, the schemes are quite complex with numerous levels of responsibilities, sometimes overlapping, and that very often involve international cooperation with some level of political interest. Actions have already been launched in the aeronautical and maritime domains that benefit from the very clearly identified standardisation frameworks in ICAO and IMO. Work is on going within the rail and road communities to satisfy their specific standardisation needs. Finally, other communities, likely to use Galileo, such as cellular phone operators and location-based service providers in general are also starting to participate in the development of standards contributing to the promotion of Galileo.

Globally recognised signal and user receiver standards will be essential for the worldwide acceptance of satellite navigation and will permit a faster adoption of the system by all user communities.

2.5 Service Guarantees

The Galileo services result from the processing of a combination of signals, by the user terminal, under certain nominal environmental conditions (no intentional interference, low multi-path….).

It is envisaged that a guarantee will be offered for all applications for which a disruption of service would have significant Safety of Life or economic impacts. This guarantee is a major differentiator between Galileo and GPS.

The Joint Undertaking, as mentioned in section 6.1, will proactively undertake discussions with the appropriate regulatory bodies to initiate the certification[7] process concerning both the Galileo-Signal-in-Space and user terminals.

[7] The general understanding is that the term certification applies to safety of life terminals, whereas commercial terminals would be 'type approved' through a procedure jointly agreed, between the operator and the users.

The Galileo Operating Company (GOC) will commit to provide the quality of the Signal In Space to achieve the specified service at end-user level. An agreement or contract will be concluded between the Operator and the users or, in certain cases with third party Service providers, in which the quality of the Signal In Space will be guaranteed by the GOC with certain specifications defined in the Interface Control Document. In case the Signal In Space (SIS) fails to meet certain margins of accuracy, the GOC will provide timely warnings to users.

The system will record the status of the Signals In Space (SIS). Should the SIS fall below specified standards, the records can be investigated to assist in finding the cause of the problem.
Compensation may be payable to Galileo users if loss can be proved through use of the signal, but, perhaps also if the performances guaranteed fall short of those stipulated.
Practical modalities for the implementation of the above-defined guarantees will be further investigated during the development phase.

In the case of the open service, which will be accessible by users without any control from the Galileo Operating Company, no contractual guarantee is foreseen. Since this service will be used for mass-market applications, the Galileo Operating Company will endeavour to avoid service disruption and will provide the open signals with nominal performances.

3 Galileo Services

The definition of the Galileo services is based on a comprehensive review of user needs and market analysis. There will be some services provided autonomously by Galileo and other services resulting from the combined use of Galileo and other systems. This leads to the classification of the Galileo services into four categories:

1) Galileo satellite-only services
These services will be provided worldwide and independently from other systems by combining the signals broadcast by the Galileo satellite. There is a wide range of possible applications with different operational requirements that have been grouped around the following five reference services:

- Galileo Open Service (OS)
- Safety of Life (SoL).
- Commercial service (CS).
- Public regulated Service (PRS).
- Support to Search and Rescue service (SAR).

2) Galileo locally assisted services
The Galileo satellite-only services can be enhanced on a local basis through a combination of local elements. The result will be the provision of local services.

3) EGNOS services
EGNOS will provide over Europe an augmentation to GPS and GLONASS services from 2004 onwards. This service will allow for early experience in development of Galileo-like applications. The EGNOS services will be combined with the Galileo satellite-only services. This will allow higher performance levels to be met by using different sources of integrity and navigation information.

4) Galileo combined services
All the above-mentioned services will be combined with services provided by other navigation or communication systems. This possibility will improve the GNSS services availability at user level and open the door to a wide range of applications. The result will be the provision of combined services.

3.1 Galileo satellite-only services

The Galileo services can be referred back to the latest publicised and accepted realisation of the international terrestrial reference frame (ITRF) and to the universal time coordinate (UTC). This is important for interoperability with other GNSS, most notably GPS.

The Galileo satellite-only service performances are expressed at user level. All performance statistics include the contribution of the receiver (noises, failures, etc).
Users equipped with Galileo receivers (or having Galileo functionality in their terminals) conforming to minimum operational requirements shall be able to achieve the specified

performance under nominal conditions with no intentional jamming, no exceptional interference, no exceptional ionospheric or tropospheric activity, a masking angle of 10° and low multipath environment.

3.1.1 Open Service

Purpose

The Galileo Open Service provides positioning, velocity and timing information that can be accessed free of direct charge. This service is suitable for mass-market applications, such as in-car navigation and hybridisation with mobile telephones. The timing service is synchronised with UTC when used with receivers in fixed locations. This timing service can be used for applications such as network synchronisation or scientific applications.

Performance and features

The performance objectives in terms of position accuracy and availability will be competitive with respect to existing GNSS and further planned evolutions. In addition, the Open Service will also be interoperable with other GNSS, in order to facilitate the provision of combined services.

		Open Service (positioning)	
Type of Receiver	***Carriers***	*Single Frequency*	*Dual-Frequency*[8]
	Computes Integrity	*No*[9]	
	Ionospheric correction	*Based on simple model*	*Based on dual-frequency measurements*
Coverage		*Global*	
Accuracy (95%)[10]		*H: 15 m* *V: 35 m*	*H: 4 m* *V: 8m*
Integrity	***Alarm Limit***	*Not Applicable*	
	Time-To-Alarm		
	Integrity risk		
Availability		*99.8 %*	

Table 1 *Service performances for the Galileo Open Service (positioning)*

	Open Service (timing)
Carriers	*Three- Frequency*
Coverage	*Global*
Timing Accuracy wrt UTC/TAI	*30 nsec*
Availability	*99.8 %*

Table 2 *Service performances for the Galileo Open Service (timing)*

[8] The performances of a service with 3 carriers is under assessment.
[9] Some level of integrity can be achieved through the application of RAIM techniques at user level (see Annex 4 for a definition of RAIM).
[10] Figures are based on use of 10 degrees mask angle.

Annex 4 includes the definitions of all the performance parameters used in the above tables and in all the subsequent tables referring to Galileo Services.

Implementation
The Open Service signals are separated in frequency to permit the correction of errors induced by ionospheric effects by differentiation of the ranging measurements made at each frequency. Each navigation frequency will include two ranging code signals (in-phase and quadrature). Data are added to one of the ranging codes while the other "pilot" ranging code is data-less for more precise and robust navigation measurements. The precise definition of Open Service signals is given in section 4.1.2 and in Annex 2.

3.1.2 Commercial Service

Purpose
The Commercial Service will allow the development of professional applications, with increased navigation performances and added value data, compared with the Open Service. The foreseen applications will be based on:

- Dissemination of data with a rate of 500 bps, for added value services;
- Broadcasting of two signals, separated in frequency from the Open Services signals to facilitate advanced applications such as integration of Galileo positioning applications with wireless communications networks, high accuracy positioning and indoor navigation.

Performances and features
The Galileo Operating Company (GOC) will determine the level of performance it can offer for each commercial service together with ascertaining the demands of Industry and the needs of the consumer. It is intended to provide a guarantee for this service as outlined in section 2.5.

The Commercial Service will be a controlled access service operated by Commercial Service Providers acting after a license agreement between them and the GOC.
Commercial service providers will make decisions on the offered services: e.g. integrity data, differential corrections for local areas, etc… which will depend on the final characteristics of the other services offered by Galileo.

Implementation
The Commercial Service signals will be the Open Services Signals, plus two encrypted signals (ranging codes and data), on the "E6" band, as detailed in section 4.1.2 and Annex 2.

3.1.3 Safety of Life Service

Purpose
The target markets of the Safety of Life service are safety critical users, for example maritime, aviation and trains, whose applications or operations require stringent performance levels.
This service will provide high-level performance globally to satisfy the user community needs and to increase safety especially in areas where services provided by traditional ground infrastructure are not available. A worldwide seamless service will increase the efficiency of companies operating in a global basis, e.g. airlines, transoceanic maritime companies.

Performance and features

With regard to Safety of Life Services, there are certain levels of service that are stipulated by law in various international transportation fields, and other that are recommended practices (e.g. Standards and Recommended Practices -SARPS- by ICAO). A very specific level of service from Galileo will be needed to comply with legislation applicable for all considered domains of transport and existing standards. It is intended to provide a guarantee for this service as outlined in sect. 2.5.

This service will be offered openly and the system will have the capability to authenticate the signal (e.g. by a digital signature) to assure the users that the received signal is the actual Galileo signal. This system feature, which will be activated if required by users, must be transparent and non-discriminatory to users and shall not introduce any degradation in performances.

The provision of integrity[11] information at global level is the main characteristic of this service. The Safety of Life service will be provided globally according to the performances indicated in table 3. These specifications include two levels to cover two conditions of risk exposure and are applicable to many applications in different transport domains, for example air, land, maritime, rail:

- The Critical level covers time critical operations for example, in the aviation domain approach operations with vertical guidance.
- The Non-Critical level covers extended operations that are less time critical, such as open sea navigation in the maritime domain.

		Safety-Of-Life Service	
Type of Receiver	***Carriers***	*Three Frequencies*[12]	
	Computes Integrity	*Yes*	
	Ionospheric correction	*Based on dual-frequency measurements*	
Coverage		*Global*	
		Critical level	**Non-critical level**
Accuracy (95%)		*H: 4 m* *V: 8 m*	*H: 220 m*
Integrity	***Alarm Limit***	H: 12 V 20 m	H: 556 m
	Time-To-Alarm	6 seconds[13]	10 seconds
	Integrity risk	3.5×10^{-7} / 150 s	10^{-7}/hour
Continuity Risk		10^{-5}/15 s	10^{-4}/hour – 10^{-8}/hour
Certification/Liability		*Yes*	
Availability of integrity		*99.5%*	
Availability of accuracy		*99.8 %*	

Table 3 *Service performances for the Galileo Safety of Life Service*

[11] Integrity is the ability of a system to provide timely warnings to the user when it fails to meet certain margins of accuracy.

