System and Policy Inventory

Development of the European Radio Navigation Plan

Contract: ETU-B57000A-E4-193-2003 S07.26312-ERNP

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1 Introduction

1.1 Scope

This report has been produced by Helios Technology Ltd (Helios) for the European Commission Directorate for Energy and Transport (EC DG TREN) as the first deliverable (D1) of its study (Contract No) for the development of a European Radio Navigation Plan (ERNP).

1.2 Study Background

1.2.1 Objectives

The objective of this study contract is to contribute to the development of a European Radio-Navigation Plan (ERNP) and support European Radio-Navigation policy.

More specifically (and as stated in the ITT), the objectives of the study are to:

- provide a detailed inventory of the systems currently in use;
- document radio-navigation requirements and address commonly-used systems and applications;
- provide information on existing system planning;
- define the compatibility and interoperability between existing systems; and
- propose a methodology for evaluating the benefits of systems with a reference to its users.

The output of this study will effectively be a draft ERNP, including:

- EU policies for European radio-navigation systems;
- plans for the operation and cost recovery of radio-navigation systems;
- rationalisation plans for withdrawing systems;
- guidance to users with respect to system/service certification and system selection; and
- European Radio-Navigation System (ERNS) document, containing a summary of civil user requirements and system descriptions.

The scope of the study needs to cover all common-use radio-navigation systems, including baseline systems, augmentations and other complementary systems. This study also needs to address all countries of the European Union and accession countries. Other countries relevant to a coherent ERNP should also be considered, including neighbouring countries/services as well as those upon which the EU depends.

1.2.2 Structure

The structure of this study is based on the requirements outlined in the terms of reference for this study and the duration of the study (nine months). The approach is sound in terms of addressing the tasks described in the terms of reference and achievable with regard to the timescales.

The development of an ERNP is complex, and a clear and logical process is needed. Helios's ERNP study addresses the development of the ERNP in three phases:

- Phase 1 Inventory;
- Phase 2 System Qualification; and
- Phase 3 Implementation.

Each of these three phases produces one of the three required output deliverable documents (Figure 3 1). Consultation with stakeholders underpins each phase to ensure:

- that the EC owns key decisions;
- there is constant Member State, industry and user validation; and
- that there is buy-in from stakeholders along the way.

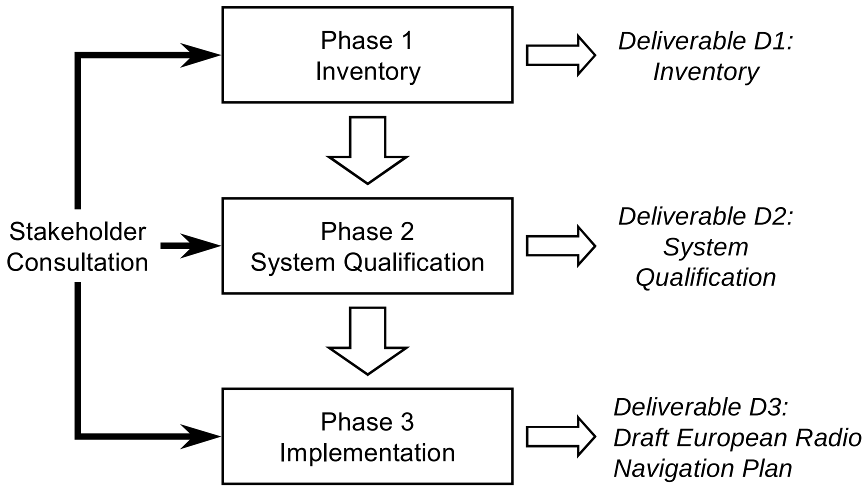

Figure 1 – The Approach

1.3 Motivation

1.4 Approach

The work package logic for Phase 1 is illustrated in FIGURE based on the tasks identified in the Terms of Reference [REF]. The tasks identified in the terms of reference [REF] are included in WP1100 and WP1300. We have introduced a new task, WP1200 Define Evaluation Criteria, to establish the criteria used to down-select the radio-navigation systems in Phase 2. WP1200 is included here to focus the user requirements activities in WP1300 thereby ensuring that we have sufficient data for Phase 2. We will agree the criteria in WP1200 with the European Commission before moving on to attend to WP1300. The service delivery model described in Section 3.4 is particularly important because it allows us to describe how commonly used baseline radio-navigation and augmentation systems deliver services to users at the application level.

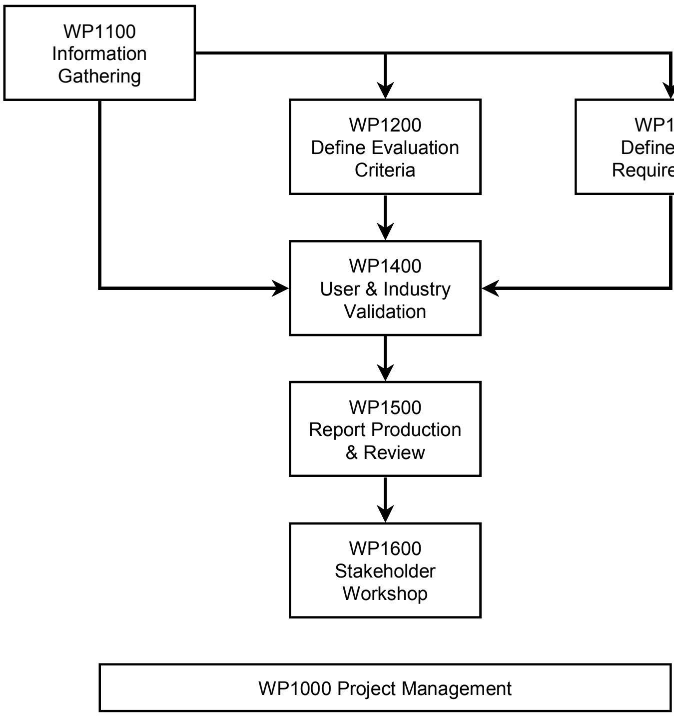

Figure 2 - Phase 1 (Inventory) Logic

1.5 Contents

This System and Policy Inventory is structured to draw out the salient issues and information in Sections 2 to 9 while the original baseline data are presented in Appendices A to I.

Sections in the Main Body of the Report		**Appendices with Baseline Data**	
1	Introduction	A	Abbreviations and Acronyms
2	Definitions	B	Institutional Member State Groupings
3	High-Level Objectives	C	Reference Documents
4	Existing Radionavigation Plans	D	Stakeholder Organisations
5	Regulatory Instruments	E	Existing Radionavigation Plans
6	Evaluation Criteria	F	Regulatory Instruments
7	Existing Systems	G	Existing Systems
8	Market Requirements	H	Market Requirements
9	The Way Forward	I	Consultation Activities

2 Definitions (3 pages max, Helios)

2.1 Service Area

The ERNP and associated policy developed by the EC is only applicable in the EU Member States, i.e. the current (November 2003) 15 Member States and the 10 Accession States from 1 May 2004. However, the terms of reference for this study require that it should also consider neighbour countries to the EU relevant to a coherent ERNP and so we are also considering the following countries:

- EU Applicant Countries;
- Eurocontrol Member States and those countries where there are bilateral agreements for air navigation charges;
- European Civil Aviation Conference (ECAC) States that are not Eurocontrol Member States;
- European Space Agency (ESA) Member States;
- MEDA States;
- European Economic Area (EEA) Member States;
- European Free Trade Associate (EFTA) Member States;
- Russian Federation; and
- United States of America.

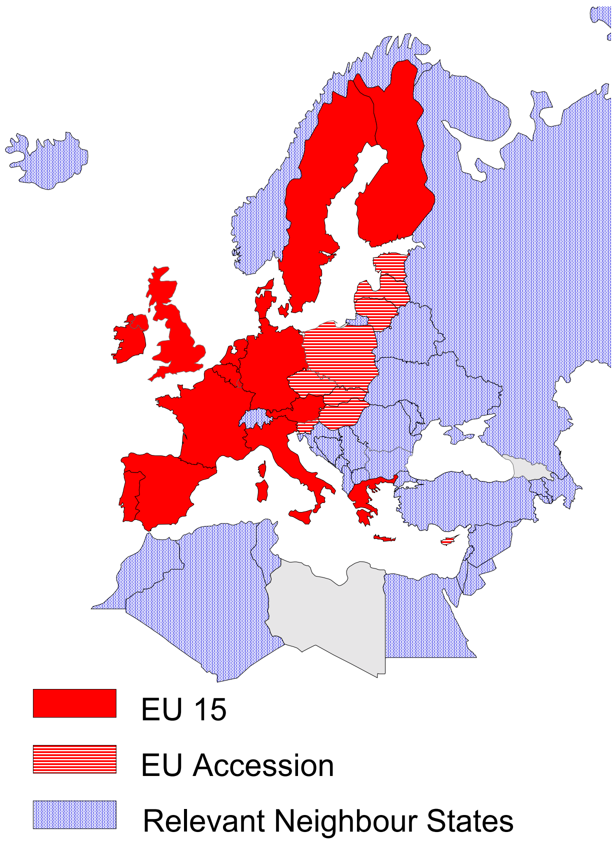

Figure 3 – ERNP service area and relevant neighbouring states

These are detailed in Appendix B. The core service area for the ERNP and the associated European Radio Navigation Service (ERNS) is thus assumed to be the EU Member States and the EU Accession States. There is assumed to be an extended service area to ensure coherence comprising the other States in the above list. These are illustrated in Figure 3.

2.2 Baseline Radionavigation Systems etc

Within the ERNP systems are classified as:

- baseline radio avigation systems;
- regional augmentations;
- local augmentations; and
- complementary non-radio navigation systems.

Users of radio-navigation systems determine their position (and possibly velocity and time) from knowledge of the propagation of electromagnetic radio waves. All radio-navigation systems are underpinned by precise timing (used to generate the radio waves) and precise co-ordinates.

Baseline radio-navigation systems available or planned for in Europe include:

- US Global Positioning System (GPS);
- European Galileo;
- Northwest European Loran-C System (NELS);
- US Loran-C;
- Russian Federation (RF) Chayka; and
- aviation specific systems (eg NDB, VOR, VOR/DME, ILS, MLS).

Augmentation systems provide additional signals that are combined with the baseline radio-navigation systems to improve performance. We have differentiated between regional augmentations and local augmentations. Regional augmentation systems deploy a number of reference stations around the region and produce a single harmonised augmentation signal, whereas local augmentation systems produce an augmentation signal from each reference station.

Regional augmentation systems available or planned for in Europe include:

- the European Geostationary Navigation Overlay Service (EGNOS);
- the US Wide Area Augmentation System (WAAS) ; and
- Loran-C/EUROFIX – a data distribution capability modulated on Loran-C.

Local augmentation systems available or planned for in Europe include:

- Differential GPS (DGPS) eg the International Association of Lighthouse Authorities (IALA) marine radio beacons; and
- Assisted GPS (A-GPS) disseminated over, say, GSM or 3G mobile networks.

Complementary non-radio navigation systems are not based on the principle of radio-navigation and include:

- LF time and frequency systems (eg German DCF77 or UK MSF) that provide time rather than position;
- inertial systems that use accelerometers; and
- balises used widely by the railway sector.

2.3 Modelling Service Delivery

Both baseline radio-navigation systems and regional/local augmentation systems are best modelled in terms of a Data Generation System and a Data Delivery Mechanism (Figure 4) when service delivery is important - this underpins the approach.

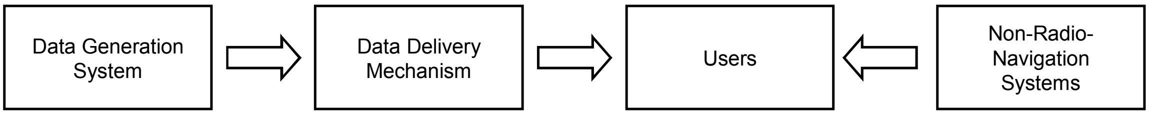

Figure 4 – Data generation and data delivery

Modelling service delivery in this way is good and has a number of key benefits for this study:

- the entire service delivery environment (baseline radio-navigation system to user including augmentation systems) can be modelled effectively in a straightforward and graphical manner;
- separating the data generation and data delivery activities allows us to consider the value of the data and the revenue opportunities provided through the data delivery mechanism;
- once we have established the current service delivery environment in each market sector, we can then rapidly focus in on the down-selected baseline radio-navigation and augmentation systems to determine if the user requirements can be met by the down-selected systems;
- the operational impact of service disruption is immediately apparent and can be traced through the service delivery model to specific user applications. Linked to this, we can readily assess the impact of mitigation strategies (eg backup radio-navigation systems) on service delivery; and
- it allows us to address the rationalisation of navigation aids in terms of impact on users.

3 High-level Objectives (2 pages max, Helios)

To Be Completed following the meeting of the ERNP expert group.

4 Existing Radio Navigation Plans (2 pages max, Helios)

To Be Completed following the meeting of the ERNP expert group.

5 Regulatory Instruments (2 pages max, Helios)

To Be Completed following the meeting of the ERNP expert group.

6 Evaluation Criteria (3 pages max, Helios)

To Be Completed following the meeting of the ERNP expert group.

7 Existing Systems (3 pages max, Helios)

To Be Completed following the meeting of the ERNP expert group.

8 The Application Environment

To Be Completed following the meeting of the ERNP expert group.

9 The Way Forward (2 pages max, Helios)

To Be Completed following the meeting of the ERNP expert group.

A Abbreviations and acronyms (All as required)

AAR	Association of American Railroads
AEIF	European Association for Railway Interoperability
A-GNSS	Assisted GNSS
A-GPS	Assisted GPS
AOA	Angle Of Arrival
ATP	Automatic Train Protection
BSC	Base Station Controller
BSS	
BTS	Base Transceiver Station
CENELEC	
CEP	
COO	Cell Of Origin
COTIF	
DSRC	Dedicated Short-Range Communications
EBICAB	
EC	European Commission
ECAC	European Civil Aviation Conference
EEA	European Economic Area
EFTA	European Free Trade Association
EMC	
E-OTD	Enhanced Observed Time Difference
ERNP	European Radio-Navigation Plan
ERNS	European Radio-Navigation Systems
ERTMS	
ESA	European Space Agency
ETCS	
ETML	
ETSI	European Telecommunications Standards Institute
EU	European Union
FSK	
GIS	Geographic Information System

GNSS	Global Navigation Satellite System
GPRS	
GPS	Global Positioning System
GSM	
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
GSM	
GSM-R	GSM-Rail
LZB	
MEMS	Micro-Electro-Mechanical System
MSC	Mobile Service Switching Centre
RAMS	*Rail Related*
RBC	
RF	Radio Frequency
RFID	Radio Frequency Identification
RN	Radio Navigation
RSDD	
SA	Selective Availability
SC	Switch Commander
SIM	Subscriber Identity Module
SMS	Short Message Service
TERFN	Trans European Rail Freight Network
TOA	Time Of Arrival
TSI	Technical Specifications for Interoperability
TTFF	Time To First Fix
TVM	
UMTS	

B Institutional Member States

EU 15	EU Accession States	EU Applicant Countries
Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain Sweden, United Kingdom	Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland Slovakia, Slovenia	Bulgaria, Romania, Turkey
Eurocontrol	**ECAC, not Eurocontrol**	**European Space Agency (ESA)**
Albania, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, FYROM, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Malta, Moldova, Monaco, Netherlands, Norway, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, UK (Bilateral agreements for air navigation charges with Belarus, Bosnia and Hertzegovina, Latvia, Lithuania, Morocco, Ukraine and Uzbekistan)	Armenia, Azerbaijan, Bosnia and Hertzegovina, Estonia, Iceland, Latvia, Lithuania, Poland, Romania, Republic of Serbia and Montenegro, Ukraine	Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK (Co-operation agreements with Canada and Hungary)
MEDA	**European Economic Area (EEA)**	**European Free Trade Associate (EFTA)**
Algeria, Cyprus, Egypt, Israel, Jordan, Lebanon, Malta, Morocco, The , Palestinian Territory, Syria, Tunisia, Turkey	Iceland, Liechtenstein, Norway	Norway, Switzerland
Others		
Russian Federation, United States of America		

C Reference Documents

Please send electronic or paper copies of all documents to Helios so that we can create the database required by the EC.

D Stakeholder Organisations

D.1 Governmental Authorities and Regulators

D.1.1 International Regulators and Standards Bodies

(ICAO, IMO, UIC)

D.1.2 European Political Institutions

EC, ESA, Eurocontrol, ETSI, NELS

D.1.3 Non-European Political Institutions

FAA, FCC, US DoT, IGEB, non-European Space Agencies

National Government Departments

Transport, Security, Trade, Research

National Safety/Economic Regulators

Aviation, Maritime, Rail

National Telecommunications and Spectrum Managers/Regulators

National Navigation Institutions

EUGIN, RIN, ION, …

Infrastructure Providers

Air Navigation Service Providers

NATS, DFS, AENA, …

Lighthouse Authorities

Trinity House, NLB, …

Rail Infrastructure Providers

E.g. DB, FS, RENFE ,SNCF

Road Infrastructure Providers

E.g. road tolling operators, ASECAP, highways operators, …

Mobile Network Operators

E.g. GSM Europe

Time and Frequency Providers

NPL, IEN, …

End-Users

Professional Institutions

EUGIN, chartered surveyors …

Market Specific Groups

AOPA, EMRF, …

Safety Critical User

Train operating companies, airlines, shipowners

Corporate Users

Fleet managers, emergency services

Consumers

Yachting, farming, surveyors

Industry and Value Chain Participants

Standards bodies

EUROCAE, ISO, CENELEC, ETSI, 3GPP

Receiver and Equipment Manufacturers

Septentrio, Thales, …

Radionavigation service Providers

Thales Geosolutions, Fugro, …

Value added applications service providers and system integrators

Thales …

E Existing Radionavigation Plans / Policies

E.1 International Overview

To obtain an overview on national Radionavigation Plans and other policy related papers on radionavigation, which exist within the area defined in chapter **Error! Reference source not found.**; national contact persons have been consulted for most of the countries, to provide the relevant information for their country, as well as other (neighbouring) states. The results of this research is visualised in the following figure:

No national POC	No feedback	No national RNP and no policy papers in English	National policy paper	National RNP	National RNP (English version / summary)

Country	Title	English Version / Summary	RNP Harmonisation with other countries	Responsible Organisation	Volumes	Newsletter	First edition	Current edition	Scheduled Update	Other documents describing the national policy for radionavigation (preferably in English)
Albania										
Algeria										
Austria										
Azerbaijan										
Belarus										
Belgium										
Bosnia and Hertzegovina										
Bulgaria										
Croatia										
Cyprus										
Czech Republic										
Denmark										
Egypt										
Eire (Republic of Ireland)										See Irelands Department of Communications, Marine and Natural Resources website: http://www.dcmnr.gov.ie/display.asp?pg=793
Estonia										

Finland										
Former Yugoslavian Republic of Macedonia										
France										
Germany	Deutscher Funknavigationsplan DFNP	No	No	Bundesministerium für Verkehr, Bau- und Wohnungswesen - Referat A 24 (Ministry of Transport, Building and Housing – Department A 24) www.bmvbw.de	2 + Executive Summary	Yes	1996	2003	Continuously till 30.6.2005	No
Greece										
Hungary										
Iceland										
Israel										
Italy										
Jordan										
Latvia										

Lebanon										
Liechtenstein										
Lithuania										
Luxembourg										
Malta										
Moldova										
Monaco										
Montenegro										
Morocco										
Norway										
Poland										
Portugal										
Romania										
Russian Federation										
Serbia										
Slovak Republic										
Slovenia										
Spain										
Sweden	Swedish Radio Navigation Plan 2003	Yes Policy & Plans	No	Swedish Maritime Administration	2	No	1991	2003	3 year interval	No

Switzerland	Schweizerischer Radionavigations-plan CH-RNP	No	No	Bundesamt für Zivilluftfahrt BAZL Federal Office for Civil Aviation FOCA http://www.aviation.admin.ch	2	Yes (Newsletter and Hotnews)	1999	2003	TBCd	No
Syria										
The Netherlands	Nationaal Radionavigatie Plan	No	No	Ministry of Transport, Public Works and Water Management	1		1993	No new updates available		
The Palestinian Territory										
Tunesia										
Turkey										
Ukraine										
United Kingdom		No							2020 The Vision – Marine Aids to Navigation Strategy, GLA	
Uzbekistan										

Figure 5 – Overview on existing Radionavigation Plans

E.2 National RNPs

E.2.1 Germany

The first German Radionavigation Plan “Deutscher Funknavigationsplan (DFNP)” was published in 1996 by the Ministry of Transport, Building and Housing. The Radionavigation Plan was updated in 1999. Since 2001 the DFNP is being updated continuously, which means that newsletters are published to inform users on current developments and important news, dedicated chapters are being exchanged on demand, and the overall plan is being updated in regular intervals.The DFNP is structured into two volumes (both in German):

Volume 1 contains:

- background information on the German Radionavigation Plan
- descriptions of the national responsibilities in the domains of positioning and navigation
- an overview on different domains of applications (by each mode)
- an overview on the specific requirements for each application identified
- conclusions for the future use of systems within each mode of transport
- descriptions of the German R&D activities on national and international level
- time schedules for the operation of the various systems
- conclusions for the future use and combination of systems.

Volume 2 contains:

- detailed descriptions of the applications and requirements listed in volume 1 (structuring the applications into: existing, under implementation, and future developments)
- detailed system descriptions
- information on certification aspects
- an overview on information services for GPS
- an overview on differential GPS services available in Germany
- information on frequency- and orbit co-ordination
- strategy of the German air traffic control DFS for the use of GNSS in civil aviation

E.2.2 Sweden

The first Swedish Radio Navigation Plan was published in 1991 on the initiative of and by the Swedish Board of Radio Navigation (RNN). The members of the RNN are:

- Swedish Defence Research Agency
- Swedish National Space Board
- ÅF-Communicator AB
- Chalmers University

- Lantmäteriet (National Land Survey)
- Swedish Defence Materiel Administration
- Telemar Scandinavia AB
- Swedish Civil Aviation Administration
- Swedish Maritime Administration

The main objective of RNN is to be an informal meeting place and forum for discussions and opinions and to keep its members informed of the development and progress in general within the area of radio navigation.

By a decision of the Swedish Government the Swedish Maritime Administration (SMA) was later given the official responsibility for the continued work with the plan. RNN was tasked to proceed with the updating work and so a new thoroughly revised version of the plan was developed by RNN and officially published by SMA in 1997. The plan is to be updated every third year with the previous edition published in year 2000. An updated summary in English was published in 2002. The present version (2003) replaces both the Radionavigationplan 2000 and the English summary from 2002.

