EUROPEAN COMMISSION


# *Mission High Level Definition*

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**EUROPEAN COMMISSION**

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**EUROPEAN COMMISSION**


## Abstract

The High-Level Mission Definition document presents a picture of the main characteristics and performance of the GALILEO Mission. It will be used as framework for the GALILEO programme and will form the basis for the Mission Requirements Document and the System Requirements Document. This issue of the document, prepared by the joint EC/ESA Programme Management Board, results from a consultation process with Member States, Users and prospective investors.

Services result from specific applications of GALILEO's Signals in Space.
The system will provide:

a. **Three navigation signals** supporting the following services:
   i. *Open Service* implemented through two navigation signals separated in frequency. The Open Service, provides position and timing performances, free of user charge. Performance will be competitive with, but complementary to, GPS to enable dual constellation usage.
   ii. *Safety of Life Service*. The Safety of Life Service provides global integrity with a defined time to alarm limit. Integrity data, which can be encrypted, is included as part of the open service signals.
   iii. *Commercial Service*. Encrypted data are available within the open signals to provide a commercial service. This service will provide, also, access to a third navigation signal in a separated frequency from the rest, to enable users to exploit three Carrier Phase Ambiguity Resolution techniques to improve accuracy.

b **Two Controlled Access Navigation Signals** supporting the *Public Regulated Service*. This service provides position and timing to specific users requiring a high continuity of service. Two navigation signals with encrypted ranging codes and data will be provided. Access to this service will be controlled.

c **Local Components Signals.** Some classes of user have local area performance requirements more demanding than those available from the global system (accuracy, integrity time to alarm, signal reacquisition etc). These enhanced services will be met through the use of local components.

**Search and Rescue Services**. Galileo will improve the time to detection and the accuracy of location of distress beacons over the current Search and Rescue services (Global Maritime Distress and Safety System: COSPAS-SARSAT) and will provide acknowledgement to the user of receipt of the distress message.

**Navigation Related Communications Services**. Commercial exploitation of navigation data and communications systems is identified as a major opportunity. The baseline for this service is the combined use of Galileo with current terrestrial or satellite radio networks. The possibility of providing an on board communication payload is being evaluated.

**GNSS-1 Services**. The first generation GNSS-1 (EGNOS), will determine integrity correction data for the single frequency GPS and GLONASS. This data will be disseminated through the European Region's EGNOS GEO satellites. The technical, operational, financial transition plan from GNSS-1 to GNSS-2 will be approved during 2001.

The GALILEO programme is aimed at full operational capability by 2008. The total cost of design, development, in-orbit validation, full deployment and integration of EGNOS is estimated at 3200 M€.

# 1. Introduction

GALILEO will be the European Global Navigation Satellite System (GNSS), consisting of a constellation of satellites in Medium Earth Orbit (MEO) and its associated ground infrastructure. The GALILEO Programme also includes the development of satellite navigation user equipment, applications and services. GALILEO is designed to be interoperable with existing other radio-navigation systems in the world.

## 1.1. Scope and Objective of the Document

The present 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 HLD is a living document updated regularly to take into account the latest results of the programme.

The GALILEO HLD is applicable to the elaboration of the GALILEO Mission Requirements Document (MRD) and GALILEO System Requirements Document (SRD), which represent the applicable documents for development activities.

## 1.2. Approval and Management of the Document

The GALILEO Programme is at present jointly managed and financed by the EC and ESA under a mandate from their Member States.

The GALILEO HLD is elaborated by the GALILEO Program Management Board (EC/ESA) and takes into account the remarks and suggestions resulting from a Member States, users[1] and industry consultation made in February and March 2001.

Complementary design work and consolidation of users needs may further modify the HLD in the future.

The HLD will be updated by the future unique GALILEO management structure which will conduct the programme.

## 1.3. The European Satellite Navigation Strategy

Satellite navigation, positioning and timing has already found widespread applications in a large variety of fields. Satellite navigation, positioning and timing will become an integral part of the of the Trans European Network[2]. Many safety-critical services, in large areas of transport and numerous commercial applications will depend on this infrastructure.

[1] **The consolidated view of the airspace users will be taken into account as a revision to the HLD.**

[2] TEN guidelines Decision Council /EP 1996

Recognising the strategic importance of its applications, a European approach has been developed over recent years. It started with a European investment in the first generation of Global Navigation Satellite Systems (GNSS-1): the EGNOS programme to continue with the future generation of Global Navigation Satellite Systems (GNSS-2): the GALILEO programme.

EGNOS[1] compensates the shortcomings of the current GPS and GLONASS[2], to serve the needs of maritime, land and aeronautical transport applications in the European region and beyond. EGNOS can fulfil a range of user service requirements by means of a regional overlay augmentation to GPS and GLONASS, based on the broadcast, through Geo-stationary satellites, of ranging signals containing integrity and differential corrections.

This first step provides Europe with early benefits but provides Europe and world users neither with a sufficient level of control over GNSS nor with a signal of quality and guaranteed performance as it depends upon the GPS. Therefore, upon request of the EU Council in July 1999 preparations for the next step have been undertaken in parallel to the implementation of EGNOS. Those preparations have led to the definition of GALILEO[3], a satellite constellation providing world-wide coverage which is proposed as the European contribution to GNSS-2.

Combined use of GALILEO, EGNOS and GPS/GLONASS will increase the performance and the safety, of the service achievable from each of the systems alone, and will allow for world-wide acceptability of the exploitation and use of satellite navigation for the benefit of all potential users.

### 1.4. Outcome of the GALILEO Definition Phase

Following preparatory activities carried out in the previous years, the GALILEO Definition Phase was initiated, consisting in a number of activities undertaken by EC and ESA during the year 2000.

This has led to the issuing of EC Communication on GALILEO in November 2000 and ESA Definition Report, which resulted in the ESA Council Resolution in December 2000.

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[1] - ARTES 9, "Initial Global Navigation Satellite System", ESA/JCB(93)66, 17 November 1993.
- EU Council Resolution of 19 December 1994 on the European Contribution to the Development of GNSS, 94/c 379/02
- ARTES Declaration, ESA/JCB(94), 28 November 1996.
- "EGNOS AOC Mission Requirement Document for a Multi-Modal & Inter-Regional SBAS" ID 5110/EP/14, 3 November 1998

[2] - GPS: Global Positioning System deployed by the United States of America released for dual military, civil use and operated by the USA Department of Defence.
- GLONASS: GLObal NAvigation Satellite System deployed by the Russian Federation released for dual military, civil use and operated by the RF Ministry of Defence.

[3] - EC Communication: "Towards a Trans-European Positioning and Navigation Network", COM(1998)29, January 1998.
- EC Communication : "Galileo: Involving Europe in a New Generation of Satellite Navigation Services, European Commission, Brussels, 10 February 1999 and EU Council Resolution 19 July 1999.
- ESA GalileoSat Declaration, ESA/JCB/CXXXII/Dec.1(final), 8 October 1999.
- EC Communication on GALILEO, November 2000.

Based on the outcome of the Definition Phase, the subject HLD (see figure 1) has been produced and consolidated through a consultation process, involving Members States, users and potential private investors.