[12] The SoL Service signals are in the E5a+E5b and L1 bands, but the level of performances indicated in the table can be achieved by using only L1 and E5b frequencies. The performances of the service based on E5a+E5b and L1 frequencies are under assessment.

[13] The actual value is TBC pending the results of the feasibility phase.

The SoL Service signals are in the E5a+E5b and L1 bands. Table 3 indicates the level of performance that can be achieved by using only L1 and E5b frequencies. Galileo will offer a robust service to the Safety of Life community providing also alternative levels of service for degraded modes of operation (e.g. where one or two frequency would not be available due to interferences)[14].

Implementation

The Safety of Life Service signals are separated in frequency to improve robustness to interference, and to permit correction of errors induced by ionospheric effects by differentiation of the ranging measurements made at each frequency. Each navigation frequency will include two ranging code signals (in-phase and quadrature). Data are added to one of the ranging codes while the other "pilot" ranging code is data-less for more precise and robust navigation measurements. The integrity data will be broadcast in the L1 and E5b bands. The precise definition of the Safety of Life Service signals is given in section 4.1.2 and in annex 2.

3.1.4 Public Regulated Service

Purpose

The PRS will provide a higher level of protection against the threats to Galileo Signals in Space than is available for the Open Services (OS, CS and SoL) through the use of appropriate interference mitigation technologies.

The need for the Public Regulated Service (PRS) results from the analysis of threats to the Galileo system and the identification of infrastructure applications where disruption to the Signal in Space by economic terrorists, malcontents, subversives or hostile agencies could result in damaging reductions in national security, law enforcement, safety or economic activity within a significant geographic area.

The objective of the PRS is to improve the probability of continuous availability of the SIS, in the presence of interfering threats, to those users with such a need. Typical applications include:

a. Trans-European level
   - Law Enforcement (EUROPOL, Customs, European Anti-Fraud Office - OLAF);
   - Security Services (Maritime Safety Agency) or Emergency Services (peace keeping forces or humanitarian interventions);

b. Member States levels
   - Law enforcement;
   - Customs;
   - Intelligence Services.

The introduction of interference mitigation technologies carries with it a responsibility to ensure that access to these technologies is adequately controlled to prevent misuse of the technologies against the interests of Member States. Access to the PRS will be controlled through key management systems approved by Member States' governments.

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[14] The performances of the single frequency services or other dual frequency services (e.g. E5a –L1) are under assessment.

Performance and features

The Public Regulated Service access will be controlled by the authorities to be defined at European level, through the encryption of the signals and the appropriate key distribution.

		Public-Regulated Service
Type of Receiver	Carriers	Dual-Frequency
	Computes Integrity	Yes
	Ionospheric correction	Based on dual-frequency measurements
Coverage		Global
Accuracy (95%)		H: 6.5 m V: 12 m
Integrity	Alarm Limit	H:20-V:35
	Time-To-Alarm	10 s
	Integrity risk	3.5 x10^{-7}/150 sec
Continuity Risk		10^{-5}/15 s
Timing Accuracy w.r.t. UTC/TAI		100 nsec
Availability		99.5 %

Table 4 *Service performances for the Galileo Public Regulated Service*

Implementation

The Public Regulated Service signals are permanently broadcast on separate frequencies with respect to open Galileo satellite-only. They are wide band signals so as to be resistant to involuntary interference or malicious jamming and therefore offer a better continuity of service.
The use of PRS will be restricted to clearly identified categories of users authorised by EU and participating states. Member States will authorise users through the implementation of appropriate controlled access techniques. Member States will maintain control of distribution of receivers.

3.1.5 Galileo support to the Search and Rescue Service

Purpose

The Galileo support to the Search and Rescue service - herein called SAR/Galileo - represents the contribution of Europe to the international COSPAS-SARSAT cooperative effort on humanitarian Search and Rescue activities. SAR/Galileo shall:

- Fulfil the requirements and regulations of the International Maritime Organization (IMO) - via the detection of Emergency Position Indicating Radio Beacons (EPIRBs) of the Global Maritime Distress Security Service and of the International Civil Aviation Organisation (ICAO) via the detection of Emergency Location Terminals (ELTs);

- Be backward compatible with the COSPAS-SARSAT system to efficiently contribute to this international Search and Rescue effort.

Performances and features

SAR/Galileo will allow for important improvements of the existing COSPAS-SARSAT system:

- near real-time reception of distress messages transmitted from anywhere on Earth (the average waiting time is currently one hour);
- precise location of alerts (a few meters for EPIRBs and ELTs equipped with Galileo receivers, while the current specification for location accuracy is 5 km);
- multiple satellite detection to avoid terrain blockage in severe conditions;
- increased availability of the space segment (27 Medium Earth Orbit satellites on top of the four Low Earth Orbit satellites and the three Geostationary satellites in the current system).

In addition, SAR/Galileo will introduce a new SAR function namely, the return link from the SAR operator to the distress emitting beacon, thereby facilitating the rescue operations and helping to identify and reject the false alerts.

Galileo support to Search and Rescue Service (SAR/Galileo)	
Capacity	Each satellite shall relay signals from up to 150 simultaneous active beacons
Forward System Latency Time	The communication from beacons to SAR ground stations shall allow for the detection and location of a distress transmission in less than 10 min. The latency time goes from beacon first activation to distress location determination.
Quality of Service	Bit Error Rate < 10^{-5} for communication link: beacon to SAR ground station
Acknowledgment Data Rate	6 messages of 100 bits each, per minute
Availability	> 99.8%

Table 5 *Service performances for the Galileo Search and Rescue Service*

Implementation

The Search and Rescue Transponder on Galileo satellites detects the distress alert from any COSPAS-SARSAT beacon emitting an alert in the 406 – 406.1 MHz band, and broadcasts this information to dedicated ground stations in the “L6” band, as detailed in section 4.1.2.

COSPAS-SARSAT Mission Control Centres (MCC) carry out the position determination of the distress alert emitting beacons, once they have been detected by the dedicated ground segment.

3.2 Locally assisted services

The Galileo Open, Commercial, Safety of Life and Public Regulated services will be, where necessary, enhanced by means of the Galileo Local Component to satisfy higher user demands with respect to accuracy, integrity, availability and communication over local areas. The Galileo Local Component, which will consist of all Galileo Local Elements, is part of the overall Galileo definition, and as such, the Galileo programme includes the design and development of a few selected experimental Local Elements in order to determine and demonstrate the achievable performance of local services.

Whilst the Galileo Local Component is part of the overall Galileo definition, its deployment is not covered within the deployment phase of the core Galileo system. It is however likely that both the GOC and external service providers will deploy Local Elements on a Global scale, and which together will offer ‘Regulated’ and ‘Unregulated’ services to a wide variety of users.

By defining Galileo Local Element performance standards it may also be possible to offer Galileo Local Element Service guarantees, if the performance characteristics of the Local Elements to be used meet or better those of the associated Local Element standard. Such guaranteed Local Services are likely to be ‘Regulated’ by the GOC, which would use as input feedback from standing forums established on a domain basis (road, rail, aviation, maritime etc). Both the GOC and external service providers are likely to deliver such services to end users who will typically come from well-established user communities with existing standards and regulations, and requiring a Local Galileo Service Guarantee (typically Safety of Life).

‘Unregulated’ Local Services are also likely to be established autonomously by external service providers, to meet purely commercial demands that have no strictly defined associated performance requirements or need for a Local Galileo Service Guarantee.

The precise deployment, associated performances and functionality of Local Elements will be driven by user and market needs, public regulation, economic factors and the existing proliferation of networks (e.g. DGPS, GSM) which share a great deal of infrastructure and functionality required by Galileo Local Elements. However four main service categories where Local Elements will play a part can be identified using as basis specific functionality, and as such Local Element demonstrators and complementary user terminals will be developed as part of the Galileo development and validation phase for each of the following:

i **Local Precision Navigation Services:** Galileo Local Elements providing differential code corrections will nominally reach positioning accuracy better than 1 meter. Furthermore, these local elements will have the potential to enhance the integrity alarm limits to a level TBD with an associated time-to-alarm (TTA) of up to 1 second.

ii **Local High-Precision Navigation Services:** The exploitation of the Three Carrier Ambiguity Resolution (TCAR) technique with Galileo Local Elements will allow users to determine their position with errors below 10 centimetres. The exact role of integrity with respect to this service over and above that offered by the Local Precision Navigation Service has yet to be determined.

iii **Local Assisted Navigation Services:** By reducing the amount of information to be decoded at the user terminal, it is possible to improve the availability of the SIS via improved Time To First Fix (TTFF) and/or improved tracking threshold for all Galileo services, especially when considering applications that operate in difficult environments (e.g. urban canyon and indoor applications). This performance can be further improved by the additional use of the Pilot Tones that exist on the Galileo Open Signals. This service is closely tied to communication techniques (e.g. GSM/UMTS) due to the need for high levels of communication (see Table 6).

iv **Local Augmented Availability Services:** Local stations broadcasting satellite-like signals (pseudolites) will also be used where necessary for increasing the availability of any Galileo service in a defined local area. In addition, positioning performance will improved through improved geometry and the fact that the pseudolite signal will not be subjected to the same level of environmental distortion. Improved availability will be desirable in restricted environments (e.g. urban) and for scenarios requiring a high level of availability (e.g. aircraft landing).

In all the above cases high potential service enhancement delivered by communications shall be taken into consideration. The Galileo Local Component will offer a means of achieving the synergy between the communication and positioning domains necessary to fully match the combined needs of the various user applications, thus capturing the maximum market share possible. Such a need and interest in the mutual added value brought about by such a combination has been expressed at all user forums on Galileo services. The potential performance enhancement is well demonstrated when the example of UMTS is used, as this can deliver bi-directional video, voice and/or data at a capacity of up to 2 Mbps in comparison to the Galileo spacecraft only system that will offer a 500bps broadcast capability on the commercial service only. Every effort will therefore be taken to ensure that harmonization of position and communication using the Galileo Local Component is achieved.