The Swedish Radio Navigation Plan is structured into two volumes:

- Volume 1 (Swedish) “Systembeskrivning” contains:
  - detailed system descriptions
- Volume 2 (English) “Policy and Plans” contains:
  - background information on the Swedish Radionavigation Plan
  - an brief overview on systems used
  - user requirements for all modes and applications identified
  - policy and plans (for each mode)

E.2.3 Switzerland

The first Swiss Radionavigation Plan “Schweizerischer Radionavigationsplan (CH-RNP)” was published in 1999 by the Federal Office for Civil Aviation. Since 2001 the CH-RNP is being updated continuously, which means that hotnews and newsletters are published to inform users on current developments and important news, dedicated chapters are being exchanged on demand, and the overall plan is being updated in regular intervals.

The CH-RNP is structured into two volumes (both in German):

- Volume 1 contains:
  - background information on the Swiss Radionavigation Plan
  - mode specific chapters including:
  - background information
  - requirements
  - conclusions
  - recommendations

- synergies between different modes
  - descriptions of the Swiss R&D activities on national and international level
  - future system planning and recommendations
- Volume 2 contains:
  - detailed system descriptions
  - operation schedules
  - certification issues
  - DGPS services
  - Geodetic reference frames and systems
  - Frequency- and orbit coordination
  - detailed application descriptions

E.2.4 The Netherlands

The Dutch Radionavigation Plan was issued in 1993. It is a descriptive report and not a policy plan. The report describes the following items:

- the various modes (aviation, maritime, inland transportation (shipping, car, navigation, geodesy))
- the international context and standards (ICAO, IMO, IALA, ITU)
- descriptions of systems in use (landbased/satellite, global/regional/local, multi-modal/sector specific)
- information on the ERNP-activities of the EC at that time.

Due to the fact that the plan was generated in 1993 it does not correspond to the current status of Radionavigation use in the Netherlands and is not used any more.

E.2.5 Russia

A Radionavigation Plan for Russia exists, but more detailed information on the document were not provided in time to be included into this version of the report.

E.2.6 USA

The Federal Radionavigation Plan (FRP) is the official source of radionavigation policy and planning for the Federal Government of the USA. The first edition of the FRP was released in 1980 as part of a Presidential Report to Congress, prepared in response to the International Maritime Satellite (INMARSAT) Act of 1978. It marked the first time that a joint Department of Transportation (DOT) and Department of Defense (DoD) plan for common-use (both civil and military) systems had been developed. Now, this biennially updated plan serves as the planning and policy document for all present and future federally provided common-use Radionavigation systems.

A Federal Radionavigation Plan is required by 10 United States Code (U.S.C.) 2281(b). A Memorandum of Agreement (MOA) between DoD and DOT provides for radionavigation planning as well as for the development and publication of the FRP. This agreement recognizes the need to coordinate all federal Radionavigation system planning and to attempt, wherever consistent with operational requirements, to utilize common systems. In addition, a Memorandum of Agreement between the DoD and DOT on the civil use of the Global Positioning System (GPS) establishes policies and procedures to ensure an effective working relationship between the two Departments regarding the civil use of GPS.

Since the 2001 edition the FRP is separated into two documents:

- The FRP, which contains:
    - background information to the Federal Radionavigation Plan
    - the U.S. policies for radionavigation systems
    - operating plans for radionavigation systems
    - a research and development summary
- and a companion document titled: Federal Radionavigation Systems (FRS), which contains:
    - information on national responsibilities
    - detailed information on user requirements
    - detailed system descriptions (including regional, national and local augmentation systems)
    - geodetic reference systems.

E.3 Policy papers

E.3.1 ECAC

Navigation Strategy for ECAC, NAV.ET1.ST16-001, Edition 2.1, Eurocontrol, 1999

The document provides a harmonised and integrated strategic framework for the development of navigation applications for ECAC Member States, to allow a cost-effective, customer oriented evolution of the European Air Navigation Systems during the period 2000-2015. The evolution of the air navigation systems is described in terms of performance, functionality and corresponding infrastructure, taking due account of the principle of global interoperability. This Navigation Strategy supports the operational developments proposed by the ATM 2000+ Strategy and is in line with the implementation of the ICAO Global Air Navigation Plan for CNS/ATM systems in ECAC.

The document contains:

- background information
- requirements, including:
- user requirements
- ATM requirements
- communication dependencies
- surveillance dependencies
- AIS dependencies
- strategic actions

E.3.2 Ireland

Review of Maritime Radionavigation Policy in Ireland, Department of Communications, Marine and Natural Resources – Maritime Safety Directorate, 2003

The Irish Minister for the Marine directed that the Department of Communications, Marine and Natural Resources undertake a fundamental review of Ireland's policy on radio-based aids to navigation for the maritime sector. The Department, in conjunction with Commissioners of Irish Lights, devised a consultation paper and questionnaire. This paper was circulated to relevant stakeholders in December 2002. The key results are presented in the document Review of Maritime Radionavigation Policy in Ireland – Summary of Analysis of Responses to Consultation paper.

E.3.3 UK

2020 The Vision – Marine Aids to Navigation Strategy, GLA

This strategy encompasses both the ongoing needs and the vision of future requirements for marine Aids to Navigation to the year 2020. The document will be subject to 5-yearly reviews to ensure advances in technology, both onboard and ashore, regulatory changes and training standards are taken into account.

The document contains:

- background information and regulatory context
- description of systems used and assessment (strategy) for future operation
- description of means to achieve the strategy
- Conclusions
- list of Aids of Navigation provided by GLA
- system timelines 2003 - 2019

E.3.4 USA

Vulnerability Assessment of the Transportation Infrastructure relying on the Global Positioning System – Final Report, John A. Volpe National Transportation Systems Center, 29.8.2001

The Volpe National Transportation Systems Center (RSPA/Volpe Center) conducted a vulnerability analysis of GPS and identified the potential impact to aviation, maritime, transportation, railroads, and Intelligent Transportation Systems (ITS). The final report, Vulnerability Assessment of the Transportation Infrastructure Relying on the Global Positioning System was published on August 29, 2001. This study contained a series of recommendations, which were reviewed and ultimately accepted by the Department's operating agencies. Recommendation sets were made relative to: overarching issues related to GPS vulnerabilities, mitigating the vulnerabilities of the GPS signal to disruption or loss, and mitigating the vulnerabilities of the transportation systems resulting from the disruption or loss of the GPS signal.

The report contains:

- background information on the report
- description of GPS use within the various modes of transport
- assessment of GPS vulnerabilities

- mitigation strategies
- assessments of transport infrastructure vulnerabilities
- transport infrastructure risk mitigation strategies
- findings and recommendations.

Radionavigation Systems: A Capabilities Investment Strategy - A Report to the Secretary of Transportation, Radionavigation Systems Task Force, January 2004

The Radionavigation Capabilities Assessment Task Force was established to develop a multi-modal capabilities assessment and recommend to the Secretary a Radionavigation investment strategy that will meet the national transportation requirements in the USA. That assessment and recommendation are documented in the report.

The report contains:

- background information on the report
- current situation of Radionavigation planning
- modal requirements and system capability assessments
- methodology of analysing the system-mixes
- back-up options to GPS
- system mix analysis
- various options for future Loran-C use
- cost scenarios
- conclusions

E.4 National Policies

E.4.1 Germany

The following figure provides an overview on the national system planning in Germany:

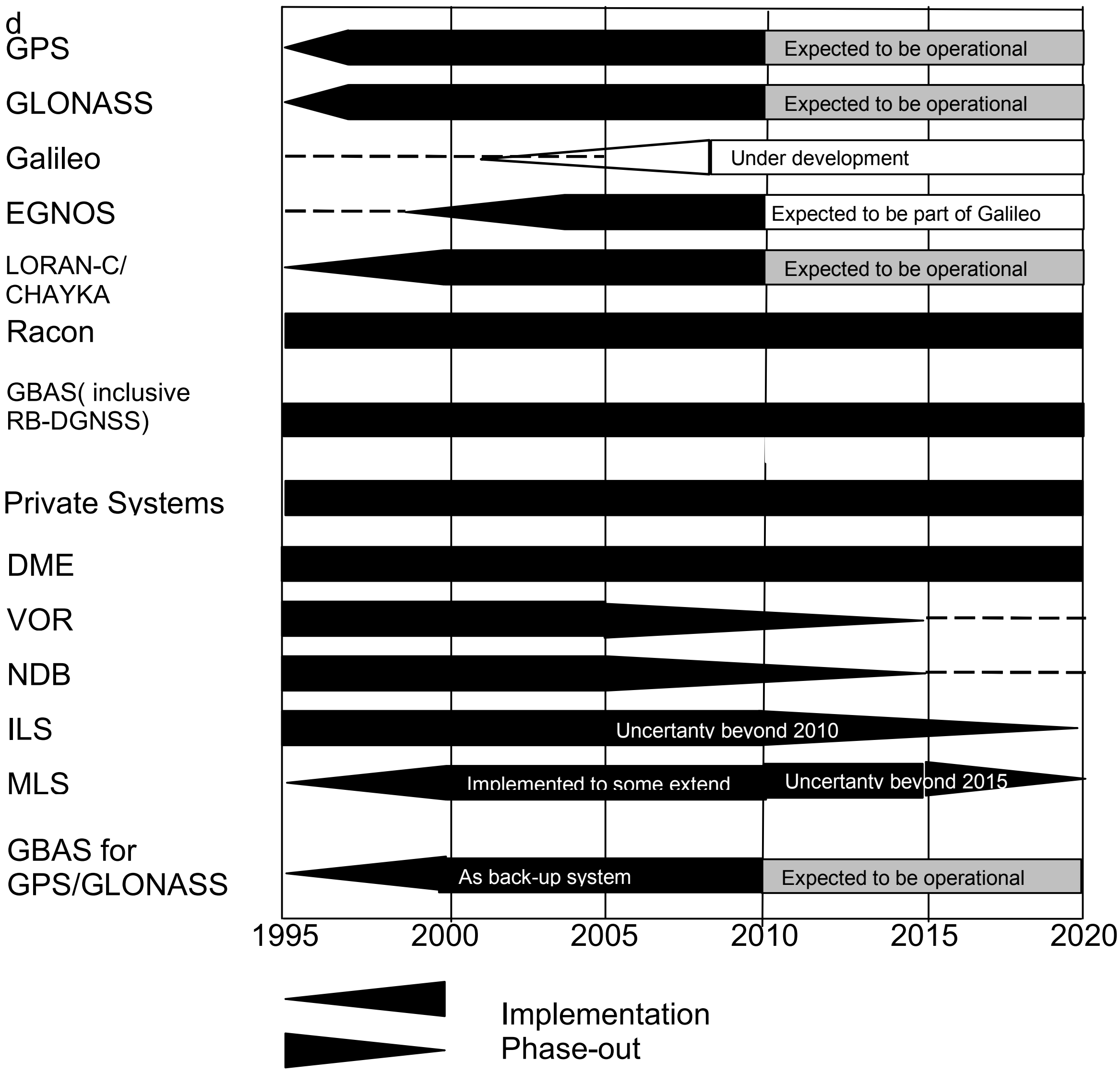

Figure 6 – System planning overview - Germany

The current status and future planning on system level is the following:

System	Status	Planning
LORAN-C	One station operated in Germany (Sylt). Few national users but increasing interest by various potential users in recent years Validation of Loran-C/Eurofix for various applications in different European countries was completed with positive results.	The future operation of the German Loran-C station has to be decided within the context of the future development of NELS and the ongoing development sin the USA. A decision is expected for mid 2004. Germany intends to withdraw from the NELS agreement and continue the operation of the Loran-C

System	Status	Planning
		infrastructure as private business.
NDB	107 national NDBs High number of users	Reduction of NDB operations after individual evaluation since 2003
(D)VOR / DME	24 VORs, 40 DVORs and 76 DMEs High number of users	Operation till 2005
ILS	90 ILS (27 for CAT II/III) High number of users	Phase out for ILS CAT I not before 2005, for ILS CAT II/III ILS not before 2010
MLS	None No operational users	At the moment no MLS planned
TACAN	32 TACAN High number of users	Operation till 2010
DGPS	Various national DGPS services [1] High number of users	Extension of reference stations
EUROFIX	Broadcasted by the Loran-C station in Sylt	
GLONASS	Few users	
Positioning technologies based on wireless communication networks	Basic technologies (e.g. cell ID) are implemented, enhanced technologies (e.g. A-GPS) are under evaluation	Increase expected

Table 1 – System planning – Germany [2]

Beyond the information given in the figure and table above following statements are given by the DFNP:

- the current systems are (in general) designed and used for a dedicated user group and do not support multi-modal use.

1 See chapter ???

2 Modified table (focus on national status and planning)

- GNSS is vulnerable to jamming, spoofing, and other interferences (sun activity, multi-path, etc.). For that reason appropriate back-up- and complementary systems and sensors are required and have to be combined with GNSS.
- GNSS services have to be protected against intentional and unintentional disturbance and non-authorised use.
- Loran-C is operated and controlled by civil authorities and has the potential to raise interest of new users. The integration of Eurofix and EGNOS is objective of ongoing EC and ESA activities.
- Systems for aviation use like NDB, (D)VOR / DME, and ILS will be continued, at least for the mid term future (2010), but it is expected that with the ongoing GNSS activities the need for those systems will be reduced. On European level DME is the basis system for area navigation and therefore a terrestrial back-up system to GNSS.
- MLS is considered to replace ILS only on sites where ILS cannot be continued (e.g. due to interferences) and GBAS will not yet be available.
- In recent years various positioning technologies based on wireless communication networks have been developed and (to some extend) implemented. The ongoing development in the USA (E911) and Europe (LBS, E112) are expected to foster these developments in the upcoming years.
- Today GNSS is the basic system for many applications, but has to be augmented by complementary systems and sensors in the future. Especially terrestrial systems are considered to be appropriate augmentations to GNSS. Both GNSS available today are controlled by national military and (primarily) designed for military applications. At the moment GPS as well as GLONASS can be used free-of-charge for civil purposes, but both systems are not able to fulfil the requirements for many safety and security related applications in terms of accuracy, integrity, continuity, and operational guarantees. For that reasons the German government supports the Galileo activities of the EC and ESA by provision of budget and participation in dedicated working groups.

Concerning the future combination of systems the DFNP provides following information:

- A system-mix of complementary systems could enhance the performance achieved by single systems. Due to the fact that GNSS provides the highest potential for future use, the focus will be put on system-mixes including GNSS:
    - The combination of GPS and GLONASS is (from a technical point of view) state-of-the-art today, but the number of users is limited, because full advantage of this combination can only be gained if the GLONASS space segment is employed to a larger extend than today.
    - Software for the combination of GNSS and Loran-C is available. The benefits of a combined GNSS and Loran-C solution have been demonstrated in recent years by various trials.
    - Detailed information on the combination of GNSS and positioning technologies based on wireless communication networks is not yet available. For that reason this system-mix is not discussed in more detail by the DFNP.

Due to the variety of different national DGPS services a need to harmonise future activities in this domain has been identified by the DFNP. Following options have been identified for future harmonisation between service providers (public and commercial):

- Jointly operation of reference stations
- Harmonisation of extension-strategies
- Exchange of data collected
- Joint activities in the domains of development of decoders
- Extension of coverage.

E.4.2 Ireland

The views expressed on the consultation paper can be divided into two areas:

- One area is the marine users who avail of radio navigation in their day-to-day business, for the purpose of navigation and position fixing. This group, in general, seem to be happy enough with the systems available at present. The overall impression is that the users have an acceptable system i.e. GPS, which performs adequately in terms of accuracy, reliability, and availability. It is easy to use and cost-effective. Although concern is expressed in relation to the U.S. military control of GPS, and the obvious advantage of not relying on a sole means of radio navigation, it is unlikely that these users would be prepared to use a new system, or invest in new equipment, until that system is up and running, and has been proven to offer the same level of performance to that which is available at present. There would seem to be little faith in Loran-C, as by comparison with GPS. Loran-C is seen as technology.

- A small number of other users expressed a view including the Commissioners of Irish Lights (CIL) and some equipment suppliers that sole reliance is a major concern and that there is a tendency to view Galileo as a completely different system to GPS. Galileo as a satellite system would be prone to the same disadvantages. With Loran-C being a terrestrial system, when used as a backup to a satellite system, a problem associated with one is unlikely to affect the other. It has been stated that Loran-C is the only system available, albeit with limited coverage at present, which "can mitigate against the vulnerability of satellite-based systems". According to CIL, compared with satellites, a Loran-C station is inexpensive to install, operate and maintain.

Across all sections, it is widely agreed that Ireland requires a maritime radio navigation policy but that this should be an integrated policy for all modes of transport, as well as timing. The majority believe that we should wait until the EU adopts a European Radio Navigation Plan but that we can contribute to that plan as it is being developed.

E.4.3 Sweden

In Aviation the requirements are fulfilled by use of ground-based facilities (e.g. VOR, DME, NDB and, for landing, ILS) and use of inertial navigation (INS). The transition to Area Navigation has facilitated considerably increased flexibility in the use of available airspace. In order to reduce the need for the costly ground-based structure, the aim is, in accordance with international agreements, to replace this with augmentation for GNSS (DGPS using type certified equipment) and use of ADS-B. Extensive testing, and further development, based on use of GPS transponders for applications in airspace and for ground movement control, is carried out by SCAA in co-operation with the industry and airlines, including SAS. Other European countries participate in the project and the introduction of transponders together with GNSS is expected to facilitate future air traffic control and make it more efficient.

In Sweden a net of Marine Radio Beacon reference stations have been operational since 1996. The system is operated and monitored by the Swedish Maritime Administration and financed by ordinary shipping fees. Thus there are no direct user fees. The system has been developed in accordance with the recommendations from IALA and in close cooperation with the Nordic countries. Within a densification programme the maritime reference net has recently been expanded into ten stations. The goal that all surrounding waters should be covered by signals with a signal strength of at least 50 uV/m from at least two radio beacons is almost obtained. This system now covers all areas of Swedish waters with high accuracy (1-2 m). Together with use of radar, Racons and GNSS transponders in AIS applications the Marine Radio Beacon system will satisfy all the requirements for marine navigation in Swedish and adjacent waters.

To improve the accuracy received from GPS in land applications in Sweden a network of permanent reference GPS stations, SWEPOS, was established during the nineties. SWEPOS is developed, operated and monitored by Lantmäteriet. All SWEPOS services are based on subscription and user fees covering parts of the operation costs of the system. The network covers the main parts of the Swedish in-land and coastal areas. During 2000-2003 a number of additional SWEPOS stations have been established for regional positioning services with centimetre level accuracy. In co-operation with groups of users, SWEPOS provides a regional positioning service in the Stockholm area and in the Southern and Western parts of Sweden (September 2003).

A nation-wide database containing up-to-date, quality-assured information on the entire Swedish road network, NVDB (the Swedish National Road Database) is now available in a first version. NVDB is managed by the Swedish National Road Administration, Lantmäteriet, the Swedish Association of Local Authorities and the forest industry. In combination with other databases it can be used in car navigation systems as well as for planning of road transports etc.

E.4.4 Switzerland

The mix of complementary systems and sensors used today for land transport systems is expected to be still used in the future, because the single systems will not provide sufficient accuracy and availability. The integration of Loran-C into such systems is expected to provide benefits and should be fostered in the future. The activities to develop and implement Galileo should be supported, too; because civil system control and service guarantees are important qualities safety and security related, as well as for commercial applications.

In aviation positioning and navigation is to a large extend based on terrestrial Radionavigation systems at the moment, but it is conceivable that some requirements could be fulfilled by GNSS in the future and air traffic costs could be reduced. This migration is a long process and the current terrestrial infrastructure will be operated for that period. The future developments have to be considered under the aspects related to integrated systems and the requirements of different user communities within the aviation sector.

For some maritime applications, e.g. automatic docking, the systems currently available are not sufficient. Enhancements in terms of accuracy, integrity, and availability are necessary, as well as the integration of navigation and communication (e.g. ECDIS updates, SAR, etc.) and the permanent availability of a redundant system. From today's perspective the use of Loran-C and Eurofix should be extended.

In the domain of surveying a combination of conventional methods (tachymetry, levelling) with GNSS is state-of-the-art today. The extent of using GNSS for a dedicated application is determined by spatial and timely availability of GNSS and economic calculations. Strategic planning of the Swiss surveying administration is related to the operation of national reference systems (LV 95), GPS reference networks (AGNES) and DGPS services (swipos).

E.4.5 UK

"The Marine Navigation Plan to 2015" was published in 1997 and is now superseded by the "2020 The Vision – Marine Aids to Navigation Strategy". In drafting this future strategy the three GLAs have concluded that the current level of service - in visual, radar and radio aids to navigation - is unlikely to significantly change, to any great degree, for the foreseeable future.

User consultation has clearly indicated that position fixing using GNSS is prevalent and that radar and visual aids are seen as the terrestrial back-up to satellite systems. This back-up role has been further emphasised by the known vulnerability of GNSS and the ease with which signals can be subject to interference from jamming, spoofing or natural influences.

In view of the forgoing it is unlikely that the level of service can change, unless:

- Loran-C is adopted as the terrestrial back-up to GNSS in Europe and integrated receivers (GPS/Galileo/Loran/DGNSS) are mandated for carriage by all SOLAS Convention Vessels.
- Automatic Identification System (AIS) Data is mandated to be displayed on all SOLAS ships over 300gt in a manner that facilitates the use of synthetic and virtual aids to navigation.
- A Network of AIS base stations around our coast facilitates stakeholders, such as us, having the coverage area to implement AIS as an aid to navigation, as an emergency wreck marking system, as well as providing traffic data which will form an important part of the risk management process that determines the deployment of aids as risk control measures.
- The introduction of routeing measures that direct traffic in high density and high-risk areas becomes possible. Leading to a measure of 'sea traffic control' and changes in the provision of aids to navigation and Vessel Traffic Services (VTS) accordingly.
- The regulation of vessels below 300gt, including fishing and leisure craft leads to mandatory carriage of position fixing receivers, of the integrated type described above, making possible rationalisation of fixed and floating aids to navigation in confined and shallow waters.
- The mandatory licensing of all leisure craft with compulsory training of their owners/operators, similar to that required of all light aircraft pilots and road users.

The developments described above, if realised, will individually or collectively influence the provision of all aids to navigation and the level of service we provide to deliver a reliable, efficient and cost effective Aids to Navigation Service for the benefit and safety of all mariners.