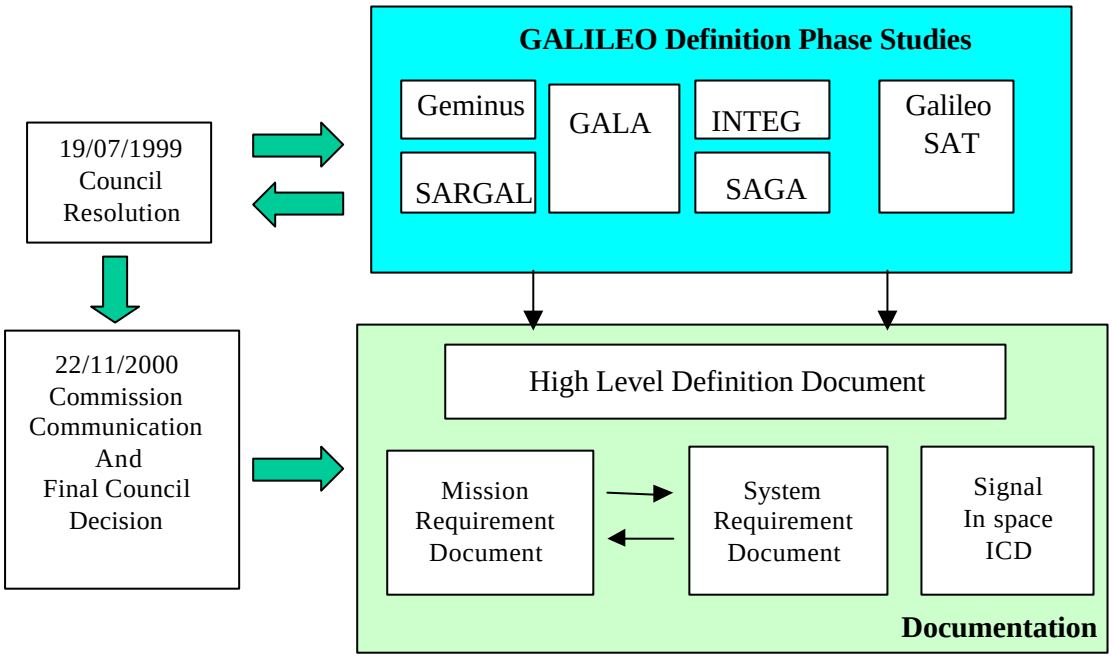


**Figure 1 Galileo Mission Definition Documentation Context**

As a consequence, the main topics addressed in this document are the following:

- **Definition of services:** open, safety-of-life, commercial and public-regulated navigation services can be developed by combining capabilities of the system offered directly through the satellite navigation signals or in combination with ground installations (local components). The system also supports a Search and Rescue service part of Global Monitoring Distress Satellite System (GMDSS). The provision of a Navigation Related Communication service is still under analysis. Satellite-based augmentation services (to GPS and GLONASS) are provided by EGNOS in accordance with the EGNOS Mission requirements and integration strategy.

- **Frequency spectrum allocated at WRC 2000:**
  a number of frequency plan scenarios are being considered for accomodating the different GALILEO navigation signals within the frequency bands allocated at the World Radio Conference 2000.

- **Baseline system architecture (space and ground segment design, including local elements):** the definition of the system architecture has been completed, balancing the complexity between the different components of the system and in particular taking into account the use of local ground components, which can also support Commercial Services and also hybridisation with existing or dedicated communication systems allowing the development of Navigation Related Communication Services.

- **Development plan:** a development plan is proposed which takes into account a coherent plan of transition between GNSS1/EGNOS and GNSS2/GALILEO, the evolution of GNSS user-base with respect to modernisation plans of existing systems and the need to reduce the time-to-market for potential GALILEO commercial services.

- **Cost assessment:** significant effort has been devoted to the assessment of the implementation costs of GALILEO with a view to identifying target figures for a design-to-cost approach for the development of the system.

- **Preliminary scenarios for the integration of EGNOS:** a scenario for the provision of GALILEO and satellite-based augmentation (SBAS) services (EGNOS) has been developed which allows the definition of an EGNOS integration plan.

- **Security policy:** prevention of misuse of GALILEO signals and need to guarantee continuity of service, even during periods of crisis, for critical applications has lead to the introduction of the capability in the satellites to broadcast both open access signals and encrypted navigation signal (Public Regulated Service). Access to the PRS is governed by a security policy under definition.

- **Interoperability issues with GPS, GLONASS and other external systems:** It is a primary requirement to enable the provision of services based on the combined use of GALILEO and GPS/GLONASS/EGNOS signals. This aspect is being taken into account in the definition of the navigation signals and in the selection of common reference standards while retaining the technical autonomy of GALILEO.

Each of the above issues are further addressed in the following sections of this document.

Acronyms

| | |
|---|---|
| ARNS | Aeronautical Radio Navigation System |
| CS | Commercial Service |
| EC | European Commission |
| ECAC | European Civil Aviation Conference |
| EGNOS | European Geo-stationary Navigation Overlay Service |
| EOIG | EGNOS Operators and Infrastructure Group |
| ESA | European Space Agency |
| FOC | Full Operational Capability |
| GLONASS | GLObal Navigation Satellite System |

| | |
|---|---|
| GMES | Global Monitoring for Emergency and Security |
| GMDSS | Global Maritime Distress and Safety System |
| GNSS-1 | Global Navigation Satellite System 1 |
| GNSS-2 | Global Navigation Satellite System 2 |
| GPS | Global Positioning System |
| ICAO | International Civil Aviation Organisation |
| ICD | Interface Control Document |
| ICC | Integrity Control Centre |
| IMO | International Maritime Organisation |
| IMS | Integrity Monitor Station |
| ITRF | International Terrestrial Reference Frame |
| ITU | International Telecommunications Union |
| IULS | Integrity Up-Link Station |
| LORAN | Long Range Navigation |
| MCC | Master Control Centre |
| MEO | Medium Earth Orbit |
| MS | Monitoring Station |
| NLES | Navigation Land Earth Station |
| NSCC | Navigation Satellite Control Centre |
| NSE | Navigation System Error |
| OS | Open Service |
| OSS | Orbitography and Synchronization Station |
| PRS | Public Regulated Service |
| RAIM | Receiver Autonomous Integrity Monitoring |
| RIMS | Ranging and Integrity Monitor Station |
| SAR | Search and Rescue |
| SARPs | Standards and Recommended Practices |
| SAS | Safety of Life Service |
| SBAS | Satellite Based Augmentation System |
| SIS | Signal in Space |
| TBC | To be confirmed |
| TBD | To be determined |
| TCAR | Third Carrier Ambiguity Resolution |
| TTA | Time to Alarm |
| TTC | Telemetry, Tracking and Command |
| UMTS | Universal Mobile Telecommunication System |
| UTC | Universal Time Co-ordinate |

**Table 1 Acronyms**

## GALILEO Overall Definition

Based on the assessment of the User Needs, the outcome of cost-benefit analyses, and the optimisation of the System design, a flexible GALILEO architecture has been defined offering a number of system capabilities which, when combined, result in the different GALILEO Services.

### 2.1. User Needs

The user needs for GALILEO have been established during the definition phase through extensive, bottom-up analysis of navigation, positioning and timing applications. User Fora and market studies have identified a large number of applications and derived the associated user needs. Data from approximately 100 applications have been processed on technical and non-technical differentiators, providing information on the use of positioning in a very wide variety of platforms, geographical regions and environments. In particular, user needs for positioning accuracy, integrity (alarm threshold, time to alarm, risk), availability, operating environment and coverage were assessed. As well as the positioning aspects, timing applications have been studied including time synchronisation requirements for banking, power grids, telecom network etc.

### 2.2. GALILEO Architecture

The GALILEO system architecture is based on a number of components as described below.