The following table indicates typical performances that are likely to be required/expected from differential code, carrier and indoor assisted techniques under nominal environmental conditions.

Type of Local Elements	Broadcast of differential corrections	Broadcast of differential corrections	Indoor Assisted Users
Accuracy (95%)	< 1 m	< 10 cm	50 m (TBC)
Integrity TTA	up to 1 second	TBD	TBD
Integrity Alarm Limit	TBD	TBD	TBD
Availability	99-99.95 (TBD)	99-99.9 (TBD)	99-99.9 (TBD)
Communications	Broadcast	Single/bi-directional data	Single/bi-directional data and voice

Table 6 *Performance for Services combining Galileo and Local Elements*

Almost all Galileo Local Elements and associated user terminals will also include additional GNSS (e.g. GPS, GLONASS) and potentially terrestrial based positioning (e.g. E-OTD) functionality, and as a result, the local services offered will be for combined services. In such instances when combined services are being offered along with an associated Local Galileo service guarantee, this guarantee will relate only to the performance of Galileo, and not that of the additional systems included as part of the service.

3.3 EGNOS Services

EGNOS will provide a multimodal and civil service to different European user categories, namely: general public/mass market users, specialist users and safety critical users. From this perspective, EGNOS will be an early tool for the development of future Galileo applications, as the EGNOS service will be available from 2004.

EGNOS will provide 3 types of services:

- Ranging service: The EGNOS geostationary satellites will provide additional GPS-like ranging sources.
- Wide area differential corrections: EGNOS will improve the accuracy of GPS and GLONASS providing differential corrections.
- Integrity: EGNOS implements a warning of system malfunction (integrity) of GPS and GLONASS constellations. The provision of this quality control service is essential for safety critical applications.

The EGNOS service will be a civil service offered openly. Although the EGNOS service is conditioned to GPS availability, it is foreseen that a contractual relationship will be established between the Service Provider and some users by which service guarantees may be given.

The EGNOS service performances and coverage area are defined in Annex 3. A prototype of EGNOS the EGNOS Test Bed has been operational since February 2000 providing an experimental signal.
According to the principles of an integrated strategic vision for the provision of European GNSS new services can be defined as a result of combining Galileo satellite-only services (e.g. Open service, Safety of Life service) and EGNOS services.

The combination of the Galileo Safety of Life service with the EGNOS service is of special interest. This combined service will provide independent and complementary integrity information on the Galileo and GPS constellations respectively, that may support for instance precision approach type operations in the aviation domain, ensuring that sufficient redundancy exists to offer the prospect of sole means availability, avoiding common failure modes between systems, and thus allowing the rationalisation of the terrestrial traditional radio-navigation infrastructure.

3.4 Combined services

Purpose

Galileo is being designed to be interoperable with other systems and, therefore, it will, in a great many instances, be used as part of a combined service. The identification of combined services is necessary to:

- Meet the most demanding user applications.
- Reduce satellite navigation system weaknesses.
- Provide robust solutions for applications requiring system redundancy for safety and/or security reasons.
- Access future GNSS market.
- Enable and expand new market opportunities.

The exact role that Galileo service guarantees can play in combined services with other systems needs to be elaborated based upon the specific features of these services and the specifications in section 2.6 on Galileo stand-alone service guarantees, section 3.2 devoted to locally assisted services and section 3.3 focused on EGNOS services.

In the case of a guarantee of a combined service, such services are likely to be regulated by the GOC, which will only held responsibility on Galileo performances, and delivered in conjunction

with the external service providers to end users who will typically come from user communities with existing standards and regulations.
External service providers may also autonomously establish unregulated combined services for users with no service guarantees on a purely commercial basis.

3.4.1 Services resulting from combination of Galileo with other GNSS systems

The most obvious systems to be combined with Galileo are the other existing GNSS systems, GPS, GLONASS, SBAS and GBAS as they share with Galileo many characteristics that facilitate a combination at user level. In addition, these GNSS systems can be further enhanced through local elements (see section 4.2)

Performances and features
By combining Galileo with other GNSS systems, improved performance in the following domains can be expected:

- Availability: Using as an example Galileo in combination with GPS and SBAS systems, the number of operational satellites will be in the region of 60. In normal urban environments this would result in an increased availability for 4 satellites from 40% to more than 90%.
- Position Accuracy: Allied to an increased availability in restricted environments (urban) is a better geometry of spacecraft or enhanced positioning performance.
- Integrity: SBAS systems, in addition to generating ranging signals, provide integrity information on GPS and GLONASS. Thus if an application requires the broadcast integrity information of two systems this can be achieved using SBAS. Typically, Safety of Life applications would benefit from this additional service.
- Redundancy: By combining services from separate and fully independent systems full redundancy can be achieved. This is particularly important for Safety of Life applications that require full system backup.

A first assessment of Galileo and GPS combined service performances have been carried out with the following estimated results (99% availability, worldwide):

	Galileo OS (10° m.a[15].) single frequency receiver	***Galileo OS + GPS (10° m.a.) single frequency receiver***	***Galileo OS (10° m.a.) dual frequency receiver***	***Galileo OS +GPS (10° m.a.) dual frequency receiver***	***Galileo OS (30° m.a.) single frequency receiver***	***Galileo OS + GPS (30° m.a.) single frequency receiver***
Horizontal accuracy	15	7-11	4	3-4	14-54	11-21
Vertical accuracy	35	13-26	8	6-8	21-81	17-32

Table 7 *Galileo OS and GPS combined service performances*

Implementation
Detailed studies of combined service features will be performed under the Joint Undertaking framework in coordination with service providers.

[15] m.a. = masking angle

Nevertheless, studies on the elaboration or revision of existing Galileo Interface Control Documents (ICDs) to other systems, receiver architecture trade-offs and assessment of combined service performances have been initiated.

3.4.2 Services resulting from Galileo with non-GNSS systems

Whilst other GNSS systems make ideal candidates for combination with Galileo, some inherent weaknesses, such as weak signal strength and limited communication capability can only be solved through combination with other existing non-GNSS navigation (Loran-C) and communication systems (UMTS) or even with on-board sensors (INS). Such systems can be grouped into the following categories:

Performance and features of combined services for positioning

- Other non satellite-based radio navigation systems (e.g. LORAN-C): Such systems may offer improved signal strength, which provides better indoor penetration and resistance to jamming. Such systems may also offer a limited communication capability (EUROFIX)
- Mobile communication networks (e.g. GSM, UMTS): These systems can be considered as positioning systems offering a complementary positioning capability (e.g. E-OTD) to the user in satellite critical environments. The complementary positioning, calculated either by the network and relayed to the user under request or by the user equipment, can be hybridised with the Galileo position solution in the user equipment. In addition, a different solution combining communication-ranging sources (e.g. Observed Time Difference measurements derived from GSM Base Stations) with Galileo ranges in a hybridised receiver will also allow positioning enhancement performances (accuracy, availability) in critical environments.
- Motion Sensors (e.g. odometers, INS): When combined in hybridised receivers, short-term outages of the Galileo signal can be overcome by forward interpolation. This combination provides an enhancement of Galileo service robustness and availability, especially in urban environments, where such short-term outages are commonplace.

Performance and features of combined navigation-related communication services

- Telecommunication systems (e.g. UMTS, INMARSAT): The harmonisation of the positioning and communication domains is necessary to match combined needs of user applications (e.g. SAR, emergency services, personal handsets) enabling the introduction of GNSS technology in the future market applications. In this sense, communication systems offer a means for transferring additional GNSS data to allow enhanced positioning performances (e.g. accuracy) as well as better communication capabilities (e.g. higher data rates, bi-directional data links). As a consequence, the expected benefits that the synergy of the combination of Galileo with these systems will bring are threefold:
    a) Enabling the enhancement of the data link characteristics of the Galileo stand-alone or locally assisted services (see section 3.2). This can be the case for the improvement of commercial service data rate or the optimisation of the communication capabilities of the local elements.
    b) In addition, performance enhancement can be achieved using communication systems functionalities as bearers of positioning data messages. This is the basis for

differential GNSS or assisted GNSS functionalities where, for particular applications, the user terminal can be assisted in the positioning computation in difficult environments with additional information (e.g. ephemeris) transmitted on generally dedicated communication links. These functionalities are also applicable to Galileo local elements (see section 4.2)

c) Enabling the provision of GNSS added value services through the relay by such systems of additional associated information or additional navigation related data (e.g. electronic maps) to be transmitted to the user or a 3rd party (e.g. a service centre)

Implementation

Studies have been initiated to assess technical solutions and elaborate the corresponding ICDs between the core Galileo system and the external systems to maximise the ease of implementation, use and benefit of this combination.

Solutions may differ as some Galileo services, such as the commercial service, were conceived to support integration with communication systems. Furthermore, specific local components can be designed to achieve the greatest advantages from the combination of Galileo with such systems (see section 4.2). The refinement of the results has to be coordinated with service providers.

4 Galileo System

The Galileo architecture is the result of the system design activities that have been driven by the services defined in the previous section. The architecture at this stage of the project has been designed to be flexible in order to:

- be adaptable to mission requirements changes.
- allow for a gradual implementation of the services described in section 3
- deal with configuration changes of system elements.

A service-oriented approach has been used to define the different components of the Galileo system. Different parts of the Galileo infrastructure are needed to provide the types of service defined in section 3, Galileo satellite-only services, Locally assisted services, EGNOS services and Combined services. According to the participation of each part of the infrastructure to the provision of the services, the Galileo system components have been grouped into the following categories:

- Global component

The Global component is the core infrastructure of the Galileo system that contains all necessary elements to provide the Galileo-satellite only services as described in section 3.1. This component is described in section 4.1.

- Local component

The local component is part of the Galileo design and is needed to provide the locally assisted services as described in section 3.2. The Galileo programme includes the development of a few selected experimental local elements to validate performances and the interfaces between the core system and its local augmentation. These experimental local elements are described in section 4.2.