The GLAs will continue to provide Aids to Navigation (AtoN) for the safety of all mariners and in doing so seek to:

- regulate standards in the provision of AtoN in general and local areas
- avoid proliferation of marine radionavigation systems and interference among radionavigation systems generally
- exercise their wreck powers to ensure the safety of navigation, in a way which is consistent with preservation of the environment
- advocate proper standards of training and competence in the use of existing and new AtoN.

E.4.6 USA

E.4.6.1 Policy described by the Federal Radionavigation Plan[3]:

The US policy on Radionavigation, as defined by the current issue of the FRP (2001) is the following:

- The Federal Government operates radionavigation systems as one of the necessary elements to enable safe transportation and encourage commerce within the United States. It is a goal of the Government to provide this service in a cost-effective manner. As the full civil potential of GPS and its augmentations is realized, the service provided by other Federally provided radionavigation systems is expected to decrease to match the reduction in demand for those services. However, operational or safety considerations may dictate the need for complementary navigation systems to support navigation or conduct certain operations. While some operations may be conducted safely using a single radionavigation system, it is Federal policy to provide redundant radionavigation service where required. A major goal for the U.S. Government is to select a mix of common-use civil/military radionavigation systems that meets diverse user requirements. When the benefits, including the safety benefits, derived by the users of a service drop below the cost of providing that service, the Federal Government will no longer continue to provide that service. A suitable transition period will be established based on safety, user equipment availability, radio spectrum transition issues, cost and acceptance, budgetary considerations, and the public interest. International commitments dictate certain levels and types of navigation services to ensure interoperability with international users. Although radionavigation systems are established primarily for safety of transportation and national defense, they also provide significant benefits to other civil, commercial, and scientific users. In recognition of this, the Federal government will consider the needs of the users before making any changes to the operation of radionavigation systems. Radionavigation systems operated by the U.S. Government are available as directed by the National Command Authority (NCA) in the event of war or threat to national security. Operating agencies may cease operations or change characteristics and signal formats of radionavigation systems during a dire national emergency. All communication links, including those used to transmit differential GPS corrections and other GPS augmentations, are also subject to the direction of the NCA.

The policies for the future operation of the different systems are the following:

- GPS: The U.S. Government has determined that two additional coded signals are essential for certain uses of GPS. A second civil signal will be added at the GPS L2 Frequency (1227.60 MHz). A third civil signal that can meet the needs of critical safety-of-life applications such as civil aviation will be added at 1176.45 MHz. The third civil signal frequency is designated as L5. GPS will be the primary Federally provided radionavigation system for the foreseeable future. GPS will be augmented to satisfy civil requirements for accuracy, coverage, availability, continuity, and integrity.

- Loran-C: The Government will continue to operate the Loran-C system in the short term while the Administration evaluates the long-term need for the system. The U.S. Government will give users reasonable notice if it concludes that Loran-C is not needed or is not cost effective, so that users will have the opportunity to transition to alternative navigation aids.

3 Federal Radionavigation Plan, DoD and DoT, 2001

- VOR/DME: VOR/DME will continue to provide navigation services for en route through nonprecision approach phases of flight throughout the transition to satellite-based navigation. The FAA plans to reduce VOR/DME services provided in the NAS based on the anticipated decrease in use of VOR/DME for en route navigation and instrument approaches.
- TACAN: The DoD requirement and use of land-based TACAN will continue until aircraft are properly integrated with GPS and GPS is approved for all operations in national and international controlled airspace.
- Precision Approach Systems: The Instrument Landing System (ILS) is the predominant system supporting precision approaches in the U.S. With the advent of GPS-based precision approach systems, the role of ILS will be reduced. ILS may continue to be used to provide precision approach service at major terminals. The FAA has terminated the development of the Microwave Landing System (MLS) based on favorable GPS test results. The U.S. does not anticipate installing additional MLS equipment in the NAS.
- NDB: Most NDBs will be phased out.

The following figure shows the current system operation plan of the USA:

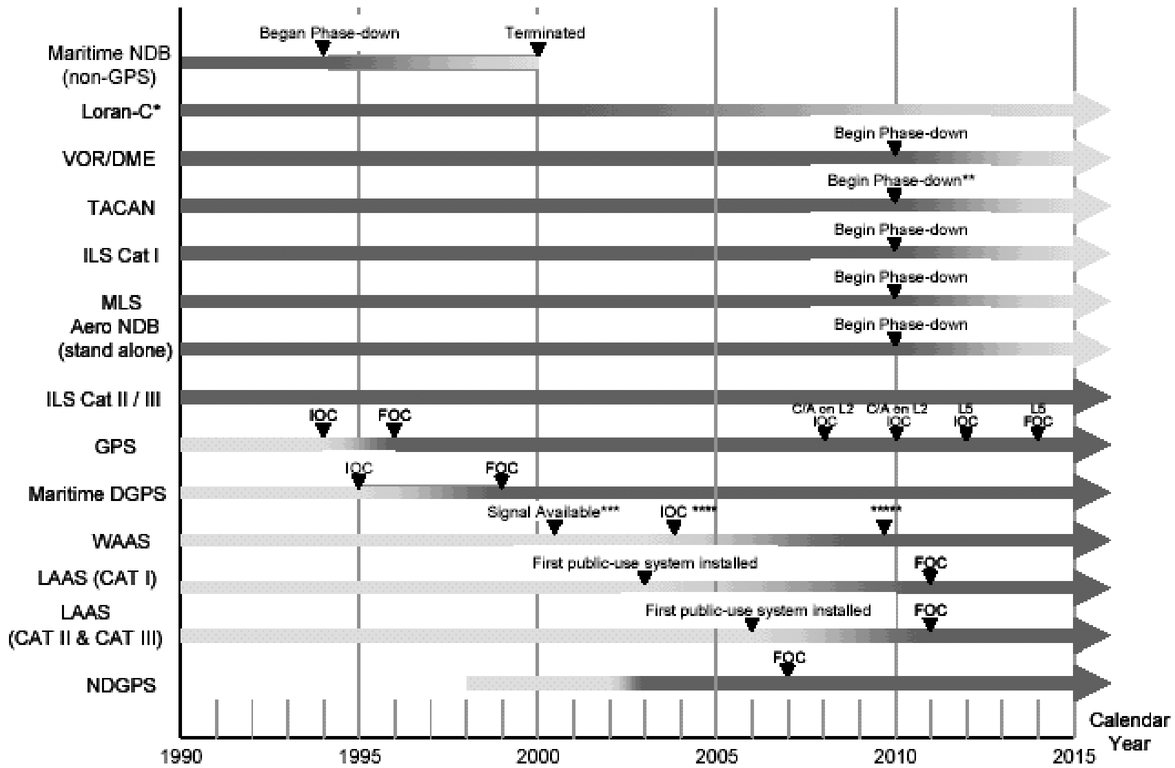

Figure 7 – System planning overview - USA

E.4.6.2 Findings of the Volpe-Report [4]:

To mitigate the vulnerability risks, caused by using GNSS for safety critical infrastructure the Volpe-Report made the following recommendations in terms of:

- Overarching issues related to GPS vulnerability
  - Public policy must ensure, primarily, that safety is maintained even in the event of loss of GPS. This may not necessarily require a backup navigation system for every application. Of secondary but immediate importance is the need to blunt adverse environmental or economic impacts. The focus should not be on determining the nature of the backup systems and procedures, but on which critical applications require protection.
  - Because requiring a GPS backup will involve considerable government and user expense, it is recommended that the transportation community determine the level of risk each critical application is exposed to, what level of risk each application can accept, the costs associated with lowering the risk to this level, and how such costs are to be funded.
- Mitigating the vulnerabilities of the GPS signal to disruption of loss
  - Continuation of on-going GPS modernization programs involving higher GPS broadcast signal power and the eventual availability of three civil frequencies should be encouraged.
  - The Federal Communications Commission (FCC), FAA Office of Spectrum Policy and Management, National Telecommunications and Information Administration (NTIA), the Departments of State and Defense, and other agencies should continue to vigorously support and protect the spectrum for GPS and its applications.
  - GPS receivers involved in critical maritime and surface applications should be certified by the appropriate regulatory authorities. These authorities should recommend receiver performance standards for non-critical applications.
  - Efforts must be taken to create and heighten awareness among the aviation, maritime, and surface user communities of the need for mitigation to degradation or loss of the GPS signal through unintended interference from such sources as VHF signals, mobile satellite services, ultra wideband communications, and broadcast television.
  - Systems and procedures to monitor, report, and locate unintentional interference should be implemented or utilized in any application for which loss of GPS is not tolerable. Mitigation of signal blockage impacts should be addressed as much as possible in the GPS application system design process. RFI incidents that affect critical transportation applications should be reported to users as potential hazards to navigation, and users need to be trained in recognizing degradation or loss of the GPS signal, how to switch to an alternate navigation system or procedure if called for, and how to switch back to GPS when it recovers performance.
- Intentional disruption

4 Vulnerability Assessment of the Transportation Infrastructure relying on the Global Positioning System – Final Report, John A. Volpe National Transportation Systems Center, 29.8.2001

- Continuing assessments should be made of the applicability of military anti-jam technology, including receiver and antennas, to the civil sector. U.S. government agencies should be encouraged to identify the more promising anti-jam technologies, and to work with industry to make them affordable and suitable for civilian applications.
- The DOT should coordinate with the DoD to ensure that appropriate anti-spoofing technologies are available to civilian applications, should the need arise. It is important to identify observables that may indicate spoofing in civil safety-critical receivers. In addition, DOT should develop independent information to determine the validity and extent of possible civil spoofing threats.
- Within the limits of security requirements, the civil sector transportation community should be apprised of on-going threats and take effective countermeasures to those threats. Civil users should be encouraged to report GPS outages.

- Mitigating the vulnerabilities of the transportation system to loss or degradation of the GPS signal
    - Create awareness among members of the domestic and global transportation community of the need for GPS backup systems or operational procedures, and of the need for operator and user training in transitions from primary to backup systems, and in incident reporting, so that safety can be maintained in the event of loss of GPS, in applications that cannot tolerate that loss.
    - Encourage all the transportation modes to give attention to autonomous integrity monitoring of GPS signals, as is being done in the aviation and maritime modes (Receiver Autonomous Integrity Monitoring, RAIM).
    - In an effort to provide the greatest benefit to the users, encourage the development of affordable vehicle-based backups such as GPS/inertial receivers, and, in the event Loran-C becomes a viable backup to GPS, aviation certifiable Loran-C receivers, and GPS/Loran-C receivers. All GPS receivers in critical applications must provide a timely warning when GPS positioning and timing signals are degraded or lost. Conditions for setting the warning indicator in the receiver, and for displaying it to users, should be standardized within each mode.
    - Conduct a comprehensive analysis of GPS backup navigation and precise timing options including VOR/DME, ILS, Loran-C, inertial navigation systems, and operating procedures. Consideration must be given to: (1) the cost of equipage for both general and commercial users -- national and international in aviation uses; (2) navigation and precision timing system capital and operating costs; and (3) operating procedures and training costs associated with the need for situation awareness when the GPS signals are degraded or lost.
    - Continue the Loran-C modernization program of the FAA and USCG, until it is determined whether Loran-C has a role as a GPS backup system. If it is determined that Loran-C has a role in the future navigation mix, DOT should promptly announce this to encourage the electronics manufacturing community to develop new Loran-C technologies.
    - DOT should take an active role in developing a roadmap for the future navigation infrastructure that will be stated clearly in the Federal Radionavigation Plan, and will be followed by the DOT modes and navigation user communities in their navigation activities.

E.4.6.3 Policy described by the Federal Radionavigation Plan[5]

Based on the Volpe-Report the Radionavigation Systems Task Force analysed four potential system mixes[6] to overcome vulnerability issues and provided the following conclusions and recommendations:

Conclusions

- Some radionavigation systems (e.g., VOR) are mode specific and cannot serve other modes.
- Today, adequate backups exist to protect current transportation and positioning requirements and applications. However, the situation for timing applications is lessclear.
- In the future, as requirements and applications continue to evolve, each operating administration must ensure that adequate backups remain available. Cross-modal radionavigation systems must likewise be carefully coordinated.
- The evaluation of enhanced Loran needs to be completed before making a firm commitment to that system. Termination of Loran would eliminate the only available cross-modal radionavigation backup to GPS.
- The current collocation and synergy of NDGPS with CORS, MDGPS, & GSOS has already avoided significant capital construction costs.
- The collocation of WAAS, NDGPS, and Loran facilities should be explored in conjunction with any future expansions of those systems.
- Further collocation of existing systems is not cost effective at this time because only a few new WAAS sites in Alaska are available for collocation with NDGPS.
- When investing in a major recapitalization of a radionavigation system, the Department needs to examine the multi-modal utility of the system, and the potential to combine facilities, before making a decision on the investment.
- Although WAAS could satisfy some land and maritime requirements, it is not designed for that purpose. Completing the NDGPS network as planned is a more practical option from a cost perspective than attempting to enhance WAAS to meet all the requirements of maritime and land transportation users or, likewise, attempting to enhance NDGPS to meet aviation requirements.
- The final four radionavigation mixes satisfy current user needs for primary and backup systems. However, not all four alternative mixes address potential future requirements.
- Although R&D systems were not considered in the final evaluation, they would need to be considered in future evaluations once they are out of R&D.

5 Federal Radionavigation Plan, DoD and DoT, 2001

6 1. Baseline option, 2. Discontinue Loran-C, 3. Collocation with Loran-C, 4. Collocation without Loran-C

Recommendations:

- As investment decisions are made regarding individual radionavigation systems, the Department should review the overall radionavigation system program strategy to ensure these systems meet the positioning, navigation, and timing requirements across the entire transportation infrastructure in the most cost-effective and efficient manner.
- The current role of the Department's Investment Review Board (IRB) should be broadened to serve this function for radionavigation system programs. This would additionally require expanding the membership of the IRB to include the Under Secretary of Transportation for Policy as a voting member.
- GPS modernization, to include the implementation of the second and third civil signals, should proceed as expeditiously as feasible in order to meet a multitude of civil applications and safety-of-life missions that are critical to our transportation infrastructure.
- Every effort should be made to meet, and accelerate if possible, the operational implementation schedule for these new GPS capabilities.
- Complete the evaluation of enhanced Loran to validate the expectation that it will provide the performance to support aviation NPA and maritime HEA operations.
- If enhanced Loran meets the NPA and HEA performance criteria, and is cost effective across multiple modes, the Federal Government should operate Loran as an element of the long-term US radionavigation system mix.
- If enhanced Loran does not meet expected performance criteria, or is not cost effective across multiple modes, the Federal Government should operate the system only to the end of 2008 to allow users sufficient time to transition to alternate navigation aids.
- Complete three additional radionavigation system studies, in addition to the enhanced Loran evaluation, as follows:
- The USCG will, in cooperation with the FAA, assess the ability of the Wide Area Augmentation System (WAAS) to meet marine requirements.
- The FHWA will, in cooperation with the FRA and the USCG, assess the ability of the High Accuracy Nationwide Differential Global Positioning System (HANDGPS) to meet surface (i.e. highway, rail, and marine) requirements.
- The FAA will assess the ability of the Local Area Augmentation System (LAAS) to meet precision approach requirements for aviation.
- The collocation of WAAS, NDGPS, and Loran facilities should be explored in conjunction with any future expansions of those systems.
- Based on the need to pursue synergism, cooperation, and collocation in future radionavigation systems, the Task Force recommends as a radionavigation mix either Option 3, 'Collocation with Loran', or Option 4, 'Collocation without Loran', contingent on the results of the enhanced Loran evaluation and benefitcost analysis.
- Explore funding strategies to ensure that NDGPS is implemented in accordance with the schedule presented in the 2001 FRP.

- As requirements and applications continue to evolve, the potential for various radionavigation systems to contribute to the overall radionavigation mix should be periodically evaluated.

E.4.7 Eurocontrol Navigation Strategy for ECAC

The policy of Eurocontrol on the future use of Radionavigation systems in the aviation sector till 2014 as described in the "Navigation Strategy for ECAC2 document"[7] is the following:

1. The growth in air transport seen in the last two decades, and the forecasts indicating that air traffic movements in Europe will more than double by 2015, compared with those for 1997, maintain a continued pressure to upgrade the capacity of the overall European ATM system, to alleviate congestion and delays.

2. The existing Air Navigation System and its sub-systems suffer from shortcomings in technical, operational and economic aspects. Despite the success of EUROCONTROL EATCHIP, and the measures already in hand to provide further improvements, the current system is unlikely to be able to cope with traffic increases of the predicted magnitude. New advanced systems and concepts can offer potential improvements in terms of safety, efficiency and/or economy of flight, provided that their implementation is based on a fully co-ordinated, harmonised, evolutionary and flexible planning process.

3. This Navigation Strategy has been developed to answer to this need. The users requirements have been the main driver in its development. The main objective of this Air Navigation Strategy is to provide a harmonised and integrated common framework which will allow a cost-effective, customer oriented evolution of the European Air Navigation Systems during the period 2000-2015. The evolution of the air navigation systems is described in terms of performance, functionality and corresponding infrastructure, taking due account of the principle of global interoperability.

4. The Navigation Strategy supports the operational developments proposed by the ATM 2000+ Strategy towards the implementation of a uniform European Air Traffic Management system. It is in line with the implementation of the ICAO Global Air Navigation Plan for CNS/ATM systems in ECAC.

5. The time horizon of this Navigation Strategy is split into three phases: short-term (2000-2005), medium-term (2005-2010) and long-term (2010-2015 and beyond), and it is in line with other EUROCONTROL strategies.

6. The main strategic streams described in this Navigation Strategy are aimed at:

    - achieving a total RNAV environment with defined RNP values for all operations ECAC-wide;

    - facilitating the implementation of the 'free routes' concept;

    - supporting the continued operations of aircraft with lower capabilities as long as operationally feasible;

    - implementing 4D RNAV operations, to support the transition to a full gate to gate management of flight by 2015 ;

    - supporting the continued operations of State aircraft, in line with the principles of the overall ATM 2000+ Strategy;

7 Navigation Strategy for ECAC, NAV.ET1.ST16-001, Edition 2.1, Eurocontrol, 1999

- providing positioning and navigation data at the required performance levels to support the various applications in the ATM/CNS environment.

- a judicious deployment of the space-based infrastructure and a rationalisation of supporting ground-based infrastructure for all phases of flight, ensuring the transition to GNSS, in line with ICAO recommendations.

7. Advances in Navigation functionality will enable improvements in airspace design (structure, sectorisation, associated route network, applicable route spacing, separation minima and responsibilities, etc.), and will allow for a high degree of flexibility for aircraft operations and for the navigational equipment used. Ultimately, all these elements, together with appropriate ATM tools will enable operators to conduct their flights in accordance with their preferred trajectories, dynamically adjusted, in an optimum and cost-efficient manner.

8. This Navigation Strategy recognises the emergence of satellite technology and its future role in the global navigation environment. However, it is expected (based on current knowledge) that the rate of technological development of the system and the time needed for the resolution of institutional limitations will result in the need for a ground-based back-up system for GNSS for the foreseeable future for all phases of flight.

9. The feasibility of some options is still surrounded by many uncertainties and requires additional study (safety, R&D, CBA). Since all phases of flight are interrelated, constraints solved in one phase will not necessarily deliver the entire expected benefits, because of unsolved (or newly-generated) constraints for the other phases. CBAs will help to avoid the development of purely technology-driven solutions.

10. This Navigation Strategy aims to achieve a harmonised evolution of the overall Navigation System. In the framework of this strategy States may give preference to one implementation option or another in order to reflect sub-regional and local differences and to provide tangible and early benefits to the users. The availability of benefits will encourage the agreement and commitment of the users to the implementation plans. Furthermore, it will help the smooth transition to new systems and will minimise the period when support of both existing and new functionality will be necessary.

The schedule for the rationalisation of ground segment is shown below:

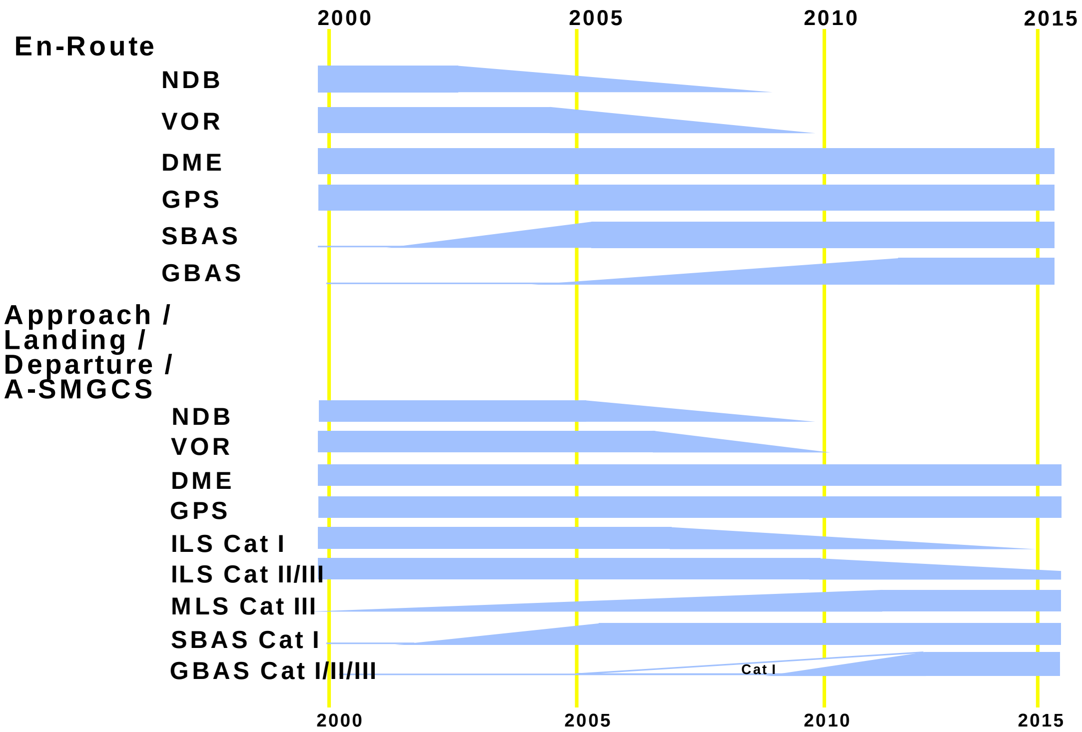

Figure 8 – Rationalisation of ground segment (ECAC)[8]

E.5 Conclusions on GPS / EGNOS policies

The overview on existing national Radionavigation Plans and policy papers, available for various states and ECAC, show that the satellite navigation and relevant augmentation systems (i.e. GPS and EGNOS) are used by many user communities within all modes of applications today.