A ***Global Component*** composed of:

- A constellation of up to 30 satellites in Medium-Earth Orbit (MEO) providing adequate coverage for the provision of the GALILEO services on a world-wide basis. Each satellite will contain[1] a navigation payload and a search and rescue transponder.

- A ground segment in charge of managing the constellation of navigation satellites, controlling core functions of the navigation mission (orbit determination of satellites, clock synchronisation) and determining and disseminating (via the MEO satellites) the integrity information (warning alerts within time-to-alarm requirements) at global level. Implementation aspects of global integrity concept are under evaluation. The Global ground segment will also provide interfaces with service centres providing value-added commercial services and with the COSPAS-SARSAT Ground Segment for the provision of S&R services.

[1] The inclusion of a dedicated communication payload for supporting Navigation Related Communication Services is still an option.

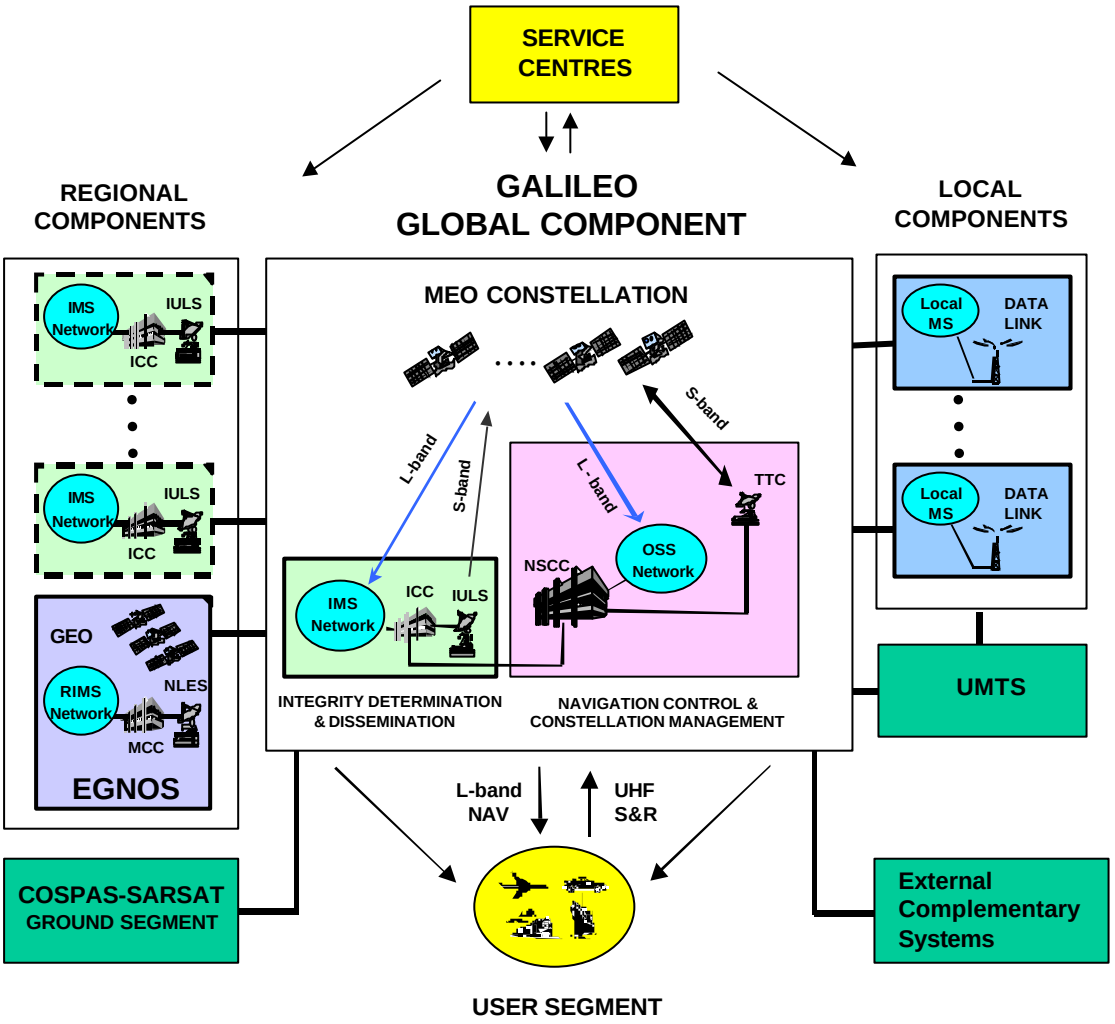


**Figure 2 GALILEO Overall Architecture**

***Regional Components*** including:

- Non-European GALILEO Regional Components, made of ground segments dedicated to GALILEO integrity determination over their specific area if regions choose not to adopt GALILEO's global integrity. The deployment, operations and funding of these components will be under the responsibility of the respective regional service providers. The regional integrity data can be up-linked directly from each region or, alternatively, routed to the Ground segment of the Global Component for up-linking to the satellites together with the SAR and service provider's data.

- EGNOS providing integrity and differential correction for GPS and GLONASS through Geo-stationary satellites.

***Local components***, Some classes of user have local area requirements more demanding than those that will be available from the global system (accuracy, integrity time to alarm, signal acquisition/reacquisition etc). These special services will be met through the use of augmentations provided by local components.

In addition to providing differential levels of accuracy and stringent integrity time to alarm requirements (within 1 second) Local Components can provide services such as:

- Commercial data (corrections, maps, databases)

- Additional navigation signals (pseudolites)

- Enhanced positioning data in areas of poor signal reception (underground car parks, garage areas etc) from GSM or UMTS station based assisted position calculations.

- Mobile communication channels

The design of the GALILEO signal is conditioned to support the operation of local components. An optimum use of those features and capabilities, together with the deployment of complementary local components under the responsibility of the respective service providers, will provide for the commercial exploitation of the GALILEO signals.

***User Segment***: the family of different types of user receivers, with different capabilities for using the GALILEO signals in order to fulfil the different GALILEO services.

Finally, GALILEO also interfaces with ***External Complementary System*** (GPS, GLONASS, LORAN-C, etc…) for the provision of combined services.

***Service Centers***: The GALILEO system provides an interface to users and value added service providers (including local component value added services) through Service Centres. Where appropriate for the different positioning, timing and navigation service categories, these centres perform functions such as providing:

- Information and warranty on performances and data archiving;
- Subscription and access key management;
- Insurance, liability; legal and litigation management;
- Certification and license information management;
- Commercial interfaces;
- Support to application development and possible elaboration of R&D approaches.

The precise functions depend on the nature of services provided, where appropriate, Service Centres can also play a role in collecting fees.

## 2.3. Services as Combination of System Capabilities

The GALILEO services are the result of the combination of the system capabilities of each of the components and segments of the GALILEO architecture: global, regional, local and the user segment. Galileo also provides services resulting from the use of other existing systems like GPS. This is illustrated in table 2.

**GALILEO Signals and Data:** The GALILEO constellation provides the capability of broadcasting globally a set of five navigation signals supporting the open, commercial, safety-of-life and public regulated services. Each navigation signal is composed of one or two ranging codes and navigation data as well as depending on the signal: integrity, commercial and search and rescue data. Satellite-to-user distance measurements based on ranging codes and data, are used in the GALILEO user receivers to fulfil the different GALILEO services.

**Encryption:** Ranging codes and data can be open or encrypted in order to exercise control over the service access. Encryption is also a capability which could be activated permanently or temporarily, therefore allowing a dynamic allocation of signals and data to services in order to respond to the evolution of the user needs and markets or other general considerations, such as security.