- EGNOS

The EGNOS system is the infrastructure needed to provide the services described in section 3.3 of this document. The co-location of some EGNOS and Galileo sites is being considered, in the on-going technical studies, to optimise resources. However, the EGNOS system will be kept functionally independent from the Galileo global component to avoid common mode of failures.

- User segment

The user segment is the component of the system that will receive and process Galileo signals and the signals coming from other systems to get the Galileo services. The user segment is described in section 4.4.

- External Galileo-related systems components

The non-European Integrity Segments and the Search and Rescue System will have interfaces with the Global component. These components are described in section 4.5.

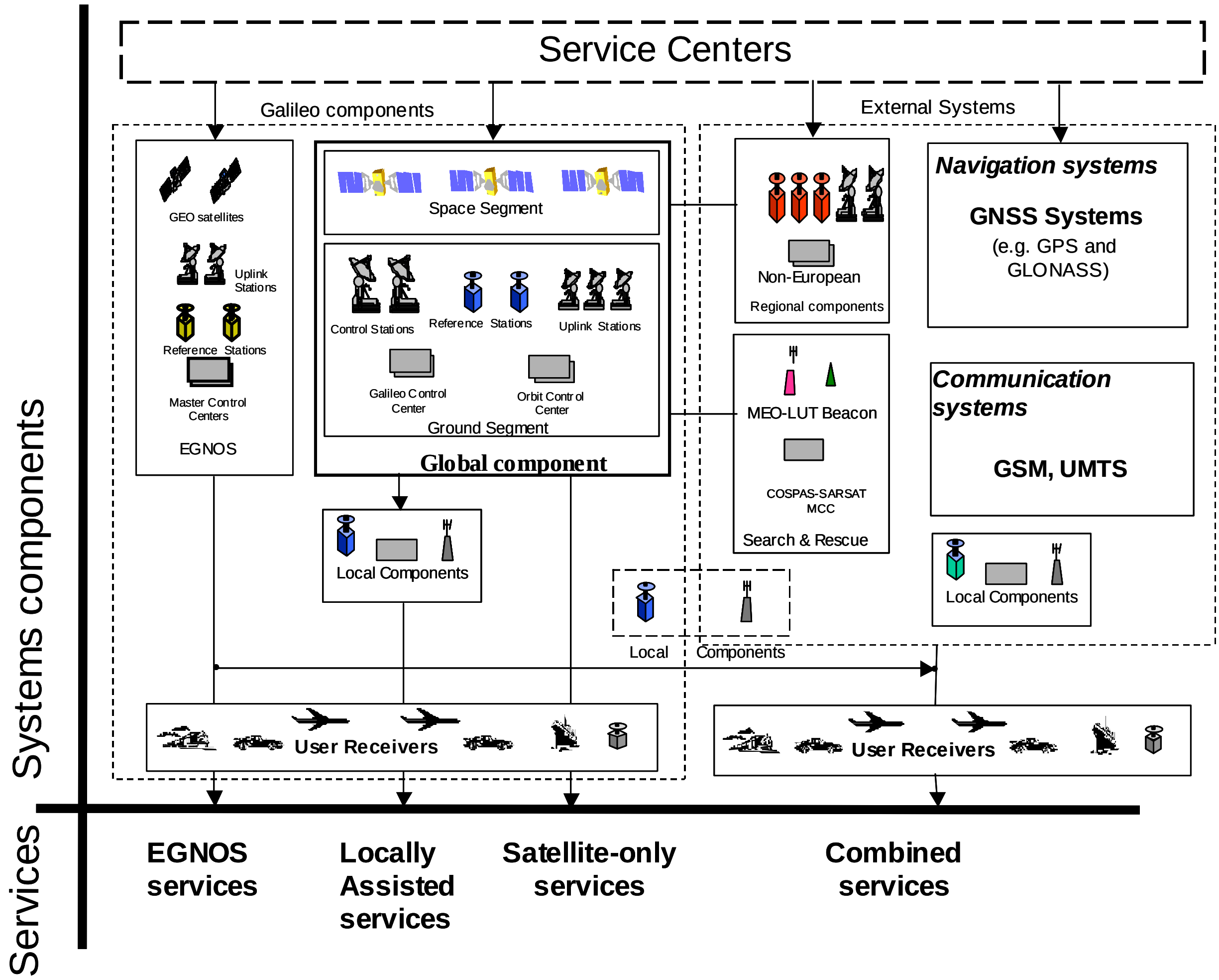

Figure 2 Systems components mapped into services

4.1 Global component

The infrastructure described in this section allows the provision of the Galileo satellite-only services. It is comprised of the space segment made of 27 active satellites + 3 spare satellites, and its associated ground segment.

4.1.1 Space segment

The Galileo Space Segment will comprise a constellation of a total of 30 MEO satellites, of which 3 are spares, in a so-called Walker 27/3/1[16] constellation, see table 8. The satellites include:

- A platform
- A navigation payload
- A Search and Rescue payload.

[16] These figures represent 27 satellites in 3 planes equally spaced.

Each satellite will broadcast precise time signals, together with clock synchronisation, orbit ephemeris and other data. The Galileo satellite constellation has been optimised to the following nominal constellation specifications:

- Circular orbits with a semi-major axis of 29 994 km (which corresponds to 23616 km altitude);
- Orbital inclination of 56°;
- Three equally spaced orbital planes;
- Nine operational satellites, equally spaced in each plane;
- One spare satellite (also transmitting) in each plane.

Orbital and constellation parameters of Galileo and GPS will therefore be different. At any time and at any location on earth the maximum number of visible satellites is calculated to be:

Receiver elevation masking angle	Number of visible Galileo satellites	Number of visible GPS satellites	Total
5°	13	12	25
10°	11	10	21
15°	9	8	17

Table 8 *Maximum number of visible satellites for various masking angles*

4.1.2 Signal in Space (SIS)

Ten navigation signals and 1 SAR signal are provided by the satellite constellation. In accordance with ITU (International Telecommunication Union) regulations, Galileo navigation signals will be emitted in the RNSS allocated bands, and the SAR signal will be broadcast in one of the frequency bands reserved for the emergency services (1544-1545 MHz).
The following chart describes the Galileo navigation signals emission:

- 4 signals are transmitted in the frequency range 1164-1215 MHz (E5a-E5b)
- 3 signals are transmitted in the frequency range 1260-1300 MHz (E6)
- 3 signals are transmitted in the frequency range 1559-1591 MHz (L1)

The detailed definition of the Galileo signals is provided in Annex 2.

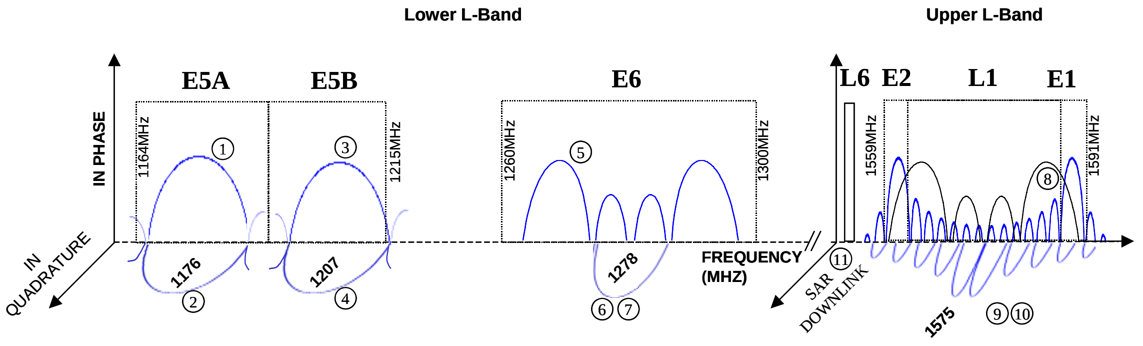

Figure 3 Galileo Signal In Space Description

Each navigation signal consists of a ranging code and data. There are different types of ranging codes and different types of data, which can be used for Galileo signals.

Ranging codes

The ranging code is a sequence of –1 and +1 with specific characteristics in the time (code length) and frequency (chip rate) domains. There is one unique sequence for each signal coming from a given satellite. Ranging codes are either publicly known, when the code is actually published, or known only to the authorised users, when the code is encrypted.

There are three types of ranging codes:

- Open access ranging code (publicly known, unencrypted)
- Ranging codes encrypted with commercial encryption
- Ranging codes encrypted with governmental encryption

Data

There are five types of data: basic navigation data, integrity data, commercial data, PRS data, and SAR data. These data are either open access data (navigation data, integrity data[17], SAR data) or protected data (commercial data using commercial encryption, PRS data using governmental encryption).

Services allocation within Galileo signals

Both the ranging code and data carry the specific information needed for a specific service. Among the 10 navigation signals:

- 6 are designed for OS and SoL (signals 1,2,3,4,9,10 of *Figure 3*)
- 2 are designed specifically for CS (signals 6,7 of *Figure 3*)
- 2 are designed specifically for PRS (signals 5,8 of *Figure 3*)

Table 9 summarises the navigation signals characteristics and their service allocation:

		Navigation Services				Signals characteristics	
Signals id.	Frequencies	OS	CS	SoL	PRS	Ranging Code Type	Data Type[18]
1,2,3, 4,9 and 10	E5a E5b L1	X	X	X		Open Access	Navigation data Integrity data SAR data[19], Commercial data[20]
6, 7	E6		X			Commercial encryption	Commercial data
5,8	E6 L1				X	Governmental encryption	PRS data

Table 9 *Navigation signals characteristics and their service allocation*

[17] A capability of integrity data encryption is envisaged.

[18] Pending final service data allocation

[19] This SAR data correspond to the information sent from SAR operators to the distress emitting beacons: alert acknowledgement, coordination of rescue teams.

[20] Possibility to include commercial data is under assessment

Note: The SAR distress messages (from distress emitting beacons to SAR operators), will be detected by the Galileo satellites in the 406-406.1 MHz band, and then broadcast to the dedicated receiving ground stations in the 1544-1545 MHz band, called L6 (below the E2 navigation band). The SAR data, from SAR operators to distress emitting beacons, will be used for alert acknowledgement and coordination of rescue teams, and will be embedded in the navigation data of the Open Service Signal emitted in the L1 band.