The use of GPS/EGNOS enables a lot of users to successfully perform various applications and emerging, new and innovative fields of applications are expected to be realised in the next future by exploiting GPS/EGNOS. Nevertheless the use of GPS/EGNOS is based on the availability of GPS signals, which could be impaired by:

- processes in the ionosphere and atmosphere
- naturally and artificial obstacles (mountains, vegetation, buildings, tunnels, etc.)
- multipath effects
- unintentional interference
- intentional interference (jamming)
- intentional manipulation (spoofing)
- re-activation of artificial signal degradation (SA)
- denial of SPS to civil users in situations of crisis, war, etc. (presidential decision).

For those reasons many commercial applications as well as safety & security applications require the use of dissimilar, independent and civil back-up/complementary systems/sensors

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8 Navigation Strategy for ECAC, NAV.ET1.ST16-001, Edition 2.1, Eurocontrol, 1999 to meet the stringent user requirements. The combination of GNSS and appropriate back-up/complementary systems/sensors offer the potential to fulfil many of the requirements identified today for commercial and safety & security applications.

Some examples for candidate systems/sensors for a combined multimodal use with GNSS are:

- positioning technologies based on wireless communication systems (e.g. various types of cell ID, E-OTD, OTDOA, etc.)
- Loran-C
- sensors (magnetometers, gyroscopes, accelerometers, barometric height sensors, etc.).

F Regulatory Instruments

F.1 Introduction

F.1.1 Scope of WP 1150 Report

The present Report constitutes the sole output to be produced under WP 1150, “Summary of Regulatory Instruments”. In addition, by means of Annex A, it includes input for WP 1110, “European Radio Navigation Plan”.

The objectives of WP 1150 were defined as follows:

- To make an inventory of all regulatory instruments related to radio navigation at the international level;
- To make an inventory of all regulatory instruments related to radio navigation at the European level;
- To analyse how regulatory instruments at the national level for EU member states would fit into the international and EU legal framework;
- To summarise existing European law as to its substance and competencies; and
- To arrive at provisional conclusions on future legal and regulatory developments desirable in the framework of the EU.

The inputs to be used for that purpose were enumerated as follows:

- Relevant ITU and other high-level documents;
- Relevant EU legislation; and
- Results from other WP’s to the extent available.

Whereas the first two sets of input were readily available, so far no input from other WP’s could be used. It is submitted, however, that at present that does not constitute a major problem.

The tasks for WP 1150, and hence for the current Report, to be achieved were listed as follows:

- To summarily describe the applicable legal and regulatory framework at the international level as far as relevant for the development of an ERNP;
- To summarily describe the regulatory instruments in Europe available for the purpose of developing an ERNP; and
- To indicate essential requirements and parameters to which such an ERNP should conform from the legal and regulatory perspective.

F.1.2 Towards a European Radio-Navigation Plan (ERNP)

A plan such as the envisaged European Radio-Navigation Plan is a conglomerate of underlying assumptions (technical and otherwise) derived from external parameters including legal ones, high-level aims and objectives, general policies and particular implementation measures of such policies – some of which may be legal in nature.

The word ‘legal’ is used here in the broad sense, i.e. including:

- Fundamental parameters and measures at the national and international level (‘laws’);
- Lower-level parameters and implementing measures, which also include those by relevant national and international organisations (‘regulations’); and
- The institutional aspects, as to which entities have which authority to promulgate, implement, execute and/or enforce laws and regulations (‘competencies’).

The role of ‘the law’, in consequence, in the formulation of any plan such as an ERNP, is essentially of a twofold nature:

1. On the one hand, existing laws, regulations and competencies provide parameters to the development of any ERNP. Certain options or elements of such a plan which might be considered feasible or even desirable from technical, operational, economic, social or political perspectives may be either outright prohibited, or conditioned to such an extent that they do not in the end represent viable options. Other options or elements, by contrast, may be slightly or hugely favoured, or even be made mandatory by existing law.
2. On the other hand, one category of instruments to implement any ERNP in the abstract would consist of future laws, regulations and competencies, alternatively of future amendments to existing ones. Ultimately it is a policy choice whether in the implementation of a particular element or aspect of an ERNP a legal/regulatory instrument (as opposed to a policy, budgetary or political instrument) will be used, either exclusively or in conjunction with other instruments; nevertheless, in some cases respectively for some aspects the use of a legal instrument would seem unavoidable or at least preferable for reasons of transparency and legal certainty..

The current Report aims at establishing an inventory of the regulatory instruments from the perspective of using them in the *future* for establishment and implementation of an ERNP. For reasons of European focus and in view of scope and size, the Report will concentrate specifically on *European* legislative and regulatory options. At the same time, in view of the aforementioned double role of law *vis-à-vis* policy and planning and the linkage between these two roles, the point of departure for analysis will be the current regulatory parameters as provided by the *existing* legal environment.

F.1.3 The ERNP and legal/regulatory parameters and instruments

The high-level aims and objectives of an ERNP are the following:[9]

- Establishing EU policies for European radio-navigation systems;
- Providing plans at a more detailed level for the operation and cost recovery of radio-navigation systems;
- Providing rationalisation plans for withdrawing such systems;
- Guidance to users with respect to system/service certification and system selection; and
- Summarising civil user requirements and system descriptions.

9. Cf. Project Plan – Development of the European Radio-Navigation Plan (ERNP), P377D03-1.0, of 8 January 2004, p. 3.

The underlying aim of an ERNP may thus be circumscribed as: the establishment of an optimum environment for radio-navigation in Europe, in view of existing parameters such as technical/operational and economic ones, and in particular for private involvement in radio-navigation services and related activities, preferably in the context of the EU Internal Market. "Optimum environment" in this context moreover means an environment with maximised benefits that should ultimately accrue to consumers, producers and service providers, governments and the public at large in Europe. In short: the ERNP itself focuses on optimising the environment for the provision of radio navigation services.

In view of the relative novelty of radio-navigation as a legal issue, however, the current legal environment does not deal with it in any comprehensive fashion. The aspects of radio-navigation effectively targeted by the envisaged ERNP would as a consequence essentially be twofold as far as the current legal regime(s) would more or less directly impact upon the development of an ERNP.

1. On the one hand, the elements of the ERNP dealing with *technical and operational aspects* turn out to be important here. Taking into account existing operators of radio-navigation or similar systems and providers of radio-navigation services, as well as existing and to-be-expected technologies, the ERNP should therefore indicate policies and measures to optimise the European radio-navigation environment in technical and operational terms. From a legal/regulatory perspective this means the ERNP inevitably will have to deal with radio frequencies, and to the extent satellites are operating or envisaged as part of a radio-navigation system, also orbital slots (in the case of the geo-stationary orbit) respectively orbits.

2. On the other hand, there is an inherent focus of the ERNP on the users and the applications these may be interested in, that is important here. Taking into account existing and soon-to-be-expected uses and users, the ERNP should indicate policies and measures that would maximise the opportunities for users in Europe to benefit from radio-navigation and broaden its usage also in terms of new applications. From a legal/regulatory perspective this means the ERNP will have to take into account that most user sectors – aviation, maritime transport, rail and road transport – have their own, sector-specific legal and regulatory regime.

It is with this twofold approach to a European Radio-Navigation Plan in mind that the current Report sets out to make an inventory of relevant legal, regulatory and competency-related instruments.

F.2 Radio-navigation, telecommunications and the law

F.2.1 Introduction

Radio-navigation as an object for legal and regulatory action outside the aviation field and (to some extent) the maritime transport sector (about which more later) presents a relatively new phenomenon. In terms of parameters for an ERNP therefore, at present there is relatively little law dedicated to this subject. Of course, at the other end that means there would, in principle, be ample room for fundamental future legislative and regulatory action as there would be no need to amend or overhaul extended and comprehensive legal regimes.

Another consequence of the general lack of dedicated existing law for radio-navigation however is that one has to look for legal parameters elsewhere which, though not dedicated to radio-navigation, do or may exercise an impact, often indirectly, 'by default'. Since radio-navigation uses radio signals as a crucial element, from this perspective it forms part in particular of the larger field of telecommunications, which generally deals with the use of radio for all sorts of purposes.

Telecommunications law deals prominently with such uses of the radio frequency spectrum, as well as with certain other aspects in a fundamental sense connected to such uses, such as licensing for safety as well as economic purposes, trans-border trade of telecommunications services and (as far as satellite communications is concerned) orbital slots alternatively orbits.

In view of the inherent cross-border nature of radio-navigation as well as telecommunications in general, there are essentially three levels at which the law operates (with a view to existing parameters for an ERNP) respectively may operate (with a view to future measures implementing an ERNP): the *national level*, the *international level* and the *European level*.

Furthermore, with a view to the sector-specific usage it should be pointed out that in particular the *aviation sector*, plus to some extent the *maritime transport sector*, provide for their own legal regimes serving as parameters alternatively (possibly) providing for regulatory instruments. This issue will therefore be addressed separately from the three levels of law, even if it is cross-linked to it in many ways.

F.2.2 The national level

The most fundamental level is (still) that of individual sovereign states – the 'national level'. As states are sovereign over their own territory, they have ultimate authority to define the legal environment with respect to any telecommunications activity on that territory. National territory from this perspective encompasses the landmass, the internal waters and territorial waters of a state, as well as the airspace above all three.

Indeed, states have since many decades developed laws and regulations for telecommunications activities, and provided for competencies of national regulatory institutions to monitor, implement and enforce the resulting legal framework. Many of those states have done so, furthermore, in the context of a distinct national telecommunications policy – which, even if further elaborated for the specific field of radio-navigation by means of a national radio-navigation plan, provides the backdrop also to that field.

In spite of the large and increasing measure of internationalisation of telecommunications, including radio-navigation, in many cases parameters for, respectively possibilities of using legal instruments to develop an ERNP are still determined at the national level. In the short to medium term, no ERNP can be expected to completely replace the law at the national level, and in most cases especially for implementation and enforcement of any relevant law reference would, of necessity, have to be had to the legal regimes existing at the national level.

At the same time, in view of the scope of the current Report and the available resources, it will not be possible to deal with the substance of such national law, since at least 25 states (the current 15 EU member states plus the 10 accession countries) would be concerned. Therefore, essentially the role and place of such national law within the wider context of European legislative and regulatory initiatives will be indicated here, in order to clarify the opportunities or obstacles in a structured sense at the European level following therefrom.

F.2.3 The international level

Whilst recognising the fundamental role of national law, the fact that telecommunications (including radio-navigation) has increasingly become an area with cross-border effects has resulted in a second level of law being involved – the 'international level'. These cross-border effects are basically twofold.

1. The unintentional cross-border effects of national telecommunications activities. Radio waves do not stop at borders and may hence interfere with other states' national telecommunications activities (as well as with international ones).

2. The intentional crossing of borders by telecommunications activities – i.e. international telecommunications. Currently, telecommunications may even be called essentially a global activity.

As a consequence of the increasing internationalisation of the telecommunications sector, ever since the last decades of the 19th century at the international level a system has been developed trying to cope with those international aspects.

International treaties have been drafted, by means of which the states parties to such treaties agreed upon measures (the establishment of mutual rights and obligations) to try and curb the negative effects of (unintentional) cross-border interference and to facilitate (intentional) international telecommunications activities by trying to harmonise technical, operational and certainly also legal standards of the national states concerned.

The bottom line for all such treaties, however, as concluded and adhered to by sovereign states, is that unless specific rules provided by them prohibit or condition certain telecommunications activities or national legal measures, states maintain their discretion as to undertaking or allowing the undertaking of such activities, alternatively as to the promulgation and enforcement of such measures.

The general extent of internationalisation, even globalisation of the telecommunications sector has also led to the establishment of distinct competencies for intergovernmental organisations to further the causes of minimising harmful international interference and promoting international co-operation, harmonisation and telecommunications activities generally. Such organisations not only serve to provide a forum for states (and occasionally other stakeholders) to discuss such issues and to enhance the chances of co-operation and co-ordination, but also as a joint central body on behalf of the member states to take measures at the regulatory level – sometimes of a truly binding, mostly however of a pre-legal, not-yet-binding character.

Most notable here is the International Telecommunication Union (ITU). The ITU focuses, in regulatory terms, especially on the use of the frequency spectrum (and for satellite communications in addition on orbital slots/orbits), in addition to technical and operational harmonisation and support to developing states in the field of technical and operational developments.

Since telecommunications has increasingly become a matter of privatisation and liberalisation also the World Trade Organisation (WTO) has developed substantial regulatory and quasi-regulatory activities at the international level, obviously focusing on international trade in equipment and in services.

Finally, the World Intellectual Property Organisation (WIPO) should be mentioned, as dealing with the specific intellectual property rights-aspects of telecommunications. These will not, however, be treated any further in the present Report.

F.2.4 The European level

In Europe, in addition to the national and international levels of law, a third somewhat intermediary level of law and lawmaking has developed over the last half century in the context of the European Community. The Community (since the entry into force of the Treaty on European Union a constituent part of the European Union) represents a unique feature in more ways than one. As a supranational halfway house between an international organisation and a federation-like structure, it effectively pools together the regulatory efforts of the still-sovereign member states while establishing its own distinct legal order. Moreover, such regulatory efforts are targeted in principle at all economic activities in the widest sense of the word.

Furthermore, it may be noted that Community law (which will be analysed in somewhat greater detail further down) applies to the member states and their combined territories, in other words: to a geographical area. Thus, for the purpose of an ERNP in first instance any legal parameter or opportunity for new law within the Community essentially applies to the member states only.

Still, in certain areas such as aviation solutions have been found through which the substantive scope of regulation has been extended to specific non-EU member states, which may be helpful to keep in mind when it comes to extension of any ERNP in terms of regulation to non-EU member states. Such solutions have in particular been introduced from two angles.

- On the one hand, there was the involvement of non-EU member Norway in the Scandinavian airline company SAS, which was further part-Swedish, part-Danish, both Sweden and Denmark being EU member states, as well as, together with Switzerland, in the European Economic Area (EEA). The Norwegian and Swiss interests in becoming part of the EU Internal Market for aviation for all practical purposes led to agreements whereby the EU rules and regulations were effectively extended to these two non-EU member states.
- On the other hand, with the expected accession to the European Union of some ten Mid- and Eastern European states, the association treaties already provided for requirements for those states to bring substantive relevant parts of their national legal system to a level on a par with the level that had been reached within the European Union. Effectively that meant for those states that in many cases they accepted the acquis communautaire; i.e. the legal principles and rules developed within the European Community, without having had any say in their development up till now.

At the same time, Community law is discussed mainly in functionalist terms – do certain *activities* fall within Community jurisdiction, exclusive or not, or still within the national domain? It may be noted here, that with the success of the Community in general political terms the scope of Community law has expanded immensely, to a point where any activities with a substantial economic aspect or elements now fall within the jurisdiction of the Community.

F.3 The aviation sector

One of the transport sectors where navigation, in particular radio-navigation, has of old received most attention is the aviation sector. In view of the large orientation on safety issues, law and regulation has been developed in a rather comprehensive and thorough fashion to properly ensure that the highest safety standards are upheld. In view of the almost inherent international character of aviation, moreover, such legal and regulatory developments have to an exceptionally large extent taken place at the international and European levels.

F.3.1 The international level in aviation law

At the international level, the Chicago Convention of 1944[10] has represented the point of departure for a structured legal and regulatory system. The International Civil Aviation Organisation (ICAO) was established by the Chicago Convention, with the main part of its aims, task and objectives lying in the field of enhancing the global safety of aviation, and ICAO was endowed with a number of competencies to fulfil that role properly.

10. Convention on International Civil Aviation (hereafter Chicago Convention), Chicago, done 7 December 1944, entered into force 4 April 1947; 15 UNTS 296; TIAS 1591; Cmd. 6614; UKTS 1953 No. 8; ATS 1957 No. 5; ICAO Doc. 7300.

Furthermore, Annexes were developed to the Chicago Convention containing quite detailed Standards And Recommended Practices (SARP's), for incorporation or implementation at the national level by the member states. Contrary to what is often thought, Standards in themselves constitute binding regulation, allowing only for an opt-out possibility for individual states subject to time requirements and argumentation. Recommended Practices by contrast are indeed mere recommendations, but in many cases adhered to by the member states.

Thus, whilst national laws ultimately provide for the instruments necessary for actual implementation of rules and principles agreed upon in the context of ICAO, the discretion of individual states to undertake such implementation in any way they would like to is severely limited when it comes to safety-related legislation.

Radio-navigation being primarily a safety-issue from the aviation-perspective, this international legal framework obviously has a bearing upon the drafting and implementation of an ERNP in determining some of its parameters as far as safety issues in aviation, such as integrity, certification and standardisation, responsibility for safety and liability, would be concerned.

F.3.2 The European level in aviation law

The major flaw of the international legal framework developed in the context of the Chicago Convention and ICAO from a safety perspective is probably that, as a consequence of its global scope, it often tends to represent a lowest common denominator. In states such as the United States and regions such as Europe, this has led in the past to efforts to raise the safety standards for the relevant states and regions as much as possible beyond such global minimum standards.

Thus, in Europe a substantial 'add-on' legal framework has developed in the context of the European Civil Aviation Conference (ECAC) and, later, the distinct European Organisation for the Safety of Air Navigation, Eurocontrol[11] as well as the Joint Aviation Authorities (JAA), which are currently being transformed into a European Aviation Safety Agency (EASA).

Whilst neither Eurocontrol nor the JAA as such possess many regulatory powers (yet), over the past years the legal instruments available to the European Union have been used to ensure binding force of relevant safety standards and requirements at least within the EU member states: such standards or developments were more or less integrated into Directives.

Similarly to the situation at the international level, the legal framework for aviation existing at the European level provides some important parameters for an ERNP as far as aviation safety issues such as integrity, certification and standardisation, responsibility for safety and liability are concerned. From the other side, in view of its European character moreover the legal framework may also be used or further built upon in developing an ERNP.

F.4 The maritime transport sector

Though the maritime transport sector with little doubt constitutes the oldest sector making use of radio-navigation, the role of law and regulation in dealing therewith cannot be compared to that in the aviation sector.[12] Due to the much lower speeds at which maritime transport usually takes place, only with the advent of immense tankers, difficult to manoeuvre at a

11. Convention Relating to Co-operation for the Safety of Air Navigation, Brussels, done 13 December 1960, entered into force 1 March 1963; 523 UNTS 117; Cmnd. 2114.

12. For a detailed analysis of the legal and institutional environment for the maritime transport sector, see Organisations, Legislative Instruments, Plans and Policies, Technical Note, General Lighthouse Authorities, V0.1, of 13 January 2004.

moment's notice, and, more recently, high-speed vessels, some distinct legal developments have taken place.

Such legal measures furthermore seemed to have focused largely on such options as devising traffic lanes, establishing sound information systems, as well as establishing safety standards and requirements for radio-navigation equipment; little attention is being paid to *services* properly speaking. To the extent such legal measures have been taken in binding fashion, moreover, this has almost exclusively been the case at the level of national law.

On the international level, the International Maritime Organisation (IMO) had been created (until 1982 as Intergovernmental Maritime Consultative Organisation, IMCO)[13] to try and enhance (*inter alia*) the safety of maritime navigation, whereas also the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA)[14] has become involved in this area. However, as distinct from ICAO in the aviation sector, neither IMO nor IALA have been endowed with regulatory competencies of a binding character, even as its recommendations are often implemented in practice. It has therefore mainly provided the impetus to the establishment of some treaties properly speaking, which indirectly may deal with radio-navigation issues.[15]

Similarly, at the European level so far no separate legal and regulatory regime has been developed along the lines of Eurocontrol, the JAA and the growing role of the European Union. The recent establishment of a European Maritime Safety Agency (EMSA)[16], created with a view to enhancing the safety of maritime transport in the European Union following the Erika-disaster, however, may be the first fundamental step to changing this situation; for good reason EMSA has already been compared with the EASA being established in the aviation area. It remains to be seen therefore how this new entity would interfere with, alternatively contribute to the causes espoused by the ERNP-to-be-created.

As radio-navigation constitutes a natural concern in maritime transport, though to a different extent and legally speaking in a different manner than in aviation, any ERNP development should take some of the parameters developed in that area into consideration in spite of their non-binding character. This especially pertains to standardisation and certification of equipment and guidelines and recommendations for safe navigation procedures. No regulatory instruments however can be readily perceived at this juncture for possible use in an ERNP context, though developments with respect to the newly established EMSA should be closely monitored as they might come to considerably qualify this conclusion.

13. Convention on the Intergovernmental Maritime Consultative Organization IMCO, Geneva, done 6 March 1948, entered into force 17 March 1958; 289 UNTS 48; TIAS 4044; UKTS 1958 No. 54; Cmnd. 589; Cmd. 7412; ATS 1958 No. 5; the title of the Convention was amended to "Convention on the International Maritime Organization" in 1975 with effect from 22 May 1982.

14. Constitution of IALA as adopted by the 8th General Assembly, 11 June 1998; http://www.iala-aism.org/web/pages/publications/cadrepubli.html.

15. E.g. International Convention for Safety of Life at Sea (SOLAS Convention), London, done 1 November 1974, entered into force 25 May 1980; 1184 UNTS 278, 1300 UNTS 391, 1408 UNTS 339, 1484 UNTS 442 & 1593 UNTS 417; TIAS 9700 & 10626; UKTS 1980 No. 46 & UKTS 1983 No. 42; ATS 1983 No. 22.

16. Regulation of the European Parliament and of the Council establishing a European Maritime Safety Agency, No. 1406/2002/EC, of 27 June 2002; OJ L 208/1 (2002); see also http://www.emsa.eu.int/.

F.5 The International Level: ITU and WTO

F.5.1 The International Telecommunication Union (ITU)

As indicated, the most important international legal context for radio-navigation would be that of the ITU, as based in its most recent incarnation upon a Constitution and a Convention. This new structure of the ITU was established at the Geneva Additional Plenipotentiary Conference of 1992; the Constitution and Convention entered into force in July 1994.[17] Further, reference should be had to the Radio Regulations, an immense body of binding regulations which are the result of all the consultative and co-ordinating activities undertaken within the framework of the ITU (see further below).

The ITU system is a public one; only states can draw direct benefits from the activities and competencies of the ITU, as well as become directly bound by any legal regime developed within the ITU framework. With currently 189 member states the ITU is one of the most globally operating intergovernmental organisations.

Private entities require a state to take up their case to the extent that the ITU is indispensable for their satellite communications activities. Under the ITU Constitution member states are also held internationally responsible for telecommunication activities by entities "authorized by them to establish and operate telecommunications and which engage in international services or which operate stations capable of causing harmful interference to the radio services of other countries".[18]

One specific competence of the ITU for the present purpose stands out above the others to the extent that radio-navigation is directly concerned, with a closely related one in case satellites are being used. The ITU co-ordinates the frequencies to be used with respect to any radio signal with an international range, and it also co-ordinates the use of orbital slots respectively orbits. This is achieved through a complex process.