**Service Denial:** Denial is the capacity of the system to deny access to a system capability, in order mainly to prevent misuse by unauthorized users. Denial should in principle be applied to the ranging codes which are the major security concern. However in some cases it may also be applied to data, e.g. for commercial purposes. Denial of access to encrypted ranging codes or data can be applied by an adequate management of keys. Denial of access to open , therefore non-encrypted, ranging codes can be applied by local radio-frequency jamming (interfering with the frequency of transmission of the navigation signal containing this ranging code).

## Mapping into Services:

The following mapping of signals and data into services is foreseen.

OPEN, COMMERCIAL AND SAFETY-OF-LIFE NAVIGATION SERVICES

- ***Two open navigation signals*** are commonly used by the open, commercial and safety-of-life services. The two signals are separated in frequency in order to allow the fulfilment of precise ionospheric measurements by differentiation of the ranging measurements made at each frequency. Each navigation signal will consist of two ranging codes. Data are added to one of the ranging codes while the other ranging code is dedicated to supporting the fulfilment of more precise and robust navigation measurements. In principle no ranging code will be encrypted since the signals are intended to support open and safety-of-life services, however, it may be considered the encryption of one of the data-less ranging codes for commercial applications[1]. In this case, the intention would be to offer this commercial encrypted data-less ranging code to value-added service providers developing local contributions such as wireless communication networks (UMTS-GSM) station-based position location for urban environments. It is to be analyzed whether this option would still be compatible with the performance requirements of the safety-of-life service.

- ***A third navigation signal*** separated in frequency from the two above signals is intended for supporting the development of precise local area elements, based on the use of Three Carrier phase Ambiguity Resolution techniques (TCAR). Encryption of the ranging code on this third carrier is a built-in capability on the satellites, which could be activated or not, if it proves to be useful for the development of TCAR as a commercial service or as an open capability within the GALILEO global component.

- ***Integrity data***, required for safety-of-life applications. The integrity data in the open signal can be encrypted on which case this opens the possibility of providing also the integrity data to develop commercial services.

- ***Commercial data*** (e.g. corrections, maps, …) can be disseminated through the open signals for the provision of commercial services.

PUBLIC REGULATED NAVIGATION SERVICES

- ***Two regulated navigation signals*** with encrypted ranging codes and data. These two signals will nominally occupy separate frequency spectrum with respect to the signals used for open, commercial and safety-of-life services described above. This will enable the application of local radio-frequency jamming to open signals without interfering with the regulated signals. The level of integrity for the Public Regulated Services is under consideration, to be concluded before the end of 2001.

[1] To be confirmed

LOCAL COMPONENT

***Local components*** provide signal and data which enhance the performance of the services achieved directly from the satellite signals where satellites are not in view(in-door, underground, tunnels, …). They are considered for commercial, safety-of-life and public regulated services. It is to be noted that commercial services can be developed by local components, even on the basis of open navigation signals. This is the case of TCAR applications, for which the encryption of the ranging code on the third navigation signal does not appear to be strictly required, taking into account that for users to exploit this TCAR capability, they require local measurements. Those local measurements could therefore be encrypted providing namely a means of user access control.

Also, commercial and open local services could co-exist if the service providers are separated geographically. The local nature of these services guarantees an adequate protection of the commercial data.

The local component will provide the interface with between GALILEO and wireless communications network.

EUROPEAN GEOSTATIONARY NAVIGATION OVERLAY SERVICE (EGNOS)

***EGNOS*** will provide the GPS/GLONASS augmentation services (see section 3.4).

NAVIGATION-RELATED SERVICES

The GALILEO global component also offer a number of capabilities in support of navigation related services:

- ***The Search and Rescue Transponder*** of the GALILEO satellites supports the provision of an enhanced COSPAS-SARSAT Search and Rescue service through GALILEO. When a user sends a distress message from his/her COSPAS-SARSAT beacon, this message is received by the S&R transponder and down-linked to ground for reception by a COSPAS-SARSAT ground station which will forward it to a rescue centre for further processing. These transmissions are made in frequency bands already allocated for this service. When action has been taken, the COSPAS –SARSAT ground segment sends feedback message (an acknowledgement message) or co-ordination message to the GALILEO Ground Segment. This message is to be sent to the originator of the alarm. This is achieved by up-linking the message to a satellite in visibility of the user. The message is then included in the navigation signal, which will then be received by the user, if equipped with a GALILEO receiver. Enhanced Search and Rescue services would be possible allowing limited message exchange between the user and the Search and Rescue centre. This is an aspect to be further investigated. Moreover, the implementation approach for the GALILEO Search and Rescue Service is under co-ordination with COSPAS-SARSAT parties.

- ***A Communications Transponder*** on the GALILEO satellites is currently under evaluation. This transponder would provide the capability to support Navigation-Related communications services. A decision on the potential inclusion of this capability is planned by mid 2001.

| GALILEO | | Services | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **System Capabilities** | | **Navigation Services** | | | | | **Navigation Related Services** | |
| ***GLOBAL COMPONENT FUNCTIONS*** | | Open Service | Commercial Service | Safety of Life Service | Public Regulated Service | GNSS-1 Augmen-tation Service | Search and Rescue Service | Nav Related Comms. Service |
| ***Broadcast of Navigation Signal and Data*** | ***Encryption*** | | | | | | | |
| **Two Open Navigation Signals and Data** | No | X | X | X | | | | |
| **Third Navigation Signal** | Yes | | X | | | | | |
| | No | X | X | | | | | |
| **Two Regulated Navigation Signals and Data** | Yes | | | | X | | | |
| **Integrity Data** | Yes | | X | X | X[1] | | | |
| | No | | | X | | | | |
| **Commercial Data** | Yes | | X | | | | | |
| ***Search and Rescue Transponder*** | According to Service | | | | | | X | |
| ***Comms. Capability*** | As needed | | | | | | | X |
| ***OTHER FUNCTIONS*** | | | | | | | | |
| **Local Components** | Yes/No | X | X | X | X | | | |
| **EGNOS Integration** | No | | | | | X | | |

**Table 2 Mapping of GALILEO System Capabilities and Services**

[1] To be defined during 2001.

## 2.4. Signal and and Frequency Plan

The navigation signals defined in the previous section are made available to the users by modulating the ranging codes and data in radio-frequency carriers which are then transmitted by the navigation payload on-board each satellite.

The set of center frequencies for the different carriers as well as the portion of the frequency spectrum around each frequency and which is required for the transmission of the navigation signals is known as the GALILEO frequency plan. This frequency plan shall respect the radio-regulations in force as they are discussed and agreed at the International Telecommunications Union (ITU) forums such as the World Radio-Communication Conference (WARC).

The available spectrum which can be used for the development of Radio-Navigation Satellite Systems is shown in figure 3. In this figure, a number of frequency bands are identified for GALILEO. Out of the definition studies, four frequency bands have been retained for the setting up of the GALILEO signals. Those are presented below. A tentative allocation of the five GALILEO navigation signals into frequency bands has also been done on the basis of the transmission of four carriers, one for each frequency band. Other solutions with three carriers only may be possible but still require further investigation:

- *E5 and L5*, covering the range 1164 MHz to 1215 MHz. Within this band, the use of 24 MHz of spectrum is being considered with the final selection of the centre frequency depending on interoperability issues with E5/L5, co-existence with other services such as DME, JTIDS/MTIDS, and on GALILEO autonomy requirements. The current studies recommend centre frequency of 1202 or 1207 MHz. In E5/L5, an open signal for supporting the Open and Safety of Life Service can be included;

- *E6*, 1260 to 1300 MHz. Within this band, the use of 30 MHz of spectrum is being considered, to accommodate the signals for the Public Regulated Service and the Open (Commercial-encrypted, TCAR) Service.