4.1.3 Ground segment

The two basic functions of the ground segment are satellite control and mission control. Satellite control includes management of the constellation through monitoring and control using the TT&C (Telemetry Tracking & Command) uplinks. Mission control will globally control the core functions of the navigation mission (orbit determination, clock synchronisation) and determine and disseminate (via the MEO satellites) integrity information (warning alerts within time-to-alarm requirements) on a global basis. The ground segment assets are as follows:

- The Galileo Control Centre is at the heart of the system and includes all control and processing facilities. The main function of the Control Centre includes Orbit Determination and Time Synchronisation, global satellite integrity determination, maintaining Galileo system time, monitoring and control of the satellites and of the services provided by these, and various off-line maintenance tasks.
- Galileo Sensor Stations collecting navigation data from the Galileo satellites as well as meteorological and other required environmental information. This information is passed to the Galileo Control Centre for processing.
- Galileo Up-link Stations that include separate two-way Tracking, Telemetry and Command stations in the S-band, specific Galileo mission related up-links in the C-band, and Galileo Sensor Stations.
- Mission Uplink Stations with only mission related C-band uplinks.
- Global Area Network to provide a communication network linking all system elements around the world.

Moreover, a Service Centre will be implemented with the objective of providing an interface to users and value added service providers for programmatic and commercial issues. Where appropriate for the different service categories, this centre performs functions such as providing:

- Information and warranty on performances and data archiving;
- Information on current and future Galileo system performances;
- Subscription and access key management;
- Certification and license information;
- Interface with non-European regional components;
- Interface with Search and rescue service providers;
- Interface with the Galileo commercial service providers.

The definition of the role of the Services Centres will be refined in coordination with the [Joint Undertaking].

4.2 Local components

The Galileo Local Component, which is made up of all Galileo Local Elements, is part of the overall Galileo definition, and as such, the Galileo programme includes the design and development of some experimental Local Elements based upon specific functionality necessary to meet associated service requirements.

Galileo Local Elements will provide, where necessary, enhanced system performance and the possibility to combine Galileo with other GNSS systems and terrestrial based positioning and communication systems on a local basis (e.g. D-GNSS, Loran-C, and UMTS) to a wide variety of users.

In order to fulfil the four main service category requirements discussed in Section 3.3 of the HLD the following system functionality is required from the corresponding Local Element Demonstrators:

i. **Local Precision Navigation Elements:** providing local differential correction signals (for example by radio data broadcast or by GSM or UMTS) which user terminals can use to adjust the effective range of each satellite to correct for ephemeris and clock inaccuracies and to compensate for tropospheric, and in the case of signal frequencies, ionospheric delay errors. It will also be possible to enhance the quality of the integrity information in terms of both Alarm Limit and TTA. It is expected that existing signal formats (RTCM, RTCA) will be adapted to accommodate all additional Galileo data.

ii. **Local High-Precision Navigation Elements:** providing local differential data signals (for example by radio data broadcast or by GSM or UMTS) which Three Carrier Ambiguity Resolution (TCAR) user terminals can use to adjust the effective range of each satellite to correct for ephemeris and clock inaccuracies and compensate for tropospheric and ionospheric delay errors. Again, it is expected that existing signal formats (RTCM, RTCA) will be adapted to accommodate the additional Galileo data.

iii. **Locally-Assisted Navigation Elements:** can use one or two-way communication functionality (for example by GSM or UMTS) to assist the user terminal in position determination in difficult environment. In a user terminal centred approach, one way communication is required deliver to the user terminal satellite information (e.g. ephemeris and Doppler) that can be used to reduce the time to first fix, enabling the user terminal to determine its own position much more quickly from newly acquired satellite signals than would otherwise be possible. This information also can reduce the tracking threshold of the SIS within the user terminal, which also results in improved availability. In a service centre approach, two-way communication is needed to enable received pseudorange information at the user terminal firstly to be transmitted back to a central processing facility, where the position is computed before being re-transmitted back to the user terminal in the field. Again, the need not to demodulate and receive additional satellite information reduces the TTFF and increases the tracking threshold. In both cases, the addition of Pilot Tones on the Open Service signals can further improve tracking threshold performance.

iv **Local Augmented-Availability Navigation Elements:** providing local supplementary "pseudolite" transmissions that the user terminal can use as if they were additional Galileo satellites to compensate the satellite visibility under restricted field of view or high availability requirement scenarios. This local ranging information is also nominally of a higher quality than those received from the Galileo satellites, as it is not subject to the same levels of environmental distortion.

In order to test, validate and demonstrate the improved performance delivered by each of these Local Element demonstrators, it will be necessary to develop associated user terminals with the appropriate additional functionality necessary to interact appropriately with the Local Element. The relationship to the core Galileo receiver of Local Element and indeed external complementary system functionality is represented in Figure 4 of this document, and needs to be fully considered when defining the various complementary user terminals to be produced as part of the development and validation phase of the Galileo programme. This is particularly the case when dealing with Locally Assisted Navigation Services, as they require a close synergy between the Galileo Receiver, the associated Local Element and the method of communications (GSM/UMTS), typically combined at the user terminal level as a mobile phone handset.

In order to maximize the ease of implementation, use and benefit of all such Galileo Local Elements, Interface Control Documents (ICD's) will be defined between the 'Core' Galileo system and external systems, in particular mobile communication systems, such as UMTS, that have been identified as having a future role in providing local augmentation to that satellite based Galileo services.

The existence of the Galileo local elements on one hand, and the proliferation of the mobile communication infrastructure on the other, offer major opportunity to build up applications based on the synergy of two basic functions (navigation and data transmission). Consequently, such a synergy will directly allow for the development of the Galileo market share.

This will also be the case for the definition of Services Centres, which may provide to the user community, via Local Elements, additional value added services and data (e.g. planned satellite outages, improved ephemeris/clock predictions).

With Local Elements being Globally proliferated, the potential will also exist to use the quality of the received SIS at the Local Elements to aid in the identification and isolation of interference sources to the Galileo SIS. This additional functionality could be of great benefit to Galileo and indeed GNSS, as the SIS are very weak and as such are particularly susceptible to many forms of interference that at best degrade performance and at worst completely deny it, and as such deserves further investigation.

4.3 EGNOS

EGNOS is composed of four segments: ground segment, space segment, user segment and support facilities.

- The EGNOS Ground Segment consists of GNSS (GPS, GLONASS, GEO) Ranging and Integrity monitoring Stations (called RIMS), which are connected to a set of redundant control and processing facilities called Mission Control Centre (MCC). The MCC determines the integrity, PseudoRange differential corrections for each monitored satellite, ionospheric delays and generates GEO satellite ephemeris. This information is sent in a message to the Navigation Land Earth Station (NLES), to be uplinked along with the GEO Ranging Signal to GEO satellites. These GEO satellites downlink this data on the GPS Link 1 (L1) frequency with a modulation and coding scheme similar to the GPS one. All ground

Segment components are interconnected by the EGNOS Wide Area Communications Network (EWAN);

- The EGNOS Space Segment is composed of geostationary transponders with global Earth coverage. The EGNOS AOC system is based on INMARSAT-3 AOR-E and IOR, and the ESA ARTEMIS navigation transponders;
- The EGNOS User Segment consists of an EGNOS Standard receiver, to verify the Signal-In-Space (SIS) performance, and a set of prototype User equipment for civil aviation, land and maritime applications. That prototype equipment will be used to validate and eventually certify EGNOS for the different applications being considered;
- The EGNOS support facilities include the Development Verification Platform (DVP), the Application Specific Qualification Facility (ASQF) and the Performance Assessment and System Checkout Facility (PACF). Those are facilities needed to support System Development, Operations and Qualification.

The EGNOS elements will be kept functionally independent from the Galileo global component to avoid common mode of failures.

4.4 User segment

The User Segment means the family of different types of user receivers, with different capabilities of using the Galileo signals in order to fulfil the different Galileo services.
To fully benefit all the Galileo services (global, local, combined), the users must be equipped with adequate multi-functional **terminals**. The **functions** implemented in the User Terminal should allow him to:

- Function 1: receive directly the Galileo Signal in Space (i.e. the GALIEO **receiver**);
- Function 2: have access to the services provided by the regional and local component;
- Function 3: be interoperable with other systems.

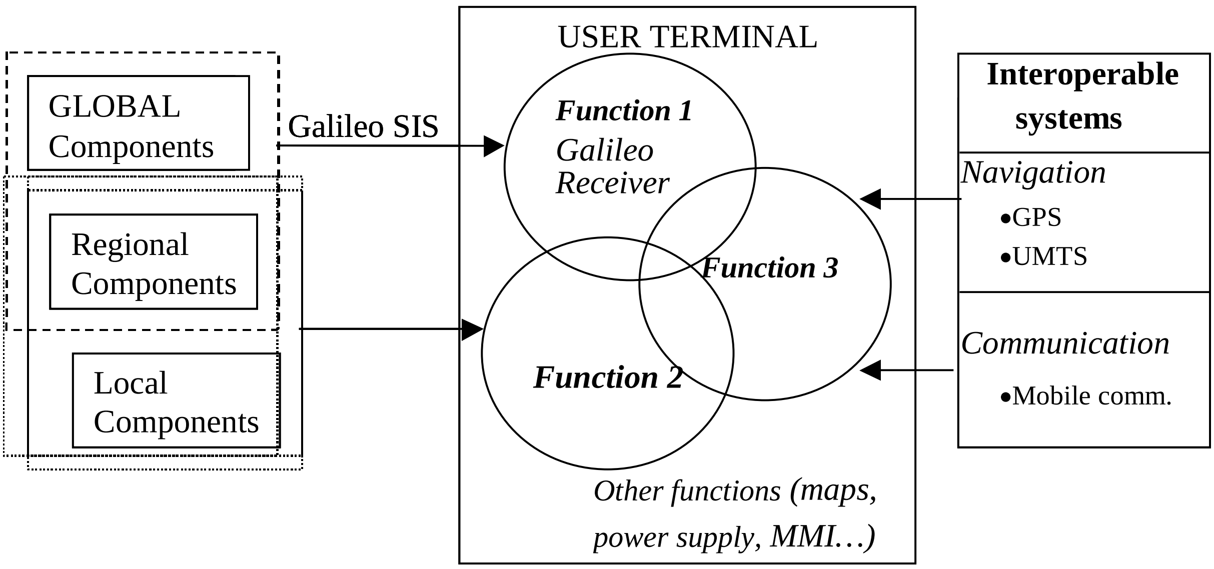

Figure 4 User terminal receiver

As with Galileo Local Components, Galileo receivers will be designed and built as part of the Galileo Development Phase. All performance characteristics of the Galileo services will be referenced to the performance characteristics of these receivers, and as such all subsequently developed user receivers will have to meet the same performance characteristics if the same levels of service are to be reached.