The basis is the 'allocation' of certain frequency bands at the World Radio Conferences that take place every other few years to certain types of usage. A large number of different services are distinguished for that purpose; and in principle only those services may use a certain frequency band that fall within the allocation. There is however a very complicated system allowing for secondary usage (i.e. as long as the primary usage is not interfered with) and/or even usage on a regional or national scale, by means of footnotes and suchlike.

Next, a state may request for 'allotment' to it of a certain frequency within a certain band for the purpose of a specific proposed service or system. This leads to the process of actual co-ordination within the ITU, which can be summarised as follows.[19]

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17. Constitution and Convention of the International Telecommunication Union (hereafter ITU Constitution resp. ITU Convention), Geneva, done 22 December 1992, entered into force 1 July 1994; Final Acts of the Additional Plenipotentiary Conference, Geneva, 1992 (1993), at 1 and 71 resp.; and Instrument amending the Constitution and Convention of the International Telecommunication Union (Geneva, 1992), Kyoto, done 14 October 1994, entered into force 1 January 1996; Final Acts of the Plenipotentiary Conference, Kyoto, 1994 (1995), at 1 and 23 resp.

18. Art. 6(2), ITU Constitution; emphasis added. This provision is literally referring to "operating agencies", so as to include both public and private operators, to the extent the former are not yet covered by the same obligation of Art. 6(1), applicable to the "Members" themselves. An "operating agency" is defined in the Annex to the ITU Constitution as "[a]ny individual, company, corporation or governmental agency".

19. See esp. Artt. 1, 4(1), 12, 25, 44, ITU Constitution; Artt. 7-10, ITU Convention.

A state has to file its plans regarding its proposed system with the ITU.[20] This also applies if the state acts on behalf of private entities. Through a co-ordination process in which the ITU organs can play a key role, any potential disputes are to be pre-empted. It is firstly checked whether the request for allotment fits within the allocation, in terms of the type of service or system envisaged, and complies with any further specific aspects of the allocation.

Then, any other member state with a radio system either actually in operation or proposed and filed prior to the filing at issue, has a chance to investigate and indicate whether the proposed system would interfere with any of its systems, either physically or in terms of radio interference. If that would be the case, a further process of consultation and co-ordination takes place, in which in principle the filing state has to amend its requests so as to accommodate the concerns of the other state or states, unless the latter are willing themselves to change frequencies or orbital slot/orbit.

Once allotted to a state, those slots/orbits and frequencies can form the subject of 'assignment' to any private party, usually by means of national legal regulation. The ultimate aim is to enter the slot/orbit-cum-frequencies, whether changed in the process or not, in the Master Register. Such entry means that, legally speaking, the claim to the slot/orbit and related frequencies has been accepted and cannot be overruled by other (subsequent) claims, and will be legally protected against interference. The value of such protection of course depends on the willingness of states (and other entities) to respect co-ordinated slots/orbits and frequencies.

In addition to providing for the crucial co-ordination procedures for frequencies and slots/orbits, Constitution and Convention contain a number of substantive but rather general rules and principles which any telecommunications operation should abide by. The most fundamental one of those concerns Article 44 of the Constitution, which provides for the obligation to use the limited natural resource of radio frequencies "rationally, efficiently and economically, in conformity with the provisions of the Radio Regulations".

In a quite different area the ITU has made what can only be seen as a first effort to establish some legal/regulatory guidance: the Global Personal Mobile Communication Systems (GMPCS; the so-called 'hand-held' phones). At the World Telecommunication Policy Forum in Geneva, held 21-23 October 1996 on the instigation of the ITU, ITU member states agreed to a Draft Memorandum of Understanding to Facilitate the Free Circulation of Global Mobile Personal Communications by Satellite User Terminals.[21] Thus, on 18 July 1997 an agreement was concluded within the ITU framework between 120 member states supposedly allowing for the carriage of satellite phones and other receivers across national borders, while retaining however national discretion to license operations. As a consequence of the Memorandum of Understanding-character and especially the last caveat, the agreement can only be characterised as a pre-legal, pre-regulatory one of little direct relevance as an instrument for any ERNP as of now.

The ITU Convention provides for only a few other relevant requirements with respect to communications. Member states "reserve the right to cut off any (...) private telecommunication" which threatens national security.[22] States also remain sovereign in

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20. Since the 1992/4-revision, the appropriate organs within the ITU for this purpose are the Radiocommunications Bureau and the Radio Regulations Board.

21. E.g. Revised Report by the Chairman of 23 October 1996.

22. Art. 34(2), ITU Constitution.

respect of their military telecommunications, subject to a few provisions relating to distress and harmful interference.[23]

Member states further have an obligation to undertake the steps necessary to ensure the highest possible technical level of operations.[24] This commitment has an obvious safety-component, which is furthermore enhanced by the obligations to "safeguard these channels and installations *within their jurisdiction*".[25] In addition, regarding "those sections of international communication circuits" not within their jurisdiction but still somehow within their control, member states have a residual engagement to ensure maintenance thereof – in as far as such control goes.[26] Finally, top priority is established for communications relevant for the safety of human beings.[27]

To the extent the ERNP will deal with frequency allotment and assignment and (as far as satellite radio navigation systems are considered) slot/orbit allotment and assignment, it will have to operate within this international system provided by the ITU. Frequencies and slots/orbits are allotted and assigned through the ITU process as described summarily above, and, if used for radio navigation, need to fit the allocation for radio navigation services and the other requirements for being included in the Master Register. Also, the other requirements imposed by the ITU legal and regulatory regime are to be adhered to. In view of the almost comprehensive global membership of ITU moreover it should be noted that this regime is not easily changed, and certainly not so by the EU member states alone.

In this regard finally one should mention the Conference of European Post and Telecommunications operators (CEPT), which is often and to good effect used as a vehicle to prepare and co-ordinate relevant European efforts within the World Radio Conferences, e.g. to allocate frequency bands to certain services, or elsewhere in the ITU, e.g. as to allotment of specific frequencies to specific telecommunication projects.

While the ITU legal framework determines a number of important legal and regulatory parameters for any ERNP in that such ERNP should abide by its rules and principles, up to and including the registrations of frequencies in the Master Register, in view of its global scope it does not provide particular regulatory instruments for the EU and its member states which may further the cause and aims of the ERNP. The other way round, actually, the ERNP should make use of the ITU legal framework to maximise its own effectiveness, e.g. by using the CEPT, , to the extent any of its policies and measures would impact upon more global issues. Reference may be had in this regard to the regulatory documents referred to in the text.

F.5.2 The World Trade Organisation (WTO)

The second major legal/regulatory environment for radio-navigation, in the context of telecommunications, is provided by the WTO. Discussions on the international liberalisation of telecommunications had arisen during the eighties, when the General Agreement on Tariffs

23. See Art. 48, ITU Constitution.

24. See Art. 38(1), ITU Constitution, Cf. also Art. 38(2).

25. Art. 38(3), ITU Constitution; emphasis added. In general, the provisions on the maximum prevention of harmful interference also enhance the safety of international telecommunications; see e.g. Art. 45.

26. Art. 38(4), ITU Constitution; this being subject to other conditions laid down by special arrangements of which no further specifications are provided.

27. See Art. 40, ITU Constitution; also Art. 46.

and Trade (GATT) had to be augmented by a General Agreement on Trade in Services (GATS).

The establishment of the WTO[28] as a combined institutionalisation of both systems provided a further impetus to these discussions. As a result, on 15 February 1997 54 member states of the WTO plus the European Commission representing all 15 member states of the European Union signed an agreement to liberalise international basic telecommunication services (hereafter "Telecommunications Agreement").[29] The parties to this agreement together accounted for more than 90% of global telecommunications revenues. Thus, the agreement comes close to a global regime for all practical purposes.

So-called individual schedules of commitment were to be submitted and scheduled to enter into force on 1 January 1998. The commitments deal with many aspects of market access for international telecommunication services and foreign entities, including fixed and mobile satellite systems and services. Except where exemptions were filed on specific services, the commitments entered into were extended to the other members of the WTO through the mechanism of the Most Favoured Nation (MFN) clauses.

Currently, it is not clear to what extent radio-navigation would fall within the scope of the Telecommunications Agreement, as it has not been specifically mentioned. As of February 1997, a total of 55 offers covering 69 member states has been made to define the precise commitments undertaken; the European Union *inter alia* committing itself to competitive supply of, and international access to voice telephony, competition on data transmission services, access to mobile services markets, and specifically as far as telecommunications satellites are concerned, competition on mobile satellite services and fixed satellite services alike.[30]

It may be reiterated, that whilst it would have been logical for the WTO to, in addition to dealing with trade in telecommunications services, also involve itself in the area of trade in telecommunications equipment, this has not occurred so far. The only effort at a very embryonic level concerned the Memorandum of Understanding on GMPCS in the context of the ITU.

Similarly to the ITU context, the WTO legal regime is crucial – to the extent trade in relevant equipment and services is concerned – in determining limits to any ERNP policies and measures, albeit that here the process is still embryonic and allowing for exceptions, which may be helpful for achieving the purposes of an ERNP. At the same time, both the almost global scope of this legal environment, and – in view precisely of its somewhat embryonic character – its limited legal and regulatory powers, the WTO as of yet does not include any sensible or useful legal/regulatory instruments for the purpose of an ERNP.

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28. Agreement Establishing the World Trade Organization, Marrakesh, done 15 April 1994, entered into force 1 January 1995; 1867 UNTS; UKTS 1996 No. 57; ATS 1995 No. 8; 33 ILM 1125, 1144 (1994).

29. The agreement formed part of the Fourth Protocol to the General Agreement on Trade in Services (GATS); 33 ILM 1167 (1994).

30. Room Document No. 11, of 10 April 1997, submitted by the WTO to the Working Party on Telecommunications and Information Services Policy of the Organization for Economic Co-operation and Development (OECD), at 1.

F.6 The European Level: EU

F.6.1 The structure of the European legal order

The European level of law and regulation for a number of reasons provides the main focus of the current Report. This level by definition encompasses the core area to be regulated in further implementation of any ERNP: that of the EU member states. As such, it may also provide the basis for extension of any such scope to other European states (currently) not member of the European Union.

More importantly also, as discussed the international level provides for parameters and occasionally for opportunities, but for few options for regulatory instruments to be used for the purpose of the ERNP. As if by contrast, at the national level almost by definition too many different options for regulatory instruments and too many (potential or actual) regulators exist for a European Radio-Navigation Plan, all inhibited moreover by the limitation of their scope to their respective national territories and (to a subsidiary extent) national persons and entities.

At present, fifteen European states have subjected themselves to a very extensive set of rights and obligations towards each other under the European legal order. This was achieved by the establishment of the European Community through, initially, the signature and ratification of the Treaties of Paris and Rome in the 1950's[31], and subsequent treaties such as the Single European Act of 1986[32], the Treaty on European Union of 1992[33], and the Treaty of Amsterdam of 1997[34]. Together they form a body of primary Community law, *inter alia* creating communal organs such as the European Commission and the European Court of Justice. Furthermore, the treaties provided these organs with extensive legal competencies which amount in many cases to supranational powers.[35]

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31. The Treaty of Paris, or Treaty establishing the European Coal and Steel Community (ECSC Treaty), Paris, done 18 April 1951, entered into force 23 July 1952; 126 UNTS 140; and the Treaties of Rome, or Treaty establishing the European Atomic Energy Community (EAEC Treaty), Rome, done 25 March 1957, entered into force 1 January 1958; 298 UNTS 167; and Treaty establishing the European Economic Community (EEC Treaty), Rome, done 25 March 1957, entered into force 1 January 1958; 298 UNTS 11. The EEC Treaty was later re-christened EC Treaty by the Treaty on European Union of 1992.

32. Single European Act, Luxembourg/The Hague, done 17/28 February 1986, entered into force 1 July 1987; 25 ILM 506 (1986).

33. Treaty on European Union, Maastricht, done 7 February 1992, entered into force 1 November 1993; 31 ILM 247 (1992). The Treaty effectively extended the scope of European integration as it had arisen on the basis of the three original treaties underlying the three European Communities, which were incorporated into the Treaty on European Union as, respectively, Titles III, IV, and II. Furthermore, two more 'pillars' of the European Union were added to these three Communities: the Common Foreign and Security Policy, and the Co-operation in the Fields of Justice and Home Affairs, as Titles V and VI respectively. The two new pillars, however, remained purely intergovernmental and (almost) completely outside the established legal structure of the three Communities.

34. Treaty of Amsterdam Amending the Treaty on European Union, the Treaties Establishing the European Communities and Certain Related Acts, done 2 October 1997, entered into force 1 May 1999; OJ C 340/73 (1997). Apart from including certain elements and areas in the scope of European Community law which hitherto were not included, the Treaty of Amsterdam resulted in a major renumbering of Articles with a view to sanitising the complex of fundamental treaties which had arisen by then.

35. See for the Commission: esp. Artt. 211-219, EC Treaty; for the Court: esp. Artt. 220-245, EC Treaty.

Then, the Community organs, to include from this perspective the two other main organs created by the treaties, the Council of Ministers and the European Parliament,[36] themselves extended the substance of European law. With the primary Community law created by the member states as basis, these organs jointly established the immense body of secondary Community law.

Secondary Community law is basically composed of Regulations, Directives, and Decisions as far as binding regulations are concerned.

Regulations are essentially laws on a European level: they are phrased in general terms and apply comprehensively, at least as far as indicated or expressly provided for by the Regulations themselves.[37] They are therefore, generally speaking used where the aim is to create a monolithic legal regime, with little or no leeway to be allowed for individual national approaches to legislation.

As a consequence, inter alia with a view to an ERNP ***Regulations*** *would be most appropriate in areas where there would be, as of yet, little or no existing legislation or regulation at the national level which EC law could interfere with, so that uniformity, if desired, would be a feasible option. This would seem to apply especially e.g. to the level of multi-modal radio-navigation services, and the establishment of bodies analogous to the Galileo Joint Undertaking (GJU).*

The same qualification as law applies to **Directives** to some extent, namely as far as the required end result is concerned; each state is free however to reach that end result in whatever way it sees fit.[38] Directives therefore generally speaking leave considerable room (and usually also time!) for individual states to achieve the overall results targeted for without having to change their own legal system or regime more than would be strictly necessary.

As a consequence, inter alia with a view to an ERNP Directives would be most appropriate in areas where there would already exist a considerable body of legislation or regulation at the national level, so that harmonisation on major points rather than complete uniformity should be aimed for. This was illustrated in particular by the four Directives fundamental to developing the appropriate telecommunications respectively satellite communications environment (see further below[39]).

Finally, **Decisions** also provide for binding legal rules, but essentially only *vis-à-vis* those entities to which they are explicitly or implicitly addressed.[40] Decisions therefore are often targeted at specific and/or *ad hoc* situations, such as when dealing with a distinct player or closely circumscribed set of players by means of implementation of the more general Regulations or Directives.

As a consequence, inter alia with a view to an ERNP Decisions would be most appropriate in areas where dedicated and targeted implementing measures are to be taken. This instrument would therefore be especially useful in the enforcement of legislation of broader scope (Regulations and Directives) on e.g. application of the competition rules, or to address specific, well-confined initiatives within the framework of the ERNP.

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36. See for the Council: esp. Artt. 202-210, EC Treaty; for the Parliament: esp. Artt. 189-201, EC Treaty.

37. See Art. 249, 2nd para., EC Treaty.

38. See Art. 249, 3rd para., EC Treaty.

39. This concerns the four bulleted Directives referred to in para. 4.3.

40. See Art. 249, 4th para., EC Treaty.

For completeness' sake, it may be added that the European Commission in particular can also avail itself of instruments not of a binding legal nature, such as Recommendations, Resolutions, and even Green Papers and White Papers and suchlike. Such instruments may occasionally have distinct legal impacts: they might either grow into customary law, or serve to interpret certain elements of EC law when uncertainties would arise from the text properly speaking.

The essentials of the Community legal order present the Community with its own measure of jurisdiction over a wide range of economic or economy-related activities, including in principle telecommunications as well as radio-navigation activities. Community jurisdiction moreover can be directly applied not only to the member states themselves, but also to private persons and entities otherwise resorting under the domestic jurisdictions of these member states.

In addition, in many cases the rights and obligations directly applicable to individual citizens and entities can also be claimed directly. Bypassing domestic jurisdictions of member states, the Court can be called upon in a number of instances by those concerned to judge upon the legality of Community actions as well as national actions.[41] The existence of this body central to the Community legal order represents an essential measure of supranational adjudication.

On economic issues the power of an individual state to legislate has thus largely been transferred to – or at least circumscribed at – the Community level. Under Community law private entities, in contrast to their position under international space law, are definitely subjects in their own right. To a major extent, a distinct and partly supranational jurisdiction of the Community has thus replaced the individual jurisdiction of the member states.

Secondary Community law offers a set of legal/regulatory instruments at the European level of supreme importance for establishment of an ERNP: ***Regulations****,* ***Directives*** *and* ***Decisions*** *are fully binding, they override national law of member states in practice when the two do not square, they apply to the whole of the European Union and moreover do so to a considerable extent directly also* vis-à-vis *private persons and entities.*

F.6.2 The general approach of the European legal order: the substantive core

The point of departure also for telecommunications, including radio-navigation, from the perspective of EC law thus refers to the general substantive focus of the European legal order on all economic issues. Telecommunications and radio-navigation activities fall within the Community legal order essentially because (and to the extent that) they form a category of economic activities in general (even if the notion of 'economic activities' has been expanded over the years so as to allow EC law to deal with most areas of society with a distinct economic element or aspect to them). From this perspective, upon closer view a few fundamental regimes of EC law would have a decisive impact.

The central and most comprehensive aim of Community integration remains the creation and maintenance of a common market.[42] While only the Internal Market, being one side of the common market, was established as of 1993, the result amounts to a free market regime.43 This regime in turn is based upon four freedoms, a competition regime and harmonisation of relevant national legislation. Furthermore, the future realisation of a common market would in addition call for external competence of the EU organs in relevant matters.

41. Cf. resp. Artt. 230, 232, and Artt. 226, 267, EC Treaty.

42. See e.g. Artt. 2, 3, EC Treaty.

43. See e.g. Artt. 13-19, Single European Act.

The four freedoms concerned are the freedoms of movement of goods[44], of persons[45], of services[46] and of capital[47]. These economic freedoms, and the more elaborated rights and obligations established in consequence, are territorially defined: they aim at movements across the borders *between* the EU member states.

In view of the focus of the ERNP on the environment for the provision of services, the free movement of services is of particular importance here. It was originally defined in EC law by reference to territory – in this case essentially to the territory from which the service is offered. Over the years, however, the application has been widened so as to also allow persons offering certain services to move freely across internal EU member state borders.

In addition to the four freedoms, the competition regime is designed to rule out other means of distorting fair competition. This competition regime *lato sensu* has two pillars: rules applying to private undertakings, and rules applying to states and their public undertakings. In all cases, the relevant rules can be judged upon by the European Court of Justice, *casu quo* the Court of First Instance, if such a need should arise.[48]

As to the former, Articles 81 and 82 preserve fair competition by imposing obligations upon the undertakings themselves. Article 81 forbids devices of market strategy co-ordination between various undertakings, as long as it substantially distorts intra-EU trade and competition.[49] This prohibition has exceptions and exemptions, but only in as far as EC law or the Commission allow for.[50] Article 82 precludes an enterprise from abusing a dominant position in a relevant market, in the sense of distorting trade and competition within the European Union.[51]

Limited exceptions to the regimes of both Article 81 and Article 82 are possible in as far as Article 86 allows states to maintain exclusive or special rights for a public undertaking.[52] This is once more the subject of scrutiny by the Commission, which can enforce these competition rules.[53] Finally, in respect of both Article 81 and Article 82, a negative clearance by the Commission would result in non-application of the respective rules in applicable cases – as subject to the Commission's scrutiny.[54]

The latter pillar of the competition regime concerns in particular Article 87, which prohibits states to give state aid to economic undertakings.[55] Exceptions are possible, but only in as far

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44. See Artt. 23-38, EC Treaty.

45. See Artt. 34-48, EC Treaty.

46. See Artt. 49-55, EC Treaty.

47. See Artt. 56-60, EC Treaty.

48. Artt. 226, 230, 232, 234, EC Treaty; also Art. 225, EC Treaty.

49. See Art. 81(1), EC Treaty.

50. Cf. Art. 81(3), EC Treaty.

51. See Art. 82, 1st sent., EC Treaty.

52. See Art. 86(1) & (2), EC Treaty.

53. See Art. 86(3), EC Treaty.

54. See Artt. 2, 3, Regulation 17/62, of 6 February 1962; OJ 13/204 (1962).

55. See Art. 87(1), EC Treaty.

as Article 87 itself allows for them.[56] Exemptions are also possible, but only in as far as the Commission and the Council have granted them.[57]

As long as activities distort competition within the European Union, the relevant EU organs may feel empowered to legally apply the competition rules to these activities, by whomsoever undertaken and wherever they are taking place. This could, in principle, apply also to telecommunications respectively radio-navigation, and thereby to such activities conducted by non-EU entities from outside 'EU territory'.

A final important issue at this point concerns harmonisation of national legislation within and by the Community legal regime. The Single European Act, more in particular by adding what is now Article 95 to the EC Treaty, provided for simplified procedures which may lead to mandatory harmonisation of national laws as long as necessary for the achievement of the internal market.[58]

The scope of this particular mechanism to promote free trade, but also recognise the legitimate role played by national regulation within the Community framework of market regulation has furthermore widened considerably with the entry into force of the Treaty on European Union in 1993. Thus, member states are allowed to individually maintain or introduce safety measures more stringent than the minimum harmonisation requires.[59]

Therefore, while market aspects still provide the major impetus behind harmonisation measures, the safety aspect by now does also play a significant role.[60] The establishment of harmonised minimum standards for safety measures as a consequence now falls within the competence of the Community. While safety forms an important aspect of any licensing procedure, it should be kept in mind that this harmonisation relates essentially to the safety aspects of hardware and the necessary technical qualifications.

The safety aspects of, for example, satellite communication operations themselves so far have not been included in this harmonisation. Extension of the scope of Article 95 of the EC Treaty to include such additional safety aspects would require further elaborating arrangements. It is likely however that these could be effectuated quite easily in legal terms.