- *E2*, 1559 to 1563Mhz. This band would accommodate a signal for the Public Regulated Service. Two main options for this signal are being considered. A strict band limiting of the signal spectrum within this band or a spill-over into the adjacent bands. A conclusion shall be reached by the middle of 2001;

- *E1*, 1587 to 1591MHz. This band would accommodate a signal for the Open and Safety of Life Service. As for E2, two implementation scenarios for this signal are being considered. A strict band limiting of the signal spectrum within this band or a spill-over into the adjacent bands. A conclusion has to be reached by the middle of 2001;

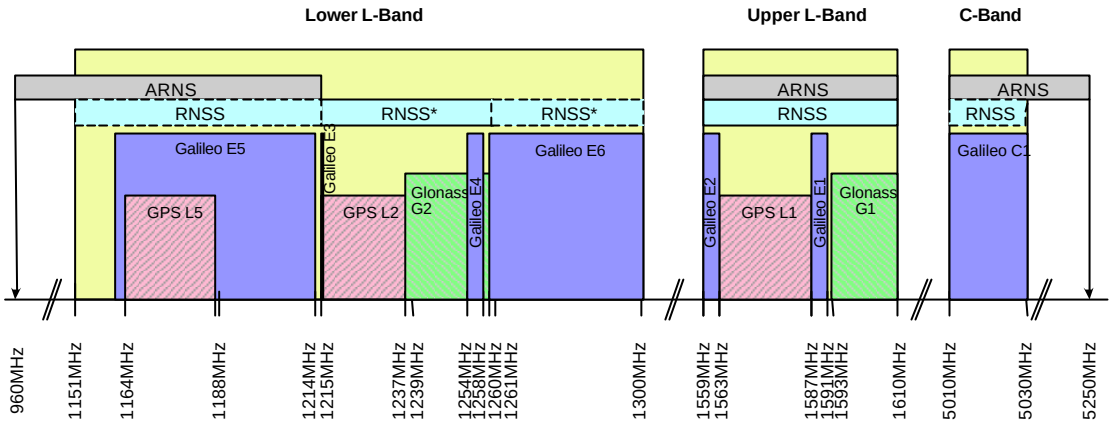


**Figure 3 Frequency Allocations from WRC 2000**

Depending on the bandwidth considered on each of these bands, chip rates for the signals ranges from 2-4 Mcps for the E1 and E2 carriers, to 5-10 Mcps for the E6 carrier (chip rate limited due to the combined use for PRS and TCAR), and 10-20 Mcps for the E5 carrier. Available data rates on each carrier are up to 1000 bps. Since, for the data supporting the computation of position, only 50 bps are strictly required (e.g. GPS), there is sufficient capacity to accommodate Integrity, Search and Rescue and Commercial data within each of the data channels supported by each carrier.

The navigation message is being defined as a number of frame types to be repeated or sent as needed for each type of data. In this way, when data channels are not fully occupied, the basic navigation data can be repeated more often which would reduce the time to first fix or to reacquire on the receivers.

Alternative frequency plans are also under evaluation addressing the sharing of bands with GPS and GLONASS. Inter-operability and performance are issues being considered when evaluating those alternative scenarios.

A selection of the optimum GALILEO signal structure and associated frequency plan is planned by mid 2001.

## 2.5. Integration of EGNOS

EGNOS will provide GPS and GLONASS augmentation services (correction and integrity) according to international standards until at least 2015-2018. Continuation beyond this date and/or up-grades of EGNOS will be decided based user needs, market requirements and cost benefit analysis.

The integration of EGNOS into GALILEO will be based on the following high-level objectives:

- The integration of EGNOS and GALILEO shall maintain a seamless continuation of EGNOS service. During the integration period, the EGNOS service as defined by international standards shall be guaranteed.
- The integration of EGNOS and GALILEO shall not cause any delay on EGNOS AOC development schedule.
- Co-location of EGNOS and GALILEO ground infrastructure is being considered taking into account technical, operational, funding and cost aspects.
- Integration of EGNOS and GALILEO system operations is being considered in relation with a possible integration of some elements of ground infrastructure.
- The GALILEO developments shall capitalise on the experience gained in the frame of EGNOS for aspects such as Hardware and Software qualification, certification, system engineering methodology and tools, verification and validation activities, training, simulation tools and support facilities.

A final plan for the EGNOS integration is expected to be adopted by the end of 2001. This will be done in close consultation with the EOIG and in relation with the selection of the EGNOS operator.

## 2.6. GNSS Interoperability

A primary objective is for GALILEO to provide its services autonomously, thus avoiding any form of dependence or common modes of failure with other satellite navigation systems .

On the other hand, GALILEO is being designed to be interoperable with other existing satellite navigation systems, leading to enhanced service performance resulting from the combined use of the different GNSS components.

Furthermore, GALILEO will achieve levels of performance comparable to those of other satellite navigation systems, thus providing a high level of inherent redundancy required for Safety of Life Applications.

GALILEO and GPS Reference Co-ordinate and Time Systems will be interoperable, thus leading to a efficient combined use at user receiver level.

### 2.7. Interoperability with complementary systems

The GALILEO design shall facilitate the use of GALILEO in combination with other complementary systems, as listed below:

- Other non-satellite based navigation systems (e.g. LORAN-C, EUROFIX), to provide good penetration in environments where the signal-in-space is not sufficiently robust, or for communication of additional information to the user;
- Space-based communications systems (e.g. INMARSAT, Globalstar, etc.) and
- Wireless communications systems, (e.g. GSM, UMTS, etc.) to provide location-based data to the user, or information concerning the user location to a base station;
- Hybridised receivers (e.g. containing gyros or odometers) to provide improved continuity.

When necessary, adequate interfaces will be defined and developed.

### 2.8. Security Policy

The European Union established the Common Foreign and Security Policy (CFSP), by the Maastricht Treaty, which came into force on 1 November 1993. The provisions of the CFSP were revised by the Amsterdam Treaty, which was signed on 2 October 1997 and came into force on 1 May 1999. Articles 11 to 28 of the Treaty on European Union are now devoted specifically to the CFSP.

The approach taken for the security of the GALILEO Programme shall be consistent with CFSP.

The security policy is defined and implemented by EU and Member States, through the System Specific Security Requirements Statement (SSRS) document and the Project Security Instructions (PSI) document, approved and maintained by the GALILEO System Security Board (GSSB).

The management of the security requirements, linked to the implementation of the GALILEO system, will be exclusively the responsibility of EU institutions and EU Member states. Specific agreements with non-EU countries wishing to be associated to the project need to be established.

Security Requirements are divided in three main topics:

- Security of the infrastructure (buildings, stations, space segment, including data and communications links between all these assets);
- Security of the signal, against jamming, spoofing and management of the potential keys used to access this service;
- Global Security, in order to prevent misuse of the Signal in Space, offering precise positioning capability to a potential hostile user.