The first function is performed by the Galileo receiver, which constitutes the baseline of any Galileo terminal. The second and third functions are optional and depend on application needs. Some of these functions can technically be performed by the same physical component. By example, the interoperability with GPS and the reception of the Galileo SIS could be performed by a single combined receiver. In addition, the reception of local components data and the interoperability with UMTS could be performed by the same hardware component.

As the performance of different Galileo services are defined at user level, some standard terminals will be developed to demonstrate the achievable performance.

4.5 External Galileo-related system components

4.5.1 Non-European Regional Components

Should non-European regions choose to supplement Galileo's global integrity, Regional Components consisting of ground segments dedicated to Galileo integrity determination over their specific area could be envisaged. The deployment, operation and funding of these components will be under the responsibility of the respective regional service providers. The regional integrity data could be routed to the Galileo ground segment for up-linking to the satellites together with the Galileo and other service provider's data.

4.5.2 Search and Rescue systems

The SAR/Galileo service is a support to the international COSPAS-SARSAT system. The complete SAR mission consists of:

- ***A User Segment*** (called distress beacons), which in case of a distress situation transmits an alert message, in the 406-406.1 MHz;
- ***A space segment***, which detects the alert messages transmitted by distress beacons, and broadcast them globally in a portion (100kHz) of the 1544-1545 MHz band;
- ***A dedicated ground segment,*** called Local Users Terminals (LUTs), which receives and process the alerts relayed by the space segment. The LUTs are designed to receive the alert messages relayed by LEO satellites (LEOLUTs), GEO satellites (GEOLUTs), or MEO satellites like Galileo (MEOLUTs);
- ***Mission Control Centres,*** which validate the alert information and distribute it to the Rescue Team of the Rescue Coordination Centres (RCC).

The contribution of the SAR/Galileo service to the international mission consists of:

- The SAR payload on board the Galileo satellites;
- The design of the receiving ground stations (MEOLUTs). Some five MEOLUTs adequately implemented around the world will be sufficient to perform a global coverage;
- The introduction of a new function (a return link from the Rescue teams to the distress alert transmitting beacons). This return message will be elaborated by a "Return Link Service Provider" (RLSP). The SAR operators (RCC) will designate the RLSP, which will interface with the Galileo ground segment. The return message will be uplink by the Galileo ground segment.

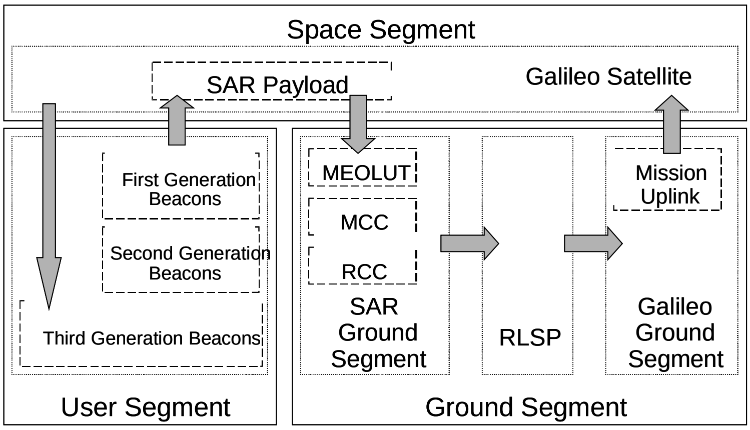

Figure 5 SAR Galileo system

First Generation Beacon	distress beacon, without GNSS receiver, located by Doppler effect
Second Generation Beacon	distress beacon with GNSS receiver, and location information inserted in the distress message
Third Generation Beacon	as second generation, plus the capability to extract return link information from the navigation message

5 Development Plan and Costs

5.1 Development Plan

The current development plan for Galileo is illustrated in Figure 6 below. Following the Definition phase, the Development & Validation phase covers the detailed design, manufacture and test of the system components leading to system validation. System validation will be performed using ground simulation facilities and in-orbit experimentation. A major tool for this work will be the Galileo System Test-bed (GSTB-V1: on-ground system test-bed, GSTB-V2: in-orbit system test-bed) for which the first experimental satellite is planned to be launched towards the end of 2004.

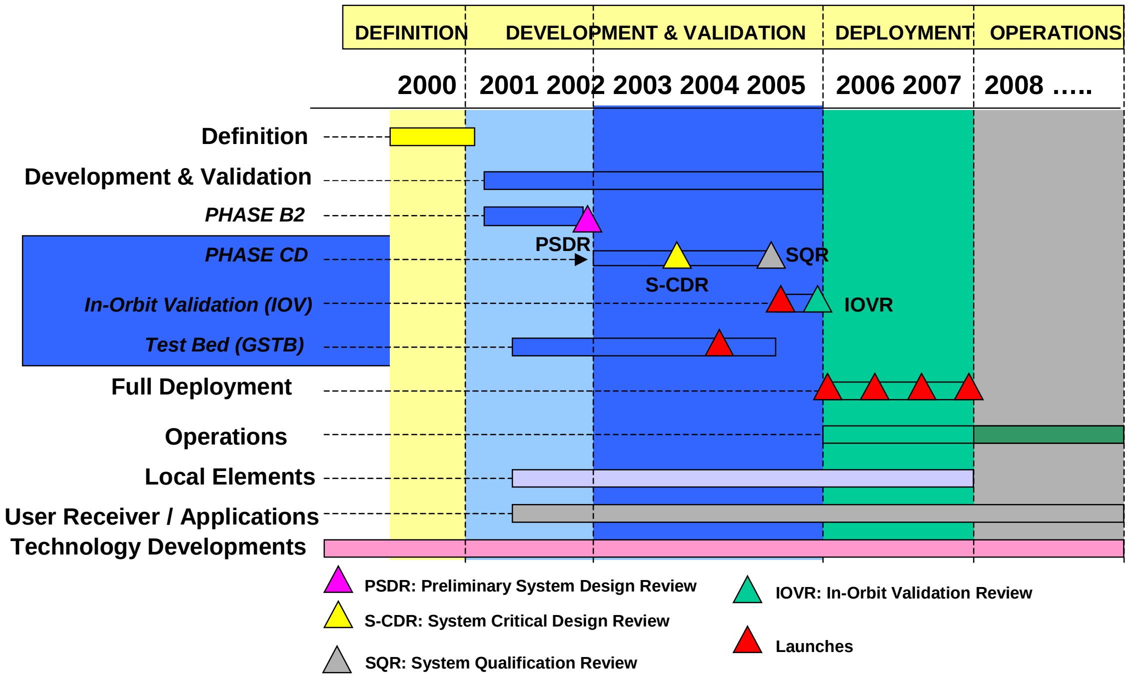

Figure 6 Development Schedule

Following the completion of key system validation milestones and any subsequent design updates, the deployment phase consists of gradually deploying the space segment and ensuring full deployment of the ground infrastructure. Studies are ongoing to analyse the provision of an initial operational capability as soon as possible, for instance a limited constellation size and reduced ground segment functionalities, followed by full deployment of operational capability by 2008.

The operations phase will cover the operations of the system (ground facilities and satellites) and the replenishment of satellites for an indefinite period[21].

[21] For costing purposes a period of 20 years has been adopted. This includes a full constellation replacement.

The development plan will take account of the progress of international negotiations and standardisation.

Launching the satellites of the various Galileo programme phases requires an optimised deployment scenario. One Galileo System Test-Bed (GSTB-V2) satellite must be launched in 2004, the first four operational satellites of the IOV phase will be launched in 2005, and the full deployment to reach the 30-satellite Galileo constellation will be performed by the end of 2007. However, bilateral agreements and the optimisation of the launch scenario might lead to use launchers from providers outside of Europe. The actual optimisation of the Galileo deployment scenario is based upon the following launchers, which have been considered adequate to perform the deployment of the constellation:

Launcher	Launch Capability into MEO orbit
ARIANE 5 ESC-B	8 satellites per launch
SOYUZ-ST	2 satellites per launch
PROTON-M	6 satellites per launch
ZENITH	2 satellites per launch

Table 10 *Launch capability of various launchers*

A combination of the launchers will be chosen such that:

- The deployment costs are optimised
- The deployment risk is reduced
- The system gradually enters into the operational mode in short time
- Production rate of Galileo satellites is taken into consideration

During the operational phases, maintenance flights will be needed to replace single satellites, once they have been placed out of service. The launchers adequate to perform these flights will be chosen during the definition of the maintenance scenarios, which is to be discussed at later programme phases.

5.2 Overall costs

The different studies of the definition phase have provided an estimated cost of the design, the development, in-orbit validation, the full deployment and the operation of the Galileo system. Those figures have been confirmed by industry in the course of the consultation process.
The financial envelope for the applicable HLD is the one approved in the ESA declaration in force and in the EC Communication in force including the respective share of cost between the two institutions.

The local components are part of the Galileo design. The cost envelope includes the design and development of a few selected experimental local elements. The envelope also includes the development of some user receivers for validation of the system performances.

Annex 1: Acronyms and abbreviations.