*In terms of an ERNP analysis of the substantive contents of EC law at the more general level, i.e. referring to the Internal Market and competition, points to a wide range of parameters to be taken into account, whereas it also demonstrates the extent to which the possible instruments of **Regulations, Directives** and **Decisions** have been able to fundamentally erode national legal borders – and hence the potential of using them for a truly European Radio-Navigation Plan. This is especially true for the areas concerning the freedom of services and application of the competition regime.*

F.6.3 The place of telecommunications (including radio-navigation) in the European legal order

The relatively new involvement of the European institutions and markets in telecommunications activities, which used to be a prerogative of sovereign states for a

56. See Art. 87(2), EC Treaty, providing categories that are automatically accepted as exceptions, and Art. 87(3), providing categories that might become so accepted.

57. See Art. 88(2), EC Treaty.

58. See Art. 95, EC Treaty.

59. See Art. 129a(3), Treaty on European Union.

60. See Art. 95(3), EC Treaty.

complex of political, strategic, social and economic reasons, requires further analysis. To what extent has the Community already acted as a regulatory force with respect to telecommunications? And as a preliminary to the question on legal action taken, to what extent would the Community legal order indeed be suited for specific application to such activities?

As also becomes clear when looking at Galileo, which is why this case will be analysed in summary fashion further down, radio-navigation activities have so far hardly been dealt with under European law (or for that matter international and national law) in any dedicated fashion. This makes it indeed opportune to look at the broader issue of telecommunications for further guidance. Following from the importance of telecommunications for the European economies at large, this does represent an extensive body of law at the European level.

In addition and specifically on satellite communications, a legal regime is developing which is acquiring a rather comprehensive character. As *lex specialis* to the *lex generalis* of general telecommunication regulations, it is intricately linked to the former, so that it somehow has to be developed on the basis thereof, more or less adding or amending specific measures focused on satellite communications.

Thus, satellite communications – in addition to having a direct impact upon radio-navigation to the extent the latter is satellite-based – may also serve in the abstract as a precedent for amending and extending the more general legal regime for telecommunications to the more specialised field of radio-navigation, whether terrestrial or satellite-based.

Analysis on the legal and regulatory side will therefore concentrate on the general structure and direction visible, rather than on any particular detail.

The Green Paper pertaining to the development of the common market for telecommunications in general, which was issued in 1987, provided the starting point for Community involvement in this field.[61] Follow-up measures have been implemented in a consistent fashion.

The main elements of this implementation are the following.

- Commission Directive on competition in the markets in telecommunications terminal equipment (Directive on Terminal Equipment).[62]
- Council Directive on the establishment of the internal market for telecommunications services through the implementation of Open Network Provision (Directive on Open Network Provision).[63]
- Commission Directive on the competition in the markets of telecommunications services (Directive on Competition in Telecommunications Services).[64]

Combined together, these measures achieved a considerable measure of non-discriminatory and efficient access by users to telecommunication networks and public services that are now

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61. Towards a Dynamic European Economy – Green Paper on the Development of the Common Market for Telecommunications Services and Equipment, Communication by the Commission (hereafter Green Paper of 1987), COM(87) 290 final, of 30 June 1987; OJ C 257/1 (1987). The Green Paper was approved by the Council in 1988.

62. 88/301/EEC, of 16 May 1988; OJ L 131/73 (1988).

63. 90/387/EEC, of 28 June 1990; OJ L 192/1 (1990).

64. 90/388/EEC, of 28 June 1990; OJ L 192/10 (1990).

largely liberalised and opened up to private enterprise. In doing so, they provided the foundations for a level playing field for telecommunications as part of the Internal Market.

National implementation turned out to be a different matter, however.[65] Nevertheless, the process of liberalisation of the telecommunication sector as a whole, as it has developed from these Directives, is now well on the way to being finalised. The EU Internal Market for telecommunications has, theoretically as well as taking individual exceptions into account, been realised as of 1 January 1998.

Already an extremely summary analysis thus shows that the European Union was able and willing to put its full juridical powers behind the regulation and harmonisation of the field of telecommunications in a relatively short period. Rather comprehensive Directives were issued, and neither Commission nor Court hesitated to take the necessary enforcement and adjudicative actions respectively.

All measures resulting from the Green Paper of 1987 explicitly excluded satellite communications: the complicated market situation arising on telecommunications in general thus so far serving as a background to satellite communications in particular. Comprehensive and direct attention of the European Union to satellite communications did not arise immediately, as a consequence of the relatively minor and rather exotic role of satellites within the sector at large.

Only the publication of a second Green Paper, in November 1990, which was specifically related to space telecommunications, triggered the first application of the Community legal order to satellite communications.[66] After its adoption by a Resolution in December 1991,[67] the Council consequently ordered the Commission to draft deregulation measures, to be submitted to the Council and the European Parliament for final review. This provided the start of the process towards realising the EU Internal Market for satellite communications.

The Green Paper of 1990 contained three principles derived from the Green Paper of 1987, to be implemented in the field of satellite communications. Thus, the underlying aim of the former was the liberalisation of the satellite communications market. The liberalisation of the provision and use of hardware and software involved in satellite communication activities provided the overriding principle in this particular context.

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65. Cf., as to the Directive on Terminal Equipment, e.g. France v. Commission of the European Communities, Case C-202/88, Judgement of 19 March 1991; [1991] ECR I-1223; while on the other hand British legislation of 1984 had already pre-empted this Directive before it had even been issued.

As to the Directive on Open Network Provision, see e.g. Ninth annual report to the European Parliament on Commission monitoring of the application of Community law, COM(92) 136 final, of 28 September 1992; OJ C 250/1 (1992), at 35; whereas the British again by means of their legislation of 1984 had pre-empted such requirement regarding national implementation; see Italy v. Commission of the European Communities, Case 41/83, Judgement of 20 March 1985; [1985] 2 CMLR 368; [1985] ECR 873; and the underlying Commission Decision, No. 82/861/EEC, of 20 December 1982; OJ L 360/36 (1982).

Finally, as to the Directive on Competition in Telecommunications Services, see e.g. Spain, Belgium, Italy v. Commission of the European Communities, Joined Cases C-271, C-281 and C-289/90, Judgement of 17 November 1992; [1992] ECR I-5833; OJ C 274 (1990); OJ C 326 (1992).

66. Towards Europe-wide systems and services – Green Paper on a common approach in the field of satellite communications in the European Community, Communication from the Commission (hereafter Green Paper of 1990), COM(90) 490 final, of 20 November 1990.

67. Council Resolution on the development of the common market for satellite communications services and equipment, of 19 December 1991; OJ C 8/1 (1992).

Accordingly, full liberalisation of earth segments should be achieved, the Community's competition regime should be enforced with respect to satellite communication services, and unrestricted access to space segment capacity should be realised. Finally, commercial freedom to market satellite capacity was to be granted to space segment providers – subject of course to the EU competition regime. Thus, the only exception to a market regime in respect of the space segments concerned the provision of the hardware itself – whether transponders or comprehensive satellites.

A few further legal parameters for the liberalisation of satellite communications in Europe were also dealt with. Separation of regulatory and operational functions should be effected, in order to avoid conflicts of interests. Furthermore, technical harmonisation measures should be implemented. By definition this can only be realised at the European level – to create a European market, European-wide technical compatibility is necessary. Finally, some lines of action were proposed to help create in the longer run an environment sympathetic to the full implementation of the proposed liberalisation.

The main first result of this process of liberalising satellite communications consisted of one Directive in particular:

- Commission Directive amending Directive 88/301/EEC and Directive 90/388/EEC in particular with regard to satellite communications (Satellite Directive).[68]

More, and more specific measures followed, which indeed confirm that the broad legal regime for telecommunications could serve as a point of departure for building a more specialised and focused regime for radio-navigation in the context of the European Internal Market and for the purposes of the ERNP.

The European legislative developments in both the broader telecommunications sector and the narrower satellite communications sector provide an excellent further insight into the measure of effectiveness of EU legal and regulatory instruments in their respective areas of scope and the problems and opportunities when it comes to implementation also for another specific sub-field of telecommunications: that of radio-navigation (in particular as focused on service provision). Therefore, Annex A to the current Report lists (only) such European regulatory documents, further to the four fundamental ones referred to already. To what extent they would merely serve as demonstrators of such instruments, or also provide parameters to the specific area of radio-navigation is another matter, going beyond the scope of this Report.

F.7 Galileo

F.7.1 Introduction

Galileo will constitute the first radio-navigation undertaking of an inherently and original trans-boundary, cross-European or even cross-global character of sufficient accuracy, continuity and integrity (as opposed to current GPS and GLONASS) for full-fledged usage in many safety-sensitive environments.

As a consequence of such perceived usage, obviously law and regulation will have to play a major role in ensuring that the benefits of Galileo usage would be maximised whereas potential negative side effects would be curbed and controlled as much as possible. Thus, the special character of Galileo in many ways also serves to illustrate the interaction between international, European and national levels of law and regulation. For that reason, it may be helpful to briefly outline the essential legal and regulatory aspects of Galileo as it is currently

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68. 94/46/EC, of 13 October 1994; OJ L 268/15 (1994).

envisaged to start operations in 2008, and the legal environment in which that is to take place.[69]

The overwhelming part of the existing legal and institutional environment is not tailor-made for Galileo or GNSS, and on the contrary has a much wider scope and relevance. Furthermore, whilst Galileo is a European project – currently of seventeen European states member of either the European Union or the European Space Agency, or both, comprising a 'Galileo core group of states' – the ramifications, both intended and unintended, of its activities and operations will be world-wide in scope.

For those reasons, the actual possibilities to change anything in the existing legal and institutional environment for Galileo would be largely confined to those seventeen states and their national markets, since relevant fundamental changes outside those states essentially require consent of the relevant third states. In such cases, legal analysis would remain confined to mapping the legal and institutional risks and opportunities facing Galileo and, as it were, its business case, and trying to come forward with legal and/or institutional recommendations in terms of activities of the Galileo core states to handle those risks and opportunities as beneficially for Galileo as possible.

F.7.2 The envisaged institutional structure for Galileo

For the forthcoming phase, establishment of a **Galileo Joint Undertaking (GJU)** has been realised upon as a first potential vehicle for the Galileo Public-Private Partnership sought after, although it will effectively act more as the public side to such a PPP: it is currently funded only by the Galileo core states through ESA, the EU and the Commission, and has as its main task the selection of the concessionaire for the private side through a bidding process.

For the operational phase, this summary institutional structure would evolve into a proper bipolar one, with the two relevant entities fundamentally linked together by a Concession Agreement, spelling out at least the details of the concession and the PPP.

The concessionaire would evolve into the private operator of Galileo (the '**Galileo Operating Company**', GOC), operating the system, providing the signals and services, and marketing and selling them, possibly with the help of subsidiary companies.

In addition, likely evolving from the GJU, a public supervisor (the '**Galileo Supervisory Authority**', GSA) would be established monitoring the activities of the private operator as far as public interests and requirements are concerned, and defending the interests of Galileo to third states and parties wherever a public entity would be better placed to deal with those then the private operator itself.

F.7.3 The Galileo services

The general set-up in terms of signals and services to be provided provides a further important parameter. Here, the assumption is that the **Galileo Core System** (GCS; operated by the GOC as supervised by the GSA) will provide five core types of services, considered as **Galileo-only services**:

- the **Open Service** (OS);
- the **Commercial Services** (CS);
- the **Safety-Of-Life Services** (SOL);

69. See Recommendations and Conclusions arising from Task I, Legal and Institutional Issues, of the GALILEI Study Cluster, DD-120, v. 2.1, of 24 July 2003.

- the **Public Regulated Services** (PRS); and
- a contribution to existing **Search-And-Rescue Services** (SAR).

In addition to these five Galileo-only services as dealt with, to be provided by the Galileo Core System, alternatively by the GCS plus Regional Elements providing regional integrity, from a broader perspective also **Galileo local services** are to be provided by Local Elements in combination with the GCS but outside of it properly speaking, plus (optionally) Regional Elements; and **Galileo combined services** are to be provided by other systems together with any combination of the GCS, Regional Elements and various types of Local Elements.

Finally, the Galileo system-and-structure, yet to be established, has a complex relationship to the current European Geo-stationary Navigation Overlay System (EGNOS) – which is, moreover, not elaborated in many respects to a sufficiently detailed level. Whilst the two systems are closely related at the technical level – Galileo will no doubt use the technical expertise and experience developed in the context of EGNOS to a large extent; whether that will result in full operational and institutional terms in Galileo subsuming EGNOS, or rather contracting EGNOS for certain European services, is as of yet not certain. As the two are anyway likely to operate in close conjunction, EGNOS to some extent might be considered as part of the service portfolio where Galileo plays a fundamental role.

F.7.4 Towards a legal framework for Galileo

The main legal document in the GSA-GOC relationship would be the **Concession Agreement** to be concluded between the two entities. This Concession Agreement, either in itself or by means of closely aligned flanking arrangements, should not just deal with the concession itself and the PPP issue, but more generally with all respective rights and obligations of GSA and GOC *vis-à-vis* each other.

In addition, the desirability of a **Galileo Convention**, i.e. an international treaty between the Galileo core group of states acting as an umbrella over the Concession Agreement, would arise. This Convention should *inter alia* provide for the proper establishment of the GSA including some measure of international legal personality and functional immunities; and deal with the residual responsibilities of the states behind it, security- and safety-interfaces with other relevant organisations and authorities, liability solutions in terms of a Compensation Fund, Galileo international relations, certification schemes and the role and competencies of any Galileo-dedicated regulatory body to be established.

Whereas in the long run a Convention would provide the optimum solution, it is clear it might take a long time to become realised, and might even turn out not to be politically feasible. For both reasons, certainly in the short run EC law harmonisation measures, taking advantage of the well-weathered legislative machinery existing within the European Union, are therefore currently being advocated, in particular to complement existing law and regulation not to be changed easily – in other words: in particular in those areas not yet structurally covered by legal regimes and dedicated to the novel, overarching and comprehensive features of Galileo.

In view of the sovereign discretion of the Galileo core states in deciding upon the future institutional structure for Galileo, it is clear that EC law – as it has already done to some extent in terms of the establishment of the GJU – can indeed play a crucial role in establishing the proper legal and institutional framework supporting the options and scenarios preferred.

In terms of the Concession Agreement, including wherever relevant flanking arrangements, clarity as to the key issues should be developed fast in close co-operation and consultation with the private sector which has to bid for the concession. The financing arrangements to be proposed should closely mirror the respective risks taken by public and private sectors under the concession PPP. The proper types of incentives, in the form of allowable revenue mechanisms, should be included, and be properly guarded by the EC legislation to be established in accordance with the above.

In outlining the respective rights and obligations of GSA and GOC vis-à-vis each other, depending upon whether the GSA will own the system as opposed to the GOC, the Concession Agreement will have to duly consider such underlying division of roles as infrastructure provision (GSA) versus infrastructure operation (GOC) in order to strike the right balance between risks better handled by the public partner versus those better handled by the private partner.

Furthermore, it would be most crucial for Galileo's future to map the various regulatory environments, none of which are targeted at Galileo but all of which are partly relevant for it, and to analyse where in particular there would be scope for a dedicated regulator in addition to all the relevant regulatory authorities existing at an international, at a European, and at a national level.

As a result of the further analysis of those parts of the Galileo regulatory environment singled out for scrutiny, it became clear that in terms of safety (i.e. primarily the SOL) especially the aviation environment, and to some extent also the maritime environment, do already provide for extended regulatory regimes also at an international level.

Any role for a Galileo regulator should hence be limited to safety issues at the overarching, comprehensive level of Galileo itself, not of sector-specific applications; thus, for example in focusing on authentication and 'integrity guarantees' of the Galileo SOL. Possible exceptions could lie in those sectors where henceforth relatively little safety-related regulation would be available. In particular the EU concept of TEN's, and the competencies (to be) developed under it, would provide an interesting option here for such sectors as rail and road transport.

In terms of especially economic regulatory issues, in the event of establishment of a role for a Galileo regulator in this area care should be taken that on such issues as privacy and data protection, but also of economic regulation in a more limited sense, next to EC law international law would be taken into consideration. In terms of economic issues in particular, the role of the WTO and the legal and regulatory framework provided by GATT and GATS cannot be ignored.

In sum, analysis pointed to the desirability of a role for a Galileo-dedicated regulator as long as several important parameters as outlined above will be heeded. In addition to the above, a role for such a regulator would in particular be relevant in the areas of certification and dispute settlement. In view of the availability of the EU legislative and regulatory machinery and the major role of the Commission in promoting Galileo, it would seem that the EU institutional framework would provide the most feasible instruments and place to establish such a regulator.

At the same time, transparency and fairness, in other words separation of possibly contradictory functions, would then require a GSA not to be institutionally aligned to, let alone integrated in, that EU institutional structure. An added benefit of establishing a GSA outside the EU institutional framework and on a proper treaty basis – the Galileo Convention! – would be that non-EU states – Norway and Switzerland to begin with, but possibly others as well – could be more appropriately included in the operations and activities of the key Galileo entities.

As to the financing and revenue-generation issues, the relevant legal aspects would have to be dealt with first of all by the Concession Agreement. Various possible mechanisms for both aspects of financing Galileo were discussed; yet, also here the ultimate choice would not be made on legal grounds, but as a policy decision based on commercial and financial market considerations and the measure of freedom granted to the GOC under the Concession Agreement.

The legal aspects which should be taken into account when deciding upon the financing mechanism(s) to be used concern the international regimes governing public procurement of major projects such as Galileo, which try to ensure fair and balanced competition in the procurement process.

F.7.5 Conclusions on Galileo

In sum: whilst there are no legal show-stoppers for Galileo, or any of its intended core operations and activities of any serious dimension down to the level of value-added service provision, there is much room for improvement and adaptation of existing regimes.

This relates essentially to the GSA and GOC and their respective roles, as given shape firstly through the Concession Agreement (and, to the extent applicable, flanking arrangements) and, preferably also through a Galileo Convention subsidiary EC law.

From the perspective of an ERNP, the case of Galileo illustrates the possibilities provided by, as well as the limits of, legal instruments in establishing the (legal and regulatory) environment aimed for. At the same time, to the extent Galileo itself would be dealt with by or under the envisaged ERNP, the developments in this regard provide further parameters to the development of such an ERNP.

F.8 Concluding remarks

The main conclusion to be drawn from the foregoing first inventory of the regulatory environment for the envisaged ERNP is that radio-navigation, as part of the larger European Internal Market for telecommunications as well as the Trans-European Networks (TEN's) for both telecommunications and transport, would clearly fall within the scope of European Community competencies in the abstract. Many of the Regulations, Directives and Decisions of the Community targeted at the telecommunications Internal Market (see also Annex A) will directly or indirectly co-define the legal framework applicable to radio-navigation.

Both the importance of radio-navigation for such crucial sectors of the European economy as telecommunications and transport, and the need to stimulate a strong and healthy European (as opposed to merely national) environment for radio-navigation services and products within the larger context of the global environment further call for application of such competencies by means of concrete measures. The current absence at the international and European level of legal frameworks for specific modes of transport focused on the paramount aspect of safety, with the exception to some extent of aviation and possibly maritime transport, would further pave the path for Commission initiatives in this field.

Notably the Commission, the Council and the Parliament, would thus have the competencies to – and the Commission should consequently take initiatives to – take further legal measures in the implementation of an ERNP, since it is clear that most legal measures taken so far in the telecommunications area (or transport area for that matter) are not sufficiently focused for purposes of the ERNP. At the same time, the example of the specialised sub-regime of satellite communications as it was established on the basis of the more general telecommunications regime, indeed serves as a clear precedent for building a specialised regime for radio-navigation (both terrestrial and satellite-based) upon the more general one for telecommunications.

Further, for those purposes the most logical and effective instruments are to be found indeed in the (competencies of the Community organs to promulgate) Regulations, Directives and Decisions. All three versions of secondary Community law have fully binding character, all in principle override relevant national law of the member states wherever the latter would be incompatible with the former, all in principle apply to the whole of the European Union and its member states, and all finally do so in large measure directly also vis-à-vis private persons and entities.

Such Regulations, Directives and Decisions would, from the current perspective (in view of the overriding aim of the envisaged ERNP), be aimed especially at ascertaining the freedom of provision of radio-navigation services (including limitations and exceptions necessary for security and safety purposes), application of the competition regime (with the same caveat), and harmonisation of relevant national legislation and regulation wherever necessary or desirable.

It is beyond the scope of the current Report to determine which particular instrument for which cases represents the optimum instruments; that partly depends upon the generality or specificity of a certain element of the ERNP to be implemented by it. Regulations and Directives are normally of a more general nature whereas Decisions would seem the better instrument for cases where policies as translated into legal and regulatory measures that would be targeted at specific and well-confined issues.

It is also beyond the scope of the current Report to analyse in any detail the existing parameters as well as the opportunities or obstacles for future legislative and regulatory action in the context of an ERNP as they arise at the national level – this concerns, after all, currently fifteen EU member states plus, at a secondary level, the ten accession countries (and perhaps more still). Therefore, in a number of cases further research would indeed be warranted at a substantive level.

The current Report has rather focused on outlining the structural issues as they pertain to the overall approach to an ERNP to the extent legal and regulatory issues are involved. This concerns the key role of EC law and available regulatory instruments, against the background of international regulation to the extent relevant on the one hand and the remaining measure of national discretion for EU member states on the other hand.

The result is also a list of legal/regulatory documents at the European level, in the first place to further demonstrate and illustrate how such structural issues have resulted at least at the more general level of the telecommunications sector in a rapidly developing body of European legislation – of the same nature as is most likely and feasible to be used for the purpose of the envisaged ERNP.

In the second place, this list would present an obvious point of departure for any substantive analysis of the applicable legal regime, rules, principles, rights and obligations, since they might prima facie have some bearing on specific policies or measures to be considered for, or in the context of, an ERNP.

Finally, a list of regulatory institutions might need to be developed; the major outline thereof however becomes already apparent from the analysis in the current Report. The current regulatory institutions operating at the European level concern the various EU organs – notably the Commission, the Council and the European Parliament in a very complicated institutional interaction process. Sector-wise in particular for aviation, Eurocontrol, the JAA and especially the EASA in statu nascendi may be mentioned; but since these organisations find themselves in the throes of a rather revolutionary process of transformation, supervised to a large extent moreover by the European Commission anyway, they need not be further considered at this point.

Last but not least, on the national level such a list would refer to the respective national regulatory authorities in the field of telecommunications, absent any radio-navigation dedicated national organs. Which national authorities are relevant from this perspective and to what extent, however, depends upon an analysis of the respective relevant legislation and regulation, which, as indicated, is beyond the scope of the current Report.

G Maritime Organisations, Legislative Instruments, Plans and Policies

G.1 Introduction

The contents of this report are as follows:

- Section 2 introduces the principal organisations that have an interest in maritime radionavigation in Europe
- Section 3 describes the maritime policies and plans for radionavigation
- Section 4 lists the regulatory instruments and standards applicable to radionavigation in the maritime sector in Europe.