As far as the GALILEO Services are concerned, the security aspects are related to:

- Security of the Public Regulated Service,[1] to guarantee a defined level of continuity
- Security of the Safety of Life Service, appropriate for its related applications
- Security of Commercial Services, appropriate to protecting the interest of its users and investors.
- Measures to avoid or impede misuse of satellite navigation signals

The security measures foreseen in GALILEO are as follows:

***Security of the Space Segment***: Conventional protections inherent to the space environment are used. The up-links (telecommunications between the Ground Control Segment and the satellites) are protected.

***Security of the Ground Segment***: Several elements of the ground segment (tracking stations, control centres, mission centres and communication links etc.) are to be considered as "sensitive infrastructure[2]" and be protected.

To prevent the misuse of GALILEO, implementation of service denial is considered in the GALILEO security policy. This would need to be co-ordinated with third countries operating their own satellite navigation systems.

Regarding Safety of Life Service, the encryption methods (if they are decided upon) shall remain compatible with the certification procedures and operational constraints. Denial within a zone of crisis shall be possible under the control of the relevant security authorities, bearing in mind that the "safety of life" principles impose the need for formal notification prior to the denial.

For the Public Regulated Service signal, encryption, possibly based on governmental key management, is foreseen. In order to guarantee the best continuity of service, resistance to possible hostile jamming will have to be ensured by adopting wide-band signals, whenever possible. Export of user equipment and related technologies shall be controlled according to the appropriate international legislation. For example, all receivers developed for the public regulated service signal will be considered as dual-use tools and submitted to the rules of the Wassenaar Convention. The encryption tools will also be submitted to these rules.

[1] In accordance with the security provisions associated with the definition of the PRS signal approved by the GSSB.
[2] Levels similar to the protection afforded to existing European Strategic Key Point installations.

# 3. GALILEO Services

The GALILEO services are the result of the specific combined utilisation at user level of the system capabilities. The definition of GALILEO services is based on a comprehensive review of user needs leading to an optimisation of the GALILEO architecture.

## 3.1. GALILEO Navigation Services

The following set of navigation services has been defined. Users, equipped with adequate GALILEO receivers conforming to minimum operational requirements on the basis of which the GALILEO service performance is defined, shall be able to achieve the specified performance.

The defined services have been considered adequate for supporting the large majority of user applications, either by using directly the satellite signals only or in combination with GALILEO local components or through interoperability with other GNSS components like GPS, EGNOS, etc…

### 3.1.1. Open Service

The GALILEO Open Service provides positioning, navigation and timing signals that can be accessed free of direct charge. This service is suitable for mass-market navigation applications, such as in-car navigation and applications of positioning with mobile telephones. The Open Service also provides a precise timing service (UTC) when used with receivers in fixed locations. This timing service can be used for applications such as network synchronisation or scientific applications

The performance for the Open Service is given in Table 3. The performance objectives for the Open Service are those of the Safety-of-Life Service with the exception of integrity (open and safety-of-life use common signals). Through the analysis of user requirements, a match has been found between the performance objectives established in this way, and the needs of the user applications.

| | | Open Service | |
|---|---|---|---|
| Type of Receiver | Carriers | Single Frequency | Dual-Frequency |
| | Computes Integrity | No[1] | |
| | Ionospheric correction | Based on simple model | Based on dual-frequency measurements |
| Coverage | | Global | |
| Accuracy (95%)[2] | | H: 15 m<br>V: 35 m | H: 4 m<br>V: 8m |
| Integrity | Alarm Limit | Not Applicable | |
| | Time-To-Alarm | | |
| | Integrity risk | | |
| Continuity Risk | | $8x10^{-6}$/15 s | |
| Timing Accuracy wrt UTC/TAI | | Not defined | 50 nsec[3] |
| Certification/Liability | | No | No |
| Availability | | 99 % - 99.9 % | |

**Table 3 Service Performance for Open Service with the Satellite Navigation Signals only and without any other augmentations.**

### 3.1.2. Commercial Service

The Commercial Service provides added value with respect to the Open Service. The specific capabilities of GALILEO, which can be exploited for the Commercial Service, are mostly related with the design of the signal which supports:

- Dissemination of encrypted value-added data in the Open GALILEO signals.
- Very precise local differential applications (Sub-meter accuracy) using the open (option encrypted) signal overlaid with the PRS signal on E6.
- Pilot signal for supporting integration of GALILEO positioning applications and wireless communications networks.

The performance of these services would be defined by the service providers based on the quality of the commercial data broadcast[4] and by the performance provided by the local components.

[1] Some level of integrity can be achieved through the application of RAIM techniques at user level.
[2] Figures are based on use of 10 degree mask angle.
[3] For specific timing applications, requiring specific receivers, the timing accuracy is 30 ns.
[4] 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.

### 3.1.3. Safety of Life Service

The performance of the Safety-of-Life service (see table 4) is compatible with the requirements of the Approach with Vertical Guidance (APV-II) as defined by ICAO SARPs[1]. Through the Definition Phase, it has been verified that the performance needs of other modes of transport (land, rail, maritime) are covered adequately through those requirements. The service availability above 99.9% would make it usable for primary means only. Combination of this GALILEO service either with the current GPS as augmented by EGNOS corrections, or the future improved GPS and EGNOS integrity-only, would support CAT-I performance and offer the prospect of sole means availability. Other applications covered would be ship docking, train control, advance vehicle control, robotics (satellite signals combined with local components when required).

A single frequency Safety-of-Life service, with a similar level of performance as the dual frequency service and usable as degraded mode in case of local interference on one GALILEO frequency would be possible if GALILEO transmits a detailed map of the ionosphere, as it is being done by EGNOS. This aspect is currently under technical and economical examination. Alternative techniques to enable accurate single frequency operation are being evaluated.

The coverage area of the GALILEO integrity service is global, and to this extent, the system architecture is being optimised for this requirement. Options for implementation of integrity will be analysed before the end of 2001 in order to take into account certification and liability constraints.

| | | ***Safety-Of-Life Service*** |
|---|---|---|
| ***Type of Receiver*** | ***Carriers*** | *Dual Frequency (single frequency under evaluation)* |
| | ***Computes Integrity*** | *Yes* |
| | ***Ionospheric correction*** | *Based on dual-frequency measurements* |
| ***Coverage*** | | *Global* |
| ***Accuracy (95%)*** | | *H: 4 m*<br>*V: 8 m* |
| ***Integrity*** | ***Alarm Limit*** | *HAL: 12 m*<br>*VAL: 20 m* |
| | ***Time-To-Alarm*** | *6 seconds* |
| | ***Integrity risk*** | $2x10^{-7}$ */ 150 s* |
| ***Continuity Risk*** | | $8x10^{-6}$*/15 s* |
| ***Timing Accuracy wrt UTC/TAI*** | | *50 nsec* |
| ***Certfication/Liability*** | | *Yes* |
| ***Availability*** | | *99 % - 99.9 %* |

[1] Performance would be equivalent to CAT-I precision approach requirements except for the vertical accuracy and integrity performance for which some design margins have been taken. As the studies and the experimentation on GALILEO progress, it may be possible to reduce those design margins and therefore to state better performance with the goal of achieving CAT-I performances.

**Table 4 Service Performance for Safety of Life Service with the Satellite Navigation Signals only and without any other augmentations/elements**

### 3.1.4. Public Regulated Service

The Public Regulated Service is provided on dedicated frequencies to provide the capability for greater continuity of service placed under EU and Member States Governments control for:

- Public applications devoted to European and/or National Security, such as police, civil protection, law enforcement, civil protection such as some emergency services, GMES and other governmental activities,
- Some regulated or critical energy, transports and telecommunications applications,
- Economic and industrial activities that are deemed of strategic interest for Europe.