AOC	Advanced Operational Capability
ARNS	Aeronautical Radio Navigation System
ASQF	Application Specific Qualification Facility
BER	Bit Error Rate
BOC	Binary Offset Carrier
bps	Bits per second
CS	Commercial Service
DVP	Development Verification Platform
EC	European Commission
ECAC	European Civil Aviation Conference
EGNOS	European Geo-stationary Navigation Overlay Service
ELT	Emergency Location Terminals
EMCA	European Maritime Core Area
EOIG	EGNOS Operators and Infrastructure Group
E-OTD	Enhanced-Observed Time Difference
EPIRB	Emergency Position Indicating Radio Beacon
ERNP	European Radio Navigation Plan
ESA	European Space Agency
EU	European Union
EWAN	EGNOS Wide Area communication Network
FOC	Full Operational Capability
GBAS	Ground Based Augmentation System
GEO	GEostationary Orbit
GEOLUT	GEostationary Orbit Local User Terminal
GISS	Galileo Interim Support Structure
GLONASS	GLObal Navigation Satellite System
GMDSS	Global Maritime Distress and Safety System
GMES	Global Monitoring for Emergency and Security
GNSS	Global Navigation Satellite System
GNSS-1	Global Navigation Satellite System 1
GNSS-2	Global Navigation Satellite System 2
GOC	Galileo Operating Company
GPS	Global Positioning System
GSC	Galileo Security Committee
GSM	Global System for Mobile communications
GSTB	Galileo System Test Bed
H	Horizontal
HLD	High Level Definition Document
ICAO	International Civil Aviation Organization

ICC	Integrity Control Centre
ICD	Interface Control Document
IMO	International Maritime Organization
IMO	International Maritime Organization
IMS	Integrity Monitor Station
INS	Inertial Navigation System
IOV	In Orbit Validation
IPR	Intellectual Property Right
ITRF	International Terrestrial Reference Frame
ITU	International Telecommunications Union
IULS	Integrity Up-Link Station
JU	Joint Undertaking
LEOLUT	Low Earth Orbit Local User Terminal
LORAN	Long Range Navigation
LUT	Local User Terminal (SAR receiving station)
Mbps	Megabit per second
MCC	Mission Control Centre
Mcps	Megachip per second
MEO	Medium Earth Orbit
MEOLUT	Medium Earth Orbit Local User Terminal
MHz	Megahertz
MRD	Mission Requirements Document
MS	Monitoring Station
MSAS	Multi-functional transport Satellite-based Augmentation System
NLES	Navigation Land Earth Station
NSCC	Navigation Satellite Control Centre
NSE	Navigation System Error
nsec	nanoseconds (10^{-9} seconds)
OD&TS	Orbit Determination and Time Synchronization
OLAF	Office Européen de Lutte Anti-Fraude
OS	Open Service
OSS	Orbitography and Synchronization Station
PACF	Performance Assessment and system Check-out Facility
PB-NAV	Programme Board on Satellite Navigation
PRS	Public Regulated Service
RAIM	Receiver Autonomous Integrity Monitoring
RCC	Rescue Coordination Centre
RIMS	Ranging and Integrity Monitor Station
RLSP	Return Link Service Provider
SAR	Search and Rescue
SARPs	Standards and Recommended Practices
SBAS	Satellite Based Augmentation System
SIS	Signal in Space
SoL	Safety of Life
TAI	International Atomic Time
TBC	To be confirmed

TBD	To be determined
TCAR	Third Carrier Ambiguity Resolution
TEN	Trans European Network
TTA	Time to Alarm
TTC	Telemetry, Tracking and Command
UMTS	Universal Mobile Telecommunication System
UTC	Universal Time Co-ordinate
V	Vertical
WAAS	Wide-Area Augmentation System

Table 11 *Acronyms and abbreviations*

Annex 2: Signals, Frequencies and mapping into services

Signal-In-Space Description

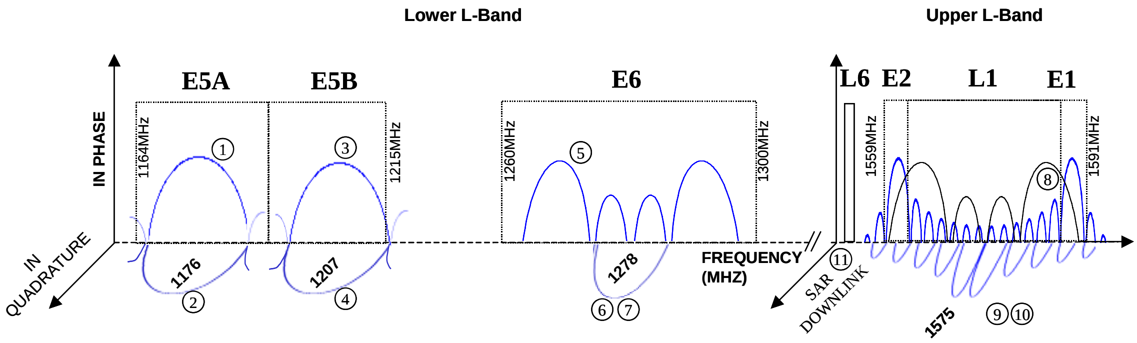

Figure 7 Galileo Signal in Space Description

Galileo will provide 10 signals in the frequency ranges 1164-1215 MHz (E5A and E5B), 1215-1300 MHz (E6) and 1559-1592 MHz (E2-L1-E1), in the Radio-Navigation Satellite Service (RNSS) allocated frequency bands. Details are described below.

Four signals will be transmitted in the band 1164-1215 MHz:

- One pair of signals centred on 1176.450 MHz, in the 1164 - 1188 MHz frequency range (E5A)[22]:
    - 1 signal carrying a low data rate navigation message (25 bps), represented by the signal ①
    - 1 signal without any data (so-called pilot signal) for increased tracking robustness at receiver level, represented by the signal ②

- One pair of signals centred on 1207.140 MHz, in the 1188 – 1215 MHz frequency range (E5B)
    - 1 signal carrying a navigation message of 125 bps, also supporting integrity and SAR data, represented by the signal ③
    - 1 signal without any data (so-called pilot signal) for increased tracking robustness at receiver level, represented by the signal ④

- The signals in E5A and E5B would be generated coherently, therefore giving the possibility to process them together for (1) increased accuracy, (2) redundancy (to mitigate interference from DMEs).

The multiplexing scheme of E5a and E5b signals is under study.

[22] This band, also called L5, will also support GPS modernised signals which, together with Galileo signals will allow cheap bi-mode GPS/Galileo receivers able to track up to 60 satellites

Three signals will be transmitted in the band 1260-1300 MHz (E6), centred on 1278.750 MHz.

- 1 split-spectrum[23] signal secured through governmental-approved encryption, designed for governmental applications requiring a continuity of service even in times of crisis, represented by the signal ⑤

- One pair of signals protected through commercial encryption providing high ambiguity resolution capabilities for differential applications, among which:
    - 1 signal carrying a navigation message of 500 bps supporting value-added data for commercial purpose, represented by the signal ⑥
    - 1 signal without any data (so-called pilot signal) for increased tracking robustness at receiver level, represented by the signal ⑦ by the same waveform than previous signal

The multiplexing scheme of E6 signals is under study

Three signals will be transmitted in the band 1559-1591 MHz (E2-L1-E1), centred on 1575.42 MHz.

- 1 flexible split-spectrum signal secured through governmental-approved encryption, designed for governmental applications requiring a continuity of service even in times of crisis, represented by two different waveforms (signal ⑧)

- One pair of signals[24], among which:
    - 1 signal carrying a navigation message of 100 bps, also supporting integrity and SAR messages, represented by the signal ⑨
    - 1 signal without any data (so-called pilot signal) for increased tracking robustness at receiver level, by the signal ⑩, by the same waveform than previous signal

The multiplexing scheme of E2-L1-E1 signals is under study.

Table 12 summarizes all signals characteristics. Data rates are still under consolidation in the frame of the Galileo design studies carried out by ESA.

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[23] Split spectrum signals are used for either for selective service denial or interference minimisation between to RNSS systems sharing the same central frequency carrier

[24] This band is already supporting GPS SPS signals, which, together with Galileo signals will allow cheap bi-mode GPS/Galileo receivers able to track up to 60 satellites.

Signals id.	Signals	central frequency	modulation	chip rate	code encryption	data rate [25]	data encryption
1	data signal in E5A	1176 MHz	BPSK(10)	10 Mcps	no	50 sps/25 bps	no
2	pilot signal in E5A	1176 MHz	BPSK(10)	10 Mcps	no	no data	no data
3	data signal in E5B	1207 MHz	BPSK(10)	10 Mcps	no	250 sps/125 bps	no[26]
4	pilot signal in E5B	1207 MHz	BPSK(10)	10 Mcps	no	no data	no data
5	spilt-spectrum signal in E6	1278 MHz	BOC(10,5)	5 Mcps	Yes – governmental approved	250 sps/125 bps	yes
6	commercial data signal in E6	1278 MHz	BPSK(5)	5 Mcps	Yes - commercial [27]	1000 sps/500 bps	yes
7	commercial pilot signal in E6	1278 MHz	BPSK(5)	5 Mcps	Yes – commercial[28]	no data	no data
8	spilt-spectrum signal in L1	1575 MHz	BOC(n,m) [29]	m Mcps	Yes – governmental approved	250 sps/125 bps	yes
9	data signal in L1	1575 MHz	BOC(2,2)	2 Mcps	no	200 sps/100 bps	no [30]
10	pilot signal in L1	1575 MHz	BOC(2,2)	2 Mcps	no	no data	no data

Table 12 *Galileo signal characteristics*

Minimum received power on the ground (by a 0 dBi antenna) would be –158 dBW for each signal except –155 dBW for signals 5 and 8.