G.2 Maritime Stakeholders

G.2.1 Introduction

This section introduces and gives brief descriptions of the organisations that are stakeholders in the maritime radionavigation world. These bodies are classified at four levels:

- international
- European
- national
- user focused.

G.2.2 International Bodies

IMO

The International Maritime Organization (IMO) was set up originally as the Inter-Governmental Maritime Consultative Organisation in 1948 as a specialised agency of the United Nations. It adopted its present title in May 1982. It acts in a consultative and advisory capacity to facilitate co-operation among Governments on technical matters affecting international shipping. IMO Members are generally the maritime administrations of its Member Sates. IMO effectively governs radionavigation in the maritime sector, at least for international traffic, although it has no executive power to do so.

The main functions of IMO are the achievement of safe and efficient navigation and the control of pollution caused by ships and other vessels in the marine environment. IMO consists of an Assembly, a Council and five main Committees:

- Maritime Safety Committee
- Marine Environment Protection Committee
- Legal Committee
- Technical Co-operation Committee
- Facilitation Committee.

From the radionavigation perspective, the most important Committee is the Maritime Safety Committee (MSC), which has the Safety of Navigation Sub-Committee (NAV) as one of its nine sub-committees. NAV is principally responsible for performing technical work as directed by MSC.

IALA

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA – originally the International Association of Lighthouse Authorities) was established in July 1957 by international agreement as a non-governmental organisation (NGO). IALA members are generally the marine aids to navigation providers of its Member States.

The principal organs of IALA are a General Assembly, a Council, a Secretary General and Secretariat, ad-hoc Council Working Groups and a Standing Technical Structure. Within the Standing Technical Structure, there are a number of technical committees: radionavigation (RNAV), aids to navigation management (ANM), engineering, environment and preservation (EEP), automatic identification systems (AIS) and vessel traffic services (VTS); the majority of which have an interest in radionavigation.

IALA is responsible for the standardisation of navigation facilities including radionavigation, in the world's coastal waters and has consultative status in IMO. Until recently all marine radionavigation systems were essentially coastwise systems, hence, IALA has had the responsibility for such systems.

International Telecommunications Union

The ITU was founded in Paris in 1865 as the International Telegraph Union, which became the International Telecommunication Union in 1934 and became a specialised agency of the United Nations in 1947.

The ITU into three sectors:

- Radiocommunication Sector (ITU-R)
- Telecommunication Standardisation Sector (ITU-T)
- Telecommunication Development Sector (ITU-D).

ITU-R is of most relevance to GNSS. ITU R's mission is to ensure rational, equitable, efficient, and economical use of the radio-frequency spectrum and satellite orbits. The ITU R operates through Radio Conferences and Radiocommunications Assemblies (including a Regulations Board) that make up the legislative branch, a Bureau handling the administrative duties, and a Radiocommunications Advisory Group (RAG) providing strategic advice. The Radio Conferences are fora to review and revise, as necessary, the Radio Regulations.

World and Regional Radiocommunication Conferences are used to develop and adopt Radio Regulations and Regional Agreements covering the use of the radio-frequency spectrum. These are held every two years along to review and revise, as necessary, the Radio Regulations on the basis of an agenda adopted by the ITU Council following consultation of the membership. The Radio Regulations can be revised partially, or exceptionally, completely.

The conferences are open to all ITU members, the UN, international organisations, telecommunications organisations, and various other stakeholder groups. The Radiocommunications Assemblies perform several functions in support of the Radio Conferences. The Assemblies provide the technical basis for the work of the conferences and approve the mandate and schedule of radiocommunication study groups.

The International Hydrographic Organization

The First International Hydrographic Conference was held in 1919 with the objectives to:

consider the advisability of all maritime nations adopting similar methods in the preparation, construction and production of their charts and hydrographic publications; of rendering the results in the most convenient form to enable them to be readily used; of instituting a prompt system of mutual exchange of hydrographic information between all countries and of providing an opportunity for consultations and discussions to be carried out on hydrographic subjects generally by the hydrographic experts of the world

Accordingly, the International Hydrographic Bureau was set up, beginning its activities in 1921. The seat of the Bureau is in Monaco. The International Hydrographic Bureau refers only to the Headquarters of the Organisation, which itself is referred to as the International Hydrographic Organisation.

The objectives of the IHO are to bring about:

- the coordination of activities of the national hydrographic offices
- the greatest possible uniformity in nautical charts and documents
- the adoption of reliable and efficient methods of carrying out and exploiting hydrographic surveys
- the development of the sciences in the field of hydrography and the techniques employed in descriptive oceanography.

International Electrotechnical Commission

The IEC was founded in 1906 as a result if a resolution passed at the International Electrical Congress held in St Louis in 1904. The objective of the IEC is to:

"promote international co-operation on all questions of standardisation and related matters in the fields of electrical and electronic engineering and thus to promote international understanding."

The IEC is composed of National Committees, of which there are 49 at present, representing all the industrial countries in the world.

The Commission is governed by a Council composed of the President of the IEC, the Presidents of the National Committees, the immediate Past President or the President Elect, Past Presidents of the IEC, the Vice-Presidents of the IEC (up to three at the most), the Treasurer and the Central Secretary.

The Council is assisted by the General Policy Committee. The decisions and policy of the Council are implemented under the supervision of the Management Board. The Council receives reports from the Committee of Action, the IEC System for Conformity Testing to Standards for Safety of Electrical Equipment (IECEE) and the IEC Quality Assessment System for Electronic Components (IECQ). The Council delegates the management of technical work to the Committee of Action, which works through a series of Technical Committees (TCs) and associated working groups (WGs).

IEC prepares standards for shipborne equipment at the request of IMO through TC 80.

Radio Technical Commission Maritime

The Radio Technical Commission Maritime (RTCM) is a US-based not-for-profit scientific and educational organisation, focusing on all aspects of maritime radiocommunications, radionavigation, and related technologies. Since its establishment in 1946, the RTCM has acted as a focal point to collect and distribute information, and to serve as a catalyst to bring together those in government and in the private sector to work together in developing jointly agreed solutions to both national and international maritime radicommunications and radionavigation issues.

G.2.3 European Bodies

The European Union

The European Commission (EC) is the executive arm of the European Union (EU). The EC has three major functions:

- arising from its right of initiative, the EC is charged with making proposals for all new legislation. It does so on the basis of what it considers best for the Union and its citizens as a whole rather than on behalf of sectoral interests or individual countries,
- the EC acts as the guardian of the EU Treaties to ensure that EU legislation is applied correctly by the Member States and to ensure fair and equitable access to the single market
- the EC is the executive body of the Union responsible for implementing and managing policy, managing the EU annual budget and running its Structural Funds.

The EC interacts with the other organs of the European Union including:

- the European Parliament
- the Council of the European Union, which is usually known as the Council of Ministers
- the European Court of Justice
- the Economic and Social Committee.

A full description of the processes involved in the European Union is beyond the scope of this report.

The European Maritime Safety Agency

The European Maritime Safety Agency (EMSA) has been established, following the Erika disaster, to enhance maritime safety in the European Union. Although radionavigation is not specifically mentioned in the remit of EMSA, closely associated systems, such as vessel traffic monitoring and information services are identified. It is clear that EMSA will have a role to play in European maritime radionavigation matters.

European Maritime Radionavigation Forum

The European Maritime Radionavigation Forum (EMRF) an informal grouping of European maritime stakeholders with an interest in radionavigation, covering national administrations, aids to navigation providers, regulators, port authorities and operators, and European and international organisations with an interest in maritime radionavigation. It meets approximately 3 times a year to discuss issues, principally associated with satellite navigation (Galileo), the development of the European Radionavigation Plan (ERNP) and, latterly, other associated issues such as automatic identification systems (AIS). The EMRF interacts regularly and fruitfully with the major European institutions – the European Commission, the European Space Agency and the Galileo Joint Undertaking on these issues. The EMRF has established itself and is now recognised as the principal point of contact on maritime radionavigation issues.

One of the key achievements of the EMRF was the proposal the new set of requirements for future satellite navigation systems recently adopted by IMO as Assembly Resolution A915(22).

The current work of the EMRF includes:

- provision of a unique forum for the consolidation of the points of view of all of the stakeholders
- provision of a mechanism for two-way information exchange between the European institutions and the maritime community
- further development and refinement of requirements for satellite navigation systems to account for new and emerging applications, for example relating to automatic docking, operation of marginal vessels, high speed and fast manoeuvrable craft
- assessment of the vulnerability of satellite-based and other aids to navigation to enable the definition of the optimum systems mix, considering safety, environmental protection and cost-effectiveness
- collaboration with the European Commission to identify enablers that could facilitate the take up and secure future market share for Galileo in the maritime sector to the benefit of all stakeholders
- contribution to the development of the European Radionavigation Plan (ERNP) through participation in the Steering Committee, and input and review of the ERNP project itself
- ongoing input to the Galileo project.

G.2.4 National Bodies

Under the SOLAS Convention, individual States are responsible for the establishment, operation and maintenance of aids to navigation sufficient to support safe navigation as local circumstances dictate. There are essentially three tiers required to meet this obligation:

- the policy level
- the regulatory level
- the service provision/operational level.

The first tier, policy, is generally dealt with through government. Depending on the institutional arrangements in place, the second level (regulatory) can be delegated to Government or independent agencies and the third level (service provision/operations) can be delegated to the same agencies, other public sector bodies or the private sector. The overall situation in Europe is complex and there is no single model that can be applied.

G.2.5 User Organisations

There are a wide range of organisations at international, European and national level that represent the views of maritime users of radionavigation systems and services. The remit of these organisations is often quite broad with radionavigation only representing a minor part of their interest.

Two of the principal user organisations at European level are:

- The European Community Shipowners Association (ECSA), which is the representative body for national shipowners' associations throughout the EU. It is tasked specifically with coverage of both technical and policy issues together with general maritime sector representation at a central level

- The European Sea Ports Association (ESPO), which was set up in 1993 in response to a growing perception among seaports that a body should represent their interests within the European Community. ESPO represents over 98% of the seaports of the European Union and has direct contacts in some 500 ports across Europe. ESPO's mission is twofold. It aims at influencing public policy in the European Union and to achieve a safe, efficient and environmentally sustainable European Port sector, operating as a key element of a transport industry where free and undistorted market conditions prevail, as far as practicable.

There is a wide range of other organisations that have an interest in maritime radionavigation, including but not limited to:

- the European Boating Association, representing the interests of small craft users
- European Maritime Pilots Association
- International Federation of Shipmasters Associations
- Intertanko, representing independent tanker operators
- Intercargo
- the International Association of Dredging Companies
- the International Association of Drilling Contractors
- the International Chamber of Shipping
- Inland Navigation Europe.

G.2.6 Maritime Policies and Plans

Radionavigation plays a key role in maritime policy and plans for provision of aids to navigation. At the international level, IMO has specified a requirement for all SOLAS vessels to carry a radionavigation receiver (satellite or terrestrial) suitable for use at all times during its voyage. Furthermore, the current version of Chapter V of the SOLAS convention mandates the use of the automatic identification system (AIS), voyage data recorders (VDR) and, where appropriate, vessel traffic services (VTS). All of these systems require or benefit from input from radionavigation systems.

The approach to service provision is coordinated through IALA, which has published a policy document on radio aids to navigation whose introduction states:

> *"The development of global satellite navigation systems has had a major impact on the requirement for other radionavigation systems. In combination with the use of Electronic Chart Display and Information System (ECDIS) in the future, the practice of maritime navigation is being fundamentally changed. Automatic Identification Systems (AIS) for ships are also likely to become very important*
>
> *There are questions about integrity, availability, and control of satellite navigation systems which need to be resolved before terrestrial systems can be considered redundant."*

With regard specifically to satellite radionavigation systems IALA stated:

> *"To support and encourage Authorities providing satellite radionavigation systems to make their systems available to users and to ensure that the accuracy and availability of the navigational information provided is to the highest standard possible."*

A plan for the further development of the IALA DGNSS system is currently being formulated within the IALA Radionavigation Committee. The same committee is also considering the future of RACONs and the requirements for backup systems in the light of the acknowledged vulnerability of GNSS.

Although individual States have significant freedom to provide aids to navigation within their international obligations, in the majority of cases services are provided and maintained in line with international standards. National plans are also almost always consistent with international plans.

G.3 Regulatory Instruments

G.3.1 Introduction

This section introduces and describes the regulatory instruments that are applicable to marine radionavigation at the international and European levels, highlighting where the instruments are mandatory or voluntary in nature.

G.3.2 International Level

IMO instruments

In the radionavigation context, the instruments available to IMO fulfil four main objectives, to:

- define national obligations for the safety of navigation
- define equipment carriage requirements
- specify navigation performance and other requirements
- provide standards for onboard equipment.

The principal instrument through which IMO operates is the "convention". The initial work on a convention is normally done in committee or sub-committee. A draft instrument is then produced which is submitted to a conference to which delegations from all States within the United Nations system - including States which may not be IMO Members - are invited. The conference adopts a final text, which is submitted to Governments for ratification.

A convention comes into force after fulfilling certain requirements, which always include ratification by a specified number of countries. Implementation of the requirements of a convention is mandatory on countries that are parties to it.

The convention most relevant to GNSS is the International Convention for the Safety of Life at Sea, the most recent version of which entered into force on 1 July 2002, states in Regulation 13 :

> *"Each Contracting Government undertakes to provide, as it deems practical and necessary either individually or in co-operation with other Contracting Governments, such aids to navigation as the volume of traffic justifies and the degree of risk requires"*

SOLAS 1974 Chapter V essentially requires a State to ensure a safe and efficient marine navigation infrastructure.

SOLAS V also mandates the carriage of some equipment. For example, Regulation 19 of SOLAS V can be paraphrased as:

> *" All ships irrespective of size shall have….*

.....a receiver for a global navigation satellite system or a terrestrial radionavigation system, or other means suitable for use at all times throughout the intended voyage to establish and update its position by automatic means"

The second instrument used by IMO is the "resolution". Again the initial work is performed in sub-committee, for example NAV as directed by MSC. Assembly resolutions are ratified by the Assembly at its bi-annual meetings. This cycle can introduce delays into adoption of the work of IMO if it is not precisely in line with the schedule for Assembly meetings.

For radionavigation, there are several Assembly Resolutions of direct relevance:

- Resolution A.529(13) on Accuracy Standards for Navigational Equipment
- Resolution A.615(15) on Radar Beacons, Transponders and Reflectors
- Resolution A.815(19) on the World-Wide Radio Navigation System (WWRNS) (proposed for review by NAV)
- Resolution A.818(19) on performance standards for shipborne LORAN-C and Chayka receivers
- Resolution A.819(19) on performance standards for shipborne GPS receiver Equipment valid for equipment installed before 1 July 2003

Resolution A.915(22) on the Requirements for a Future Global Navigation Satellite System

There are also some MSC Resolutions of interest:

- MSC.112(73) on revised performance standards for shipborne GPS receiver equipment, valid for equipment installed on or after 1 July 2003
- MSC.53(66) on Performance Standards for Shipborne GLONASS Receiver Equipment, valid for equipment installed before 1 July 2003
- MSC.113(73) on revised performance standards for Shipborne GLONASS Receiver Equipment, valid for equipment installed on or after 1 July 2003
- MSC.64(67) Annex 2 on performance standards for shipborne DGPS and DGLONASS maritime radio beacon receiver equipment valid for equipment installed on or after 1 January 1999
- MSC.114(73) adoption of the revised performance standards for shipborne DGPS and DGLONASS maritime radio beacon receiver equipment valid for equipment installed on or after 1 July 2003
- MSC.74(69) Annex 1 on performance standards for shipborne combined GPS/GLONASS receiver equipment valid for equipment installed on or after 1 January 2000
- MSC.115(73) on the adoption of performance standards for shipborne combined GPS/GLONASS receivers valid for equipment installed on or after 1 July 2003.

Through Resolution A.815(19), IMO is also responsible for recognising systems as elements of the World-Wide Radio Navigation System (WWRNS). To date the only examples of the recognition process are those of GPS and GLONASS. Both of these systems were recognised as part of the WWRNS at the 66th Session of MSC in 1996.

IMO also provides circulars for information. Those of relevance to radionavigation include:

- IMO Circular SN/Circ.223, 6 November 2002 on information and guidance on allocation of identification numbers for Differential Global Navigation Satellite system (DGNSS) reference and transmitting stations in the maritime radionavigation (radiobeacon) band
- IMO Circular SN/Circ.213, 31 May 2000 providing guidance on chart datums and the accuracy of positions on charts.

IALA standards

As an NGO, IALA develops standards, which are voluntary but are almost always adopted and adhered to by its Member States. IALA publishes these standards in a number of forms:

- recommendations
- specifications
- practical notes
- guides and guidelines.

All of these essentially take the form of voluntary standards. Those of relevance to radionavigation include:

- the IALA Navguide, Edition 4, dated December 2001
- Recommendation R-121, June 2001, on the performance standards to be adopted for DGNSS broadcasts from maritime radiobeacons
- Recommendation R-101r1, dated December 2000 on marine radar beacons
- the list of DGNSS reference and transmitting stations in the maritime radionavigation (radiobeacons) band, last published as Issue 8 in September 2002.

IHO standards

In accordance with the objectives of the IHO, one of it significant activities is in the establishment of standards for hydrography, nautical charting and associated activities. The work is carried out through a large number of working groups and committees with the results being published as specifications and standards. Publications arising from this activity, which are effectively voluntary standards, include:

- S-44 “Standards for hydrographic survey”
- S-52 “Provisional specifications for chart content and display of ECDIS”
- S-57 “IHO transfer standard for electronic data”.

ITU recommendations

ITU develops both mandatory and voluntary standards – e.g. regulations or recommendations. In the maritime radionavigation environment, the voluntary standards of most importance are:

- Recommendation ITU-R M.823 on the data format and transmission characteristics of DGNSS broadcasts from maritime radiobeacons. This recommendation incorporates the RTCM SC-104 standard
- ITU Radio Regulation 4.40 on radar beacons.

IEC standards

IEC develops voluntary standards. Those of interest to radionavigation in the maritime sector include:

- IEC 61108-1 on GPS performance standards, receiver equipment, method of testing and required results (currently being updated to Edition 2.0 and currently at Committee Draft for Voting (CDV) stage)
- IEC 61108-2 on GLONASS performance standards, receiver equipment, method of testing and required results
- IEC 1108-3 on combined GPS/GLONASS performance standards, receiver equipment, method of testing and results (discontinued)
- IEC 61108-4 on combined DGPS/DGLONASS performance standards, receiver equipment, method of testing and results. This standard is also currently at the CDV stage.

In addition, IEC 61162-1/2 specifies the interface of navigation and radiocommunication equipment to other shipboard users, e.g. ECDIS, AIS, VDR, etc.

RTCM standards

RTCM develops voluntary standards. Those of interest to maritime radionavigation are:

- RTCM Recommended Standards for Differential GNSS (Global Navigation Satellite Systems) Service, Version 2.3, 2001 (RTCM Paper 136-2001/SC104-STD)
- RTCM Recommended Standards for Differential GNSS (Global Navigation Satellite Systems) Service, Future Version 3.0, June 2003 (RTCM Paper 120-2003/SC104-310), under development.
- RTCM Recommended Standards for Differential Navstar GPS Reference Stations and Integrity Monitors (RSIM), Version 1.1, 2001 (RTCM Paper 137-2001/SC104-STD).

G.3.3 European Level

The European Commission

The EC has the mandate to become involved in maritime and radionavigation issues through a number of articles in the Treaty of Union and the Common Transport Policy (CTP):

- Article 70 concerning the objectives of the CTP
- Article 71 requiring the CTP to include measures to improve safety
- Article 154 concerning trans-European transport networks
- Article 158 concerned with strengthening economic and social cohesion.

In addition, the Council Resolution on a "Common Policy on Safe Seas" invites the EC to:

> *...investigate and encourage the coordination and harmonisation of new aids to navigation developments including satellite radionavigation and vessel traffic services in the interests of safety at seas...*
>
> *...promote cooperation between participating member states and, having regard to the principle of subsidiarity, encourage the development of network integration and*

regional agreements so as to coordinate the uniform implementation of advanced navigational technologies...

This resolution also invited the EC to promote the:

> *...improvement of maritime infrastructures and of traffic procedures to devise a European radionavigation plan and, if appropriate, to examine the possibility of introducing a mechanism whereby the costs of providing radionavigation aids are recoverable from users...*

Similar goals are also outlined in the proposal for a Decision of the European Parliament and the Council on Common Guidelines for the Installation of a Trans-European Transport Network . Article 24 addresses the communication and navigation infrastructure for the complete network and specifically refers to new radionavigation systems, such as satellite navigation:

> *...For the safety of different transport modes, esp. the sea and air traffic, radionavigation systems have a central importance. Projects of common interest should therefore contribute to the improvement of today's systems by means of performance and safety. The final goal of the efforts should be a common system for Europe with satellite and terrestrial components....*

Furthermore, Directive 2002/59 EC is aimed at establishing a Community vessel traffic monitoring and information system (VTMIS) termed SafeSeaNet. Vessel position information will be a key input to this system and, to facilitate the provision of this information, the Directive mandates the carriage of AIS and voyage data recorders (VDRs) on specific ships calling at Community ports.

H Existing Systems

H.1 Introduction

Existing systems have been characterised as:

- Baseline radio navigation systems;
- Regional augmentation systems;
- Local augmentation systems; and
- Non-radio navigation systems.

These categories are described in Section 2.

H.2 Baseline Radionavigation Systems

H.2.1 Summary

The following baseline radio navigation systems are considered in this section:

- Galileo;
- GPS;
- GLONASS;
- Loran-C; and
- Chayka.

H.2.2 Galileo

H.2.2.1 Overview

GALILEO is a joint initiative by the European Union and the European Space Agency:

- the European Union, represented by the European Commission, is responsible for the political dimension of GALILEO and for setting objectives.
- the European Space Agency is responsible for the technical definition, development and the validation of GALILEO.

The GALILEO Joint Undertaking will be responsible for the development of the GALILEO programme and the selection of a commercial operator, who will make a significant contribution to the funding of the establishment of GALILEO from 2006 and will provide the GALILEO services from 2008.

There are three phases to the Galileo programme:

- development and validation;
- deployment; and
- operations and maintenance.

These are illustrated in Figure 9 together with associated costs.