The Public Regulated Service is robust, so as to be resistant to interference, jamming and other accidental or malicious aggressions. It will be restricted to EU and other participating States authorised by Member States. Member States authorise users through the implementation of appropriate controlled access techniques. Control of distribution of receivers is maintained by Member States

The Public Regulated Service requirements versus an implementation and frequency trade-off is expected to be performed before the end of 2001.

| | | ***Public-Regulated Service*** |
|---|---|---|
| ***Type of Receiver*** | ***Carriers*** | *Dual-Frequency* |
| | ***Computes Integrity*** | *To be defined* |
| | ***Ionospheric correction*** | *Based on dual-frequency measurements* |
| ***Coverage*** | | *Global* |
| ***Accuracy (95%)*** | | *H: 4 m*<br>*V: 8 m* |
| ***Integrity*** | ***Alarm Limit*** | *Level to be defined during 2001* |
| | ***Time-To-Alarm*** | |
| | ***Integrity risk*** | |
| ***Continuity Risk*** | | *$8x10^{-6}$/15 s* |
| ***Timing Accuracy wrt UTC/TAI*** | | *50 nsec* |
| ***Certification/Liability*** | | *Under analysis* |
| ***Availability*** | | *99 % - 99.9 %* |
| ***Signal Robustness*** | | *High (TBD)* |

**Table 5 Service Performance for Public Regulated Service with the Satellite Navigation Signals only**

### 3.1.5. Navigation Services to be provided by Local Components

The Deployment of Local Components will be driven by user and market needs, public regulation, and finance.

However, for the optimisation of GALILEO System design some assumptions on possible generic local components have been made.

Local components providing differential corrections for single frequency users would reach positioning accuracy better than 1 meter. Those stations could report,also, integrity with a time to alarm of 1 second. It is expected that local service providers will adapt the signal format to accommodate additional data.

The exploitation of the TCAR technique with local components allows users to determine their position with errors below 10 centimetres.

The pilot signal, provided with the open signals, enhances the performance of wireless telecommunications networks (GSM/UMTS)-assisted position determination applications in difficult environments (e.g. urban canyon and indoor applications).

| ***Type of Local Components*** | Broadcast of differential corrections for Single or dual Frequency Users | Broadcast of Differential corrections for Triple-Frequency Users (TCAR) | UMTS-assisted user position computation |
|---|---|---|---|
| ***Accuracy*** | < 1 m | < 10 cm | 50 m (TBC) |
| ***Integrity Time to Alarm*** | 1 s | 1 s | Not applicable |
| ***Availability*** | High under open field-of-view conditions | High under open field-of-view conditions | Increased in urban canyons and for indoor applications |

**Table 6 Performance for Services combining Satellite and Local Component signals**

Local stations broadcasting satellite-like signals (pseudolites) are used for increasing the availability of GALILEO service in a defined local area.

### 3.2. Search and Rescue Sevice

The GALILEO Search and Rescue service shall be co-ordinated with the existing COSPAS-SARSAT service and be compatible with both GMDSS and Trans European Transport Network guidelines. GALILEO will allow to improve the time to detection and the accuracy of location of distress beacons with respect to current search-and-rescue system performance.

| ***Search and Rescue Service (SAR)*** | |
|---|---|
| Capacity | Each satellite shall rely signals from up to 300 simultaneous active beacons |
| Forward System Latency Time | The communication from beacons to S&R ground stations shall allow to detect and locate a distres emission in less than 10 mn. 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 S&R ground station |
| Acknowledgment Data Rate | 6 messages of 100 bits each, per minute |
| Coordination Messages Data Rate | 18 messages of 420 bits each, per minute |
| Availability | > 99% |

**Table 7 GALILEO service performance for Search and Rescue Service**

The position determination of the distressed beacons is carried out by COSPAS-SARSAT on the basis of the signals and data provided by the GALILEO Search and Rescue Service. Performances of position determination will be in the range of 5 km for the current beacons, to less than 10 meters for advanced beacons equipped with GALILEO receivers.

### 3.3. Navigation Related Communication Service

The baseline for this service is the combined use of GALILEO with existing wireless, terrestrial (e.g. GSM/UMTS) or satellite networks.

The possibility of providing an on-board communication payload within GALILEO satellites is being considered within specific accommodation constraints in order not to oversize the spacecraft design. A final decision is expected by mid 2001.

This service is appropriate for regulated applications requiring global and high availability and reliable position reporting. The service allows the quasi-instantaneous transmission of short messages from users to a service centre and vice versa.

| *Navigation Related Communications Service (NRS) Characteristics* | |
|---|---|
| Delivery Time | Delivery to recipient < 1 min after sending (TBC) |
| Acknowledge | Acknowledge to sender < 1 min after reception (TBC) |
| Error Notice | Error reported to sender < 5 mins after sending (TBC) |
| Capacity | TBD |
| Availability | > 99.5 % |

**Table 8 GALILEO service performance for NRS**

### 3.4. Satellite-based Augmentation Related Services

These related services (augmentations) are intended to be provided by EGNOS.

GPS/GLONASS wide-area differential corrections and integrity determination and dissemination are fulfilled by EGNOS, interoperable with other Satellite Based Augmentation Systems, WAAS in North America and MSAS in Japan.

The EGNOS Advanced Operational Capability (AOC) service area is defined in Annex 1. EGNOS has the capability to extend its service within the GEO's footprint area.

## 4. Development Plan and Costs

### 4.1. Development Plan

The development plan for GALILEO as illustrated below, will be finalized during 2001. This development plan is designed to achieve progressive deployment of service. EGNOS service will be provided as from 2004.