[25] using a 1/2 rate Viterbi convolutional coding scheme
[26] A capability of encryption for integrity is envisaged and may be activated pending results on potential market interest for integrity
[27] This encryption may be maintained or removed pending on market analysis results
[28] This encryption may be maintained or removed pending on market analysis results
[29] n and m operational values are the subject of on-going technical trade-offs
[30] A capability of encryption for integrity is envisaged and may be activated pending results on potential market interest for integrity

Galileo Services Mapping to Signals

OPEN SERVICES

Open services may consider any of the signals {1,2,3,4,9,10} combination, for instance:

Services [31] →	Open Service Single Frequency	Open Service Dual Frequency	*Open Service Improved Accuracy*[32]
Signal number ↓			
1 (E5a)		**X**	X
2 (E5a)		X	X
3 (E5b)			X
4 (E5b)			X
5 (E6)			
6 (E6)			
7 (E7)			
8 (L1)			
9 (L1)	**X**	**X**	X
10 (L1)	X	X	X

Table 13 *Mapping Open Service into signals*

[31] Non bolded crosses correspond to signals selection which would depend on actual applications
[32] Either absolute positioning or differential positioning based on Carrier Ambiguity Resolution Techniques such as TCAR or Wide Lane. Not currently considered in the services performance section

COMMERCIAL SERVICES

Commercial services may consider any of the signals {1,2,3,4,6,7,9,10} combination, for instance:

Services →	CS Value added	CS Multi carrier differential applications
Signal number ↓		
1 (E5a)		X
2 (E5a)		X
3 (E5b)		X
4 (E5b)		X
5 (E6)		
6 (E6)	**X**	X
7 (E6)	X	X
8 (L1)		
9 (L1)	**X**	X
10 (L1)	X	X

Table 14 *Mapping Commercial Service into signals*

SAFETY OF LIFE SERVICES

SoL services may consider any of the signals {1,2,3,4,9,10} combination, for instance:

Services →	SoL
Signal number ↓	
1 (E5a)	**X**
2 (E5a)	**X**
3 (E5b)	**X**
4 (E5b)	**X**
5 (E6)	
6 (E6)	
7 (E6)	
8 (L1)	
9 (L1)	**X**
10 (L1)	**X**

Table 15 *Mapping Safety of Life service into signals*

PUBLIC REGULATED SERVICES

PRS services would nominally use only the signals 5 and 8:

Services →	PRS
Signal number ↓	
1 (E5a)	
2 (E5a)	
3 (E5b)	
4 (E5b)	
5 (E6)	X
6 (E6)	
7 (E6)	
8 (L1)	X
9 (L1)	
10 (L1)	

Table 16 *Mapping Public Regulated Service into signals*

Annex 3: EGNOS Coverage Area and Performance

Horizontal accuracy	*16m*
Vertical accuracy	*7.7m to 4.0m*
Integrity risk	*2.10^{-7} in any 150s*
Time To Alarm	*6s*
HAL	*40m*
VAL	*20m to 10m*
Continuity	*8.10^{-5} in any 150s*
Local Availability	*0.99*

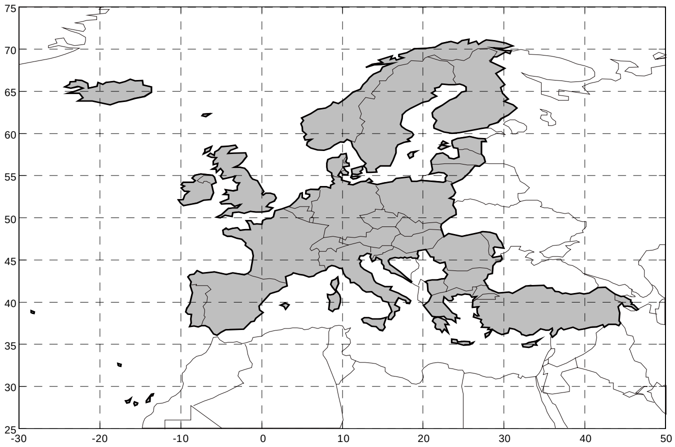

Figure 8 European Land Masses

Horizontal accuracy	*100-10m*	*10m*
Time To Alarm	*10s*	*10s*
HAL	*250-25m*	*25m*
Reliability	*$3.4.10^{-8}$/h*	*$3.4.10^{-8}$/h*
Coverage	*EMCA Oceanic waters* (Distance to the coast greater than 50NM).	*EMCA Coastal waters* (Distance to the coast less than 50NM.)

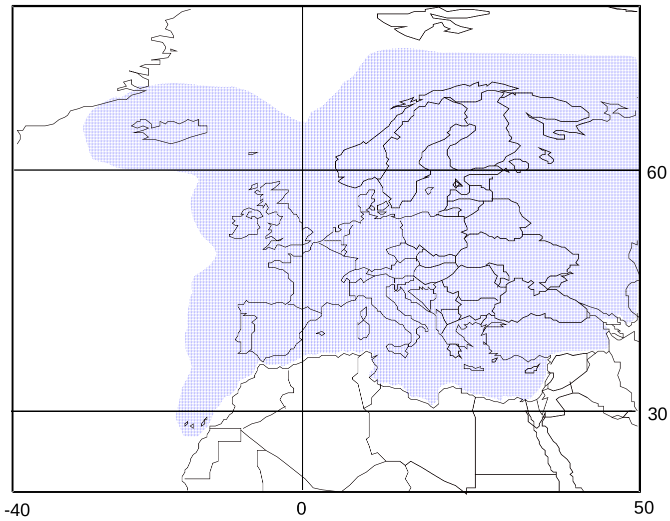

Figure 9 EMCA (European Maritime Core Area) Waters

Horizontal accuracy	*220m*
Integrity risk	*10^{-7}/h*
Time To Alarm	*10s*
HAL	*0.3NM*
Continuity	*10^{-5}/h*

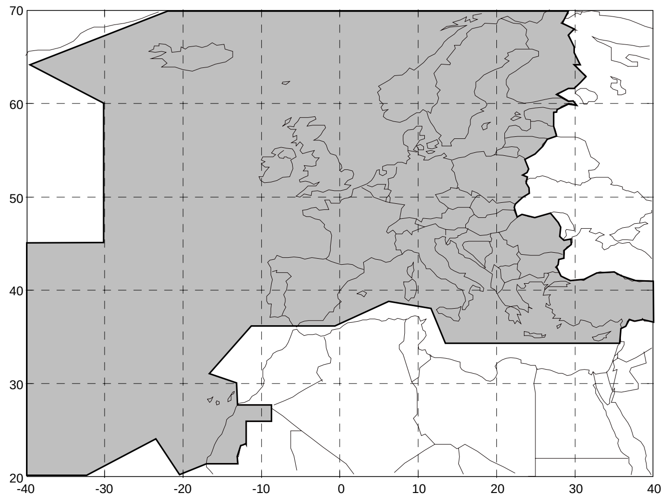

Figure 10 ECAC (European Civil Aviation Conference) Flight Information Regions

Annex 4: Definitions

Accuracy
In the present context, accuracy is a statistical value and is defined as the degree of conformance between the estimated or measured position and/or velocity and the true position and/or velocity of the user at a given level of confidence at any given instant time and at any location in the coverage area.
Accuracy is usually specified as the position error at 95% confidence level. There are several definitions of position accuracy, each depending on the particular application:

- Predictable: The accuracy of a radio navigation system's position solution with respect to the geographic or the geodetic co-ordinates of the Earth.
- Repeatable: The accuracy with which a user returns to a position whose co-ordinates has been measured at a previous time with the same navigation system.
- Relative: The accuracy with which a user determines one position relative to that of another position regardless of any error in their true positions.
- Variant: The accuracy with which a user can measure a position relative to that of another user of the same navigation system at the same time.

A more specific definition, which characterises the positioning system error (instead of the navigation application error), is the EGNOS definition for accuracy that only takes into account the error at the output of the user GNSS standard receiver

Alarm Limit
This is the maximum allowable error in the user position solution before an alarm is raised within the specific time to alarm. This alarm limit is dependent on the considered operation, and each user is responsible for determining its own integrity in regard of this limit for a given operation following the information provided by Galileo SIS.
It is often referred to as HAL (Horizontal Alarm Limit) and VAL (Vertical Alarm Limit), and XAL standing for HAL or VAL.

Availability
Availability of the Navigation Service is the probability that the Positioning service and the Integrity monitoring service (when applicable) are available and provide the required accuracy, integrity (when applicable) and continuity performances. The service will be declared available when accuracy and integrity requirements are met at the beginning of an operation and are estimated to be met during all the operation period (= continuity requirement).
Availability is a characteristic of the service for all the potential users throughout the lifetime of the system and then is applied to SIS only.

Continuity risk
Continuity risk is the probability that the system will not provide guidance information with the accuracy and the integrity required for the intended operation.

Integrity risk
This is the probability during the period of operation that an error, whatever the source, might result in a computed position error exceeding a maximum allowed value, called Alarm Limit, **and** the user not be informed within the specific time to alarm.

RAIM
The Receiver Autonomous Integrity Monitoring (RAIM) is the protection of the navigation solution provided by this user receiver against position errors exceeding the alarm limit. The integrity monitor of a user receiver processes the signals received from all visible satellites. As more satellites than required are available to compute the receiver position, it is possible to identify and reject erroneous information. The RAIM provides then a timely warning when a failure exists (i.e. when a position error exceeds the alarm limit). In addition to this, if a user receiver utilises additional information or measurements from further navigation systems and/or from other sensors, then the integrity of the navigation solution, which is provided by this user receiver, increases.

Time-to-Alarm
The (System) Time-to-Alarm is defined as the time starting from when an alarm condition occurs to the time that the alarm is available at the user interface. Time to detect the alarm condition is included as a component of this requirement.
The start event of an alarm condition is the beginning of a sampling period, in the monitoring station receiver, during which an erroneous pseudo range will be detected.

Timing accuracy
The Timing Accuracy is related to the accuracy of the navigation solution when used for timing applications. It measures the difference of the estimated time scale with a reference one. As for the positioning accuracy, the timing accuracy is also expressed with its statistic, i.e. the 95th percentile of the timing error.