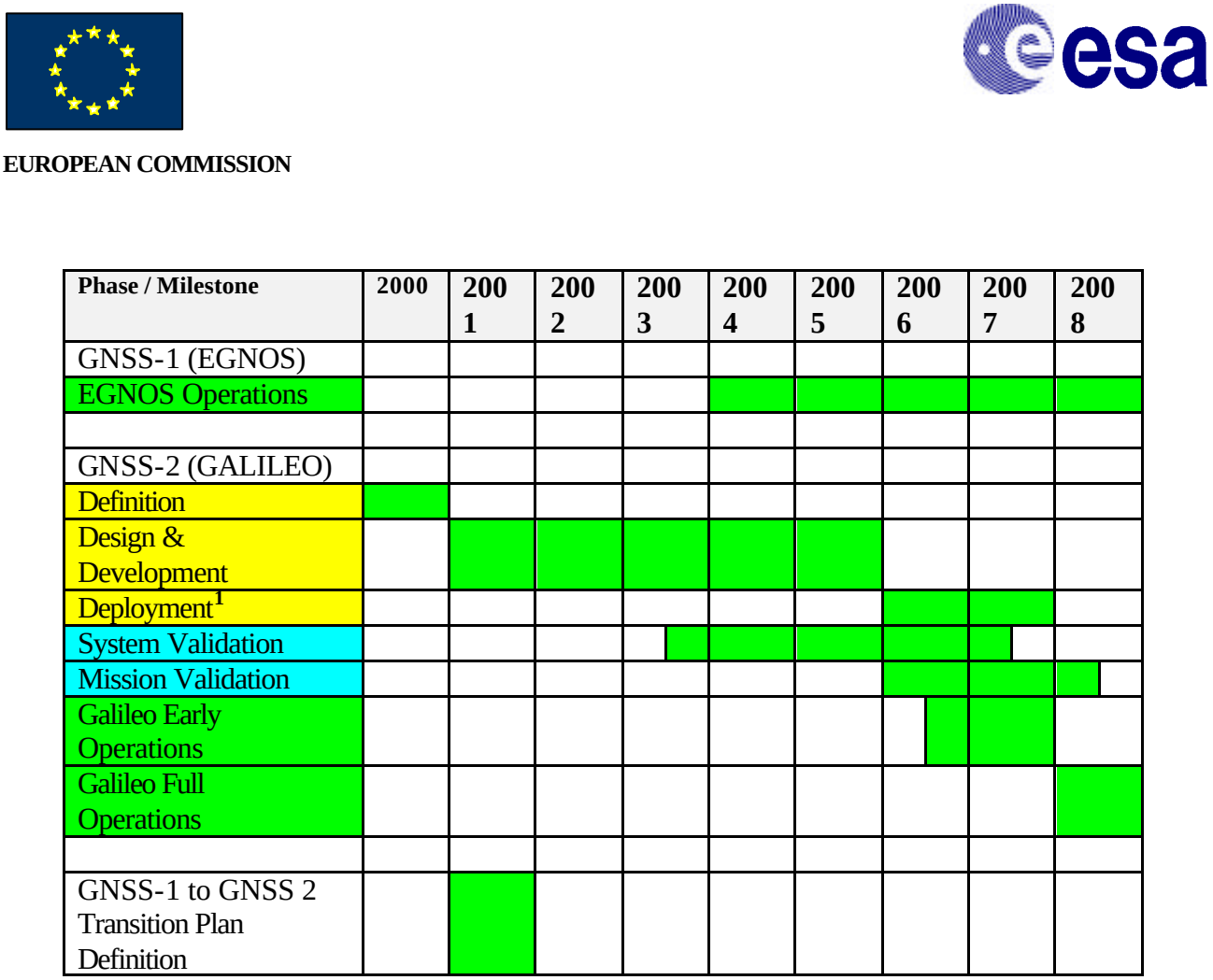


**Figure 4 Development Schedule**

Following the Definition phase, the Design & Development phase covers the detailed design, manufacture and test of the system components leading to system validation. System validation is performed with ground simulations and in-orbit experimentation. The first experimental satellite is planned towards the end of 2003, prior to the completion of system design activities.

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 on-going 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 late 2007.

The operations phase will cover the operations of the system (ground facilities and satellites) and the replenishment of satellites for an indefinite period of time[2].

[1] Depending on the date of decision to launch the project, unfreezing of public fund, and setting up of a single public authority, the involvement of the private sector could arrive earlier and one could imagine an earlier deployment phase.

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

The GALILEO mission is designed to allow private involvement in the future exploitation of the system. For instance:

- Signal design to support the exploitation of commercial services with local components;
- Encryption capabilities which could be activated according to the evolution of user needs and market: capability for encryption of integrity data in SAS, open navigation signal in E6;
- Pilot signal in Open navigation signal;
- Development schedule proposed for GALILEO identifying gradual deployment of services.

A consolidated development plan will be provided following studies during 2001. The development plan will take account of progress in international negotiations and standardisation.

### 4.2. Overall costs

The different studies of the definition phase (see Introduction, section 1) have provided an estimated cost of design, development, in orbit validation full deployment and operational of the Galileo system. Those figures have been confirmed by industry in the course of the consultation process.

The system definition against which the system has been costed is the one which allows for the provision of all the services as described in this document. The only option not included is a communication payload allowing provision of navigation related services.

The design and prototype of generic local components, the design of non-European regional components are included in the total cost whereas the cost of the purchase and installation are not. The installation of local components will be ensured by the service providers.

**The total development and deployment cost of the system as described in this document has been estimated at 3200 Meuros** (cf. EC Communication on GALILEO, November 2000).

Based on the current estimation (see 4.1), the cost of development and in orbit validation would amount to 1100 Meuros while the cost of deployment would amount to 2100 Meuros**.**

## Annex 1: 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* |

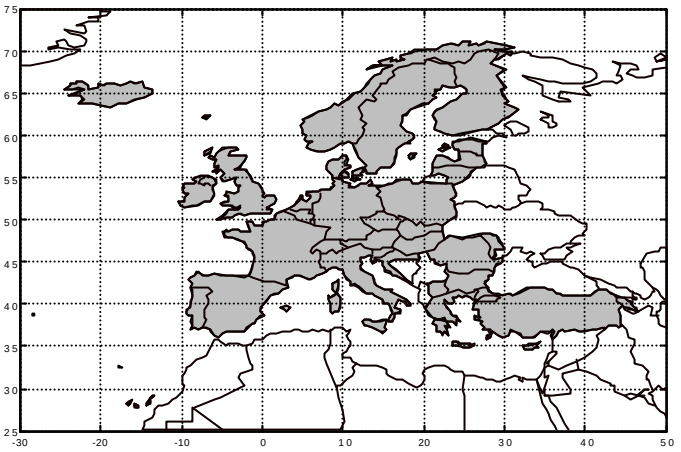


**Figure A-1: European Land Masses**

| | | |
|---|---|---|
| *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.) |

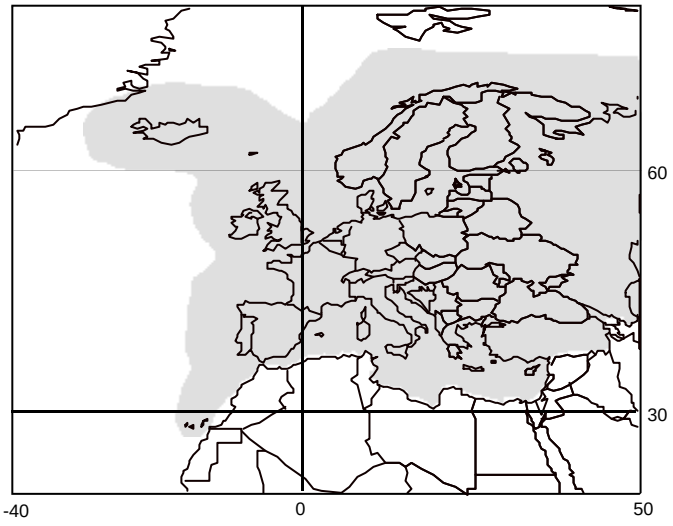


**Figure A-2: EMCA (European Maritime Core Area) Waters**

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

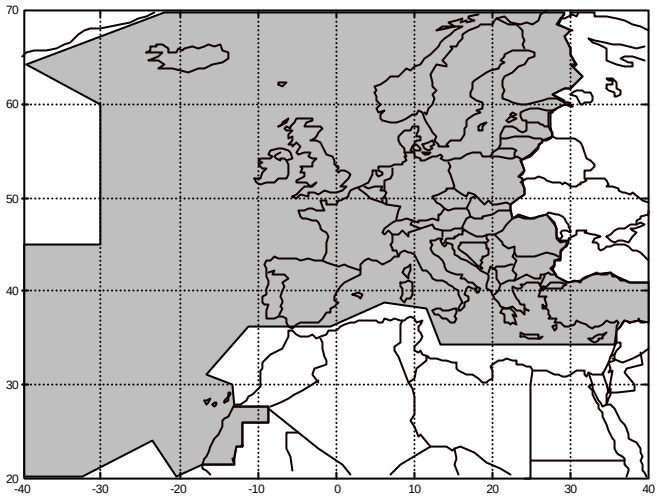


**Figure A-3: ECAC (European Civil Aviation Conference) Flight Information Regions**