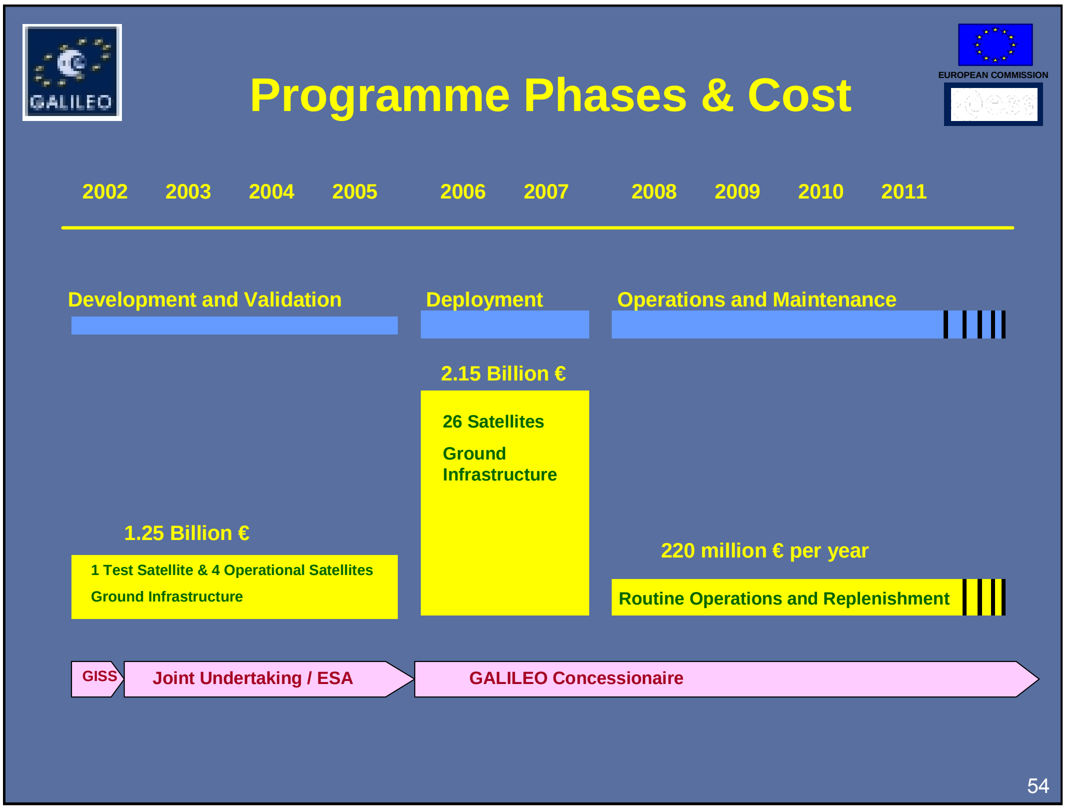

Figure 9 – Galileo programme phases and cost

GALILEO will comprise a constellation of 30 satellites in three planes inclined at 56°to the Equator orbiting at an altitude of nearly 24 000 kilometres. Ground stations will be responsible for management and control. GALILEO will be operational from 2008.

Galileo will provide five different services:

- open access;
- safety-of-life;
- public regulated;
- commercial; and
- search and rescue.

These are generated from combinations of up ten different signals with associated ranging codes and navigation data using broadcast and point-to-multipoint connectivity and will complement the GPS services to deliver enhanced benefits to users.

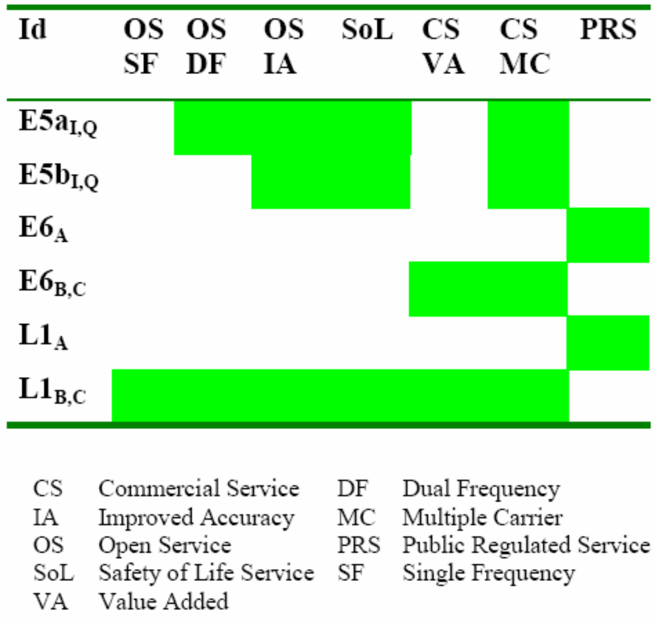

Figure 10 – Galileo services mapped to signals[70]

At this stage of the project, it is difficult to be specific about Galileo vulnerability. However, Galileo and GPS will share the same centre frequencies at L1 and L5, potentially providing a common failure mode.

H.2.2.2 Institutional

Galileo is being structured as a private / public partnership. A competition is currently underway to choose a Galileo concessionaire (the private party). The public sector will be represented by the so-called Supervisory Authority. At time of writing, the statement of work for the Galileo concession tender is not available and so the exact scope of activities (i.e. operations, service provision, regulation) is not clear.

Galileo services have neither been standardised nor accepted by user bodies at this early stage of the development process.

H.2.2.3 Service Delivery

Galileo services will provide position, velocity and timing. Table 2 presents the navigation performance to be provided by the open access, safety-of-life and public regulated services. The navigation performance provided by the commercial service will be driven by the Galileo Concessionaire.

The performance of the search and rescue service is specified in Table 3.

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[70] Hein G W, Godet J, Issler J-L, Martin J-C, Erhard P, Lucas-Rodriguez R, and Pratt T. *Status of Galileo Frequency and Signal Design*.
http://europa.eu.int/comm/dgs/energy_transport/galileo/doc/galileo_stf_ion2002.pdf

		Open		Safety-Of-Life		Public Regulated
Coverage		Global		Global		Global
Accuracy (95%)	**Horizontal (m)**	15	4	4		6.5
	Vertical (m)	35	8	8		12
Integrity	**Alarm Limit**	N/A		H: 12, V: 20	H: 556	H: 12, V: 20
	Time-to-Alarm (s)			6	10	10
	Integrity Risk			1.5×10^{-7}/150 s	10^{-7}/hour	3.5×10^{-7}/150 s
Continuity Risk		8×10^{-6}/15 s		8×10^{-6}/15 s	10^{-4}-10^{-8}/hour	10^{-5}/15 s
Timing Accuracy wrt UTC/TAI		Not Defined	50 ns	50 ns		100 ns
Certification / Liability		No		Yes		TBC
Availability		99.5%		99.8%		99% - 99.9%

Table 2 – Galileo navigation service performance[71]

[71] Galileo JU, Personal Communication, March 2004

Capacity	Each satellite capable to relay signals from 150 simultaneous active beacons
Forward System Latency Time	Comms from beacon to S&R ground station less than 10 min
Quality of Service	Bit Error rate < 10^{-5}
Acknowledgement Data Rate	6 messages of 100 bits each per minute
Availability	> 99%

Table 3 – Performance of the Galileo Search and Rescue Service

H.2.2.4 Dependencies

Galileo will be an independent baseline radio navigation system and will not be dependent on other systems for data generation or data delivery.

H.2.3 GPS Standard Positioning Service

H.2.3.1 Overview

The official descriptions of the US Global Positioning System (GPS) are contained in four documents:

- The Federal Radio Navigation Plan[72] – (including the Federal Radio Navigation Systems document) with the purpose: (1) to present the current Federal policy and plan for common-use civil and military radionavigation systems; (2) to outline the Government's approach for implementing new and consolidating existing radionavigation systems; and (3) to provide government radionavigation system planning information and schedules.
- [73] - defines levels of performance the U.S. Government commits to provide to civil GPS users. This document is written to satisfy the following objectives: (1) to identify performance standards the U.S. Government uses to manage SPS performance; (2) to standardize SPS performance parameter definitions and assessment methodologies; and (3) to describe historical SPS performance characteristics and ranges of behaviour.
- The GPS Signal-In-Space interface control documents - ICD-GPS-200C / IRN-200C-005R1[74] for the civil L1 and L2 signals and ICD-GPS-705[75] for the civil L5 signals.

The text in this section is taken from these documents unless specifically referenced otherwise.

General

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72 2001 FRP

73 2001 GPS SPS Spec

74 ICD GPS 200c

75 ICD GPS 705

GPS is a space-based dual use radionavigation system that is operated for the Government of the United States by the U.S. Air Force. The U.S. Government provides two levels of GPS service. The Precise Positioning Service (PPS) provides full system accuracy to designated users. The Standard Positioning Service (SPS) provides accurate positioning to all users. The Standard Positioning Service (SPS) was originally designed to provide civil users with a less accurate positioning capability than PPS through the use of a technique known as Selective Availability (SA). On May 1, 2000, the President directed the U.S. Department of Defense (DoD) to discontinue the use of SA effective midnight May 1, 2000.The GPS has three major segments: space, control, and user.

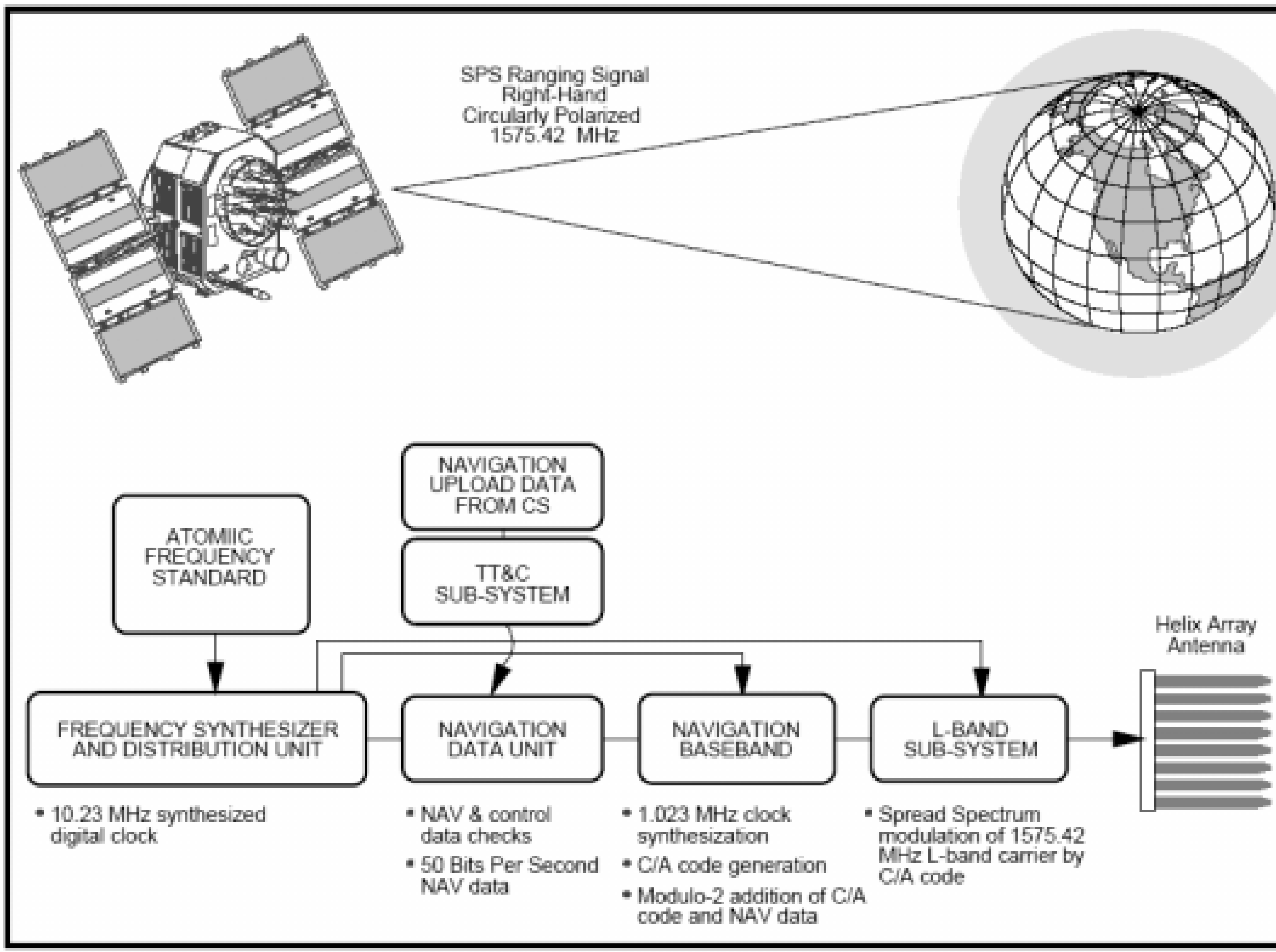

Figure 11 – Block IIA SPS ranging signal generation and transmission

Space Segment

The GPS space segment consists nominally of a constellation of 24 operational Block II satellites (Block II, IIA, and IIR).

Each satellite broadcasts a navigation message based upon data periodically uploaded from the Control Segment and adds the message to a 1.023 MHz Pseudo Random Noise (PRN) Coarse/Acquisition (C/A) code sequence. The satellite modulates the resulting code sequence onto a 1575.42 MHz L-band carrier to create a spread spectrum ranging signal, which it then broadcasts to the user community. This broadcast is referred to in this Performance Standard as the SPS ranging signal. Each C/A code is unique, and provides the mechanism to identify each satellite in the constellation. A block diagram illustrating the Block IIA satellite's SPS ranging signal generation process is provided in Figure 11. The GPS satellite also transmits a second ranging signal, known as L2, that supports PPS user two-frequency corrections. L2, like L1, is a spread spectrum signal and is transmitted at 1227.6 MHz.

The Block II satellites are designed to provide reliable service over a 7.5- to 10-year design life, depending on the production version, through a combination of space qualified parts, multiple redundancies for critical subsystems, and internal diagnostic logic. The Block II satellite requires minimal interaction with the ground and allows all but a few maintenance activities to be conducted without interruption to the ranging signal broadcast. Periodic uploads of data to support navigation message generation are designed to cause no disruption to the SPS ranging signal, although Block II/IIA satellites may experience a 6- to 24-second disruption upon transition to the new upload.

Control Segment

The GPS Control Segment (CS) is comprised of four major components: a Master Control Station (MCS), Backup Master Control Station (BMCS), four ground antennas, and six monitor stations. An overview of the CS is provided in Figure 12.

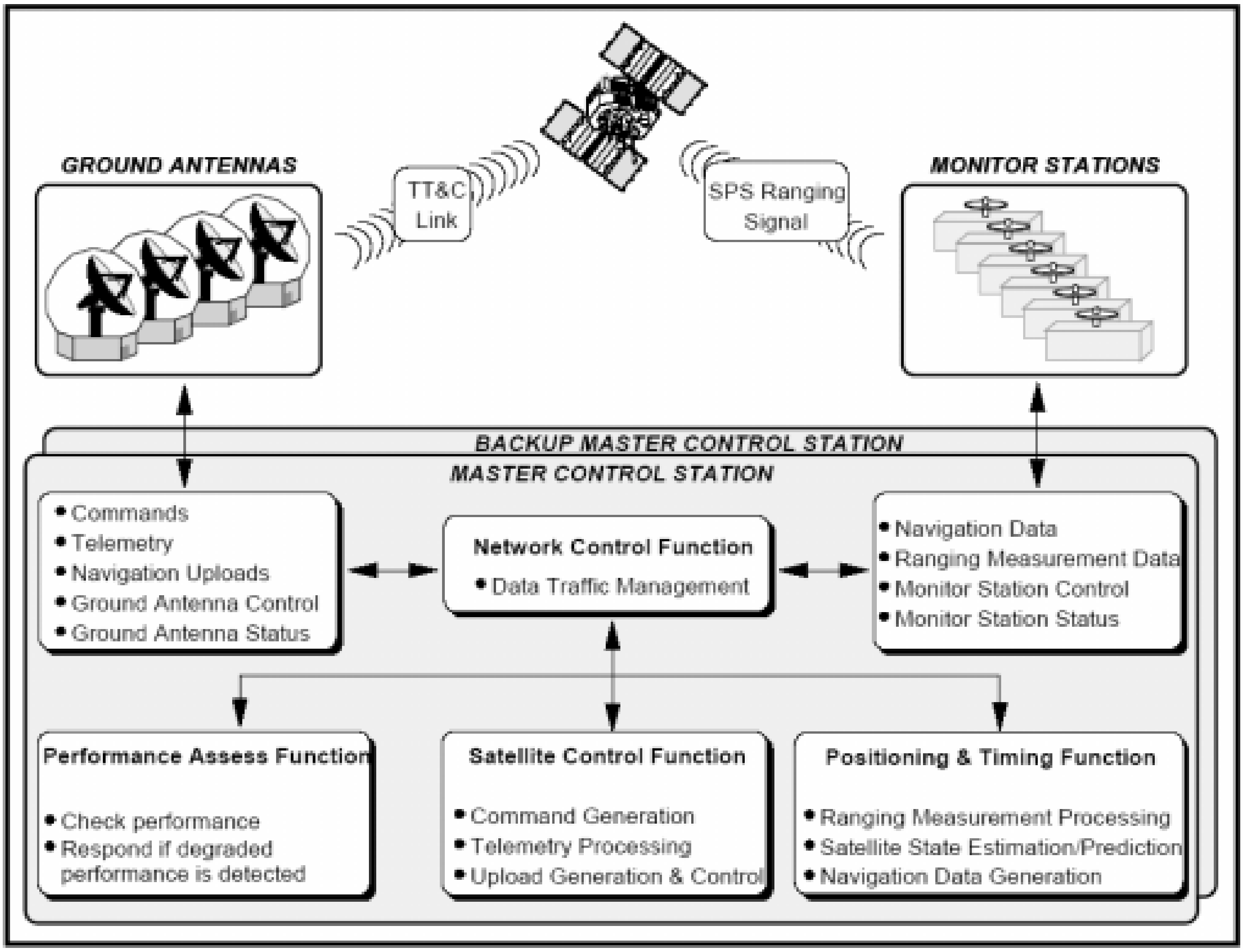

Figure 12 – The GPS control segment

The MCS is located at Schriever Air Force Base, Colorado, and is the central control node for the GPS satellite constellation. Operations are maintained 24 hours a day, seven days a week throughout each year. The MCS is responsible for all aspects of constellation command and control, to include:

- Routine satellite bus and payload status monitoring.
- Satellite maintenance and anomaly resolution.
- Managing SPS performance in support of all performance standards.
- Navigation data upload operations as required to sustain performance in accordance with accuracy performance standards.
- Prompt detection and response to service failures.

In the event of a prolonged MCS outage, GPS operations can be moved to a contractor-owned BMCS located at Gaithersburg, MD. When required, personnel from the MCS deploy to the BMCS within 24 hours. The BMCS is operationally exercised approximately four times per year to ensure system capability.

The CS's four ground antennas provide a near real-time Telemetry, Tracking, and Commanding (TT&C) interface between the GPS satellites and the MCS. The six monitor stations provide near real-time satellite ranging measurement data to the MCS and support near-continuous monitoring of constellation performance. The current CS monitor stations provide approximately 93% global coverage, with all monitor stations operational, with a 5° elevation mask angle. The actual elevation angle that a monitor station acquires any given satellite varies due to several external factors.

Signal Characteristics

Each satellite transmits three spread spectrum signals on two L-band frequencies, L1 (1575.42 MHz) and L2 (1227.6 MHz). L1 carries a Precise P(Y) Pseudo-Random Noise (PRN) code and a Coarse/Acquisition (C/A) PRN code; L2 carries the P(Y) PRN code. (The Precise code is denoted as P(Y) to signify that this PRN code can be transmitted in either a clear unencrypted "P" or an encrypted "Y" code configuration.) Both PRN codes carried on the L1 and L2 frequencies are phase-synchronized to the satellite clock and modulated (using modulo two addition) with a common 50 Hz navigation data message.

It is important to note that the L2 signal is not part of the SPS. Therefore, SPS performance standards are not predicated upon use of L2, or use of L1/L2 carrier tracking for other than code acquisition and tracking purposes.

The SPS ranging signal received by the user is a 2.046 MHz null-to-null bandwidth signal centered about L1. The transmitted ranging signal that comprises the GPS-SPS is not limited to the null-to-null signal and extends through the band 1563.42 to 1587.42 MHz. The minimum SPS received power is specified as -160.0 dBW. The navigation data contained in the signal are composed of satellite clock and ephemeris data for the transmitting satellite plus GPS constellation almanac data, GPS to UTC (USNO) time offset information, and ionospheric propagation delay correction parameters for use by single frequency (SPS) users. The entire navigation message repeats every 12.5 minutes. Within this 12.5-minute repeat cycle, satellite clock and ephemeris data for the transmitting satellite are sent 25 separate times so they repeat every 30 seconds. As long as a satellite indicates a healthy status, a receiver can continue to operate using these data for the validity period of the data (up to 4 or 6 hours). The receiver will update these data whenever the satellite and ephemeris information are updated – nominally once every 2 hours.

Signal Vulnerability

The US has evaluated the vulnerability of GPS to interference in the so-called *Volpe Report*[76]. It found:

- GPS service is susceptible to unintentional interruptions from ionospheric effects, blockage from buildings, and interference from narrow and wideband sources. Some natural phenomena such as ionospheric distortions and scintillation can be predicted. These disruptions are most noticeable for users of single-frequency (L1) receivers.

- The GPS signal is subject to degradation and loss through attacks by hostile interests. Potential attacks cover the range from jamming and spoofing of GPS signals to disruption of GPS ground stations and satellites.

- As with any radio navigation system, the vulnerability of the transportation system to unintentional and intentional GPS disruption can be reduced, but not eliminated. There is a growing awareness within the transportation community that the safety and economic risks associated with loss or degradation of the GPS signals have been underestimated.

- Backups for positioning and precision timing are necessary for all GPS applications involving the potential for life threatening situations or major economic or environmental impacts. The backups involve some combination of: (1) terrestrial or space-based navigation and precision timing systems; (2) on-board vehicle/vessel systems; and (3) operating procedures. The appropriate mix for a given application will result from careful analysis of benefits, costs and risk acceptance.

Modernisation

It is important to note that GPS is undergoing a process of continuous improvement with the aim of transitioning to GPS III.

From a civil perspective the most important developments are the availability of two new civil signals at L2 and L5 (FREQ). The new civil L2 signals will become available on the first Block IIR-M satellites to be launched in 2004. An Initial Operational Capability (IOC) is expected in 2009 and a Full Operational Capability is expected in 2012. The new civil L5 signals will become available on the first Block II-F satellites to be launched in 2006. L5 IOC is expected in 2011 and FOC is expected in 2015.[77]

Associated control segment improvements that are planned through to 2008 are described by Nagle[78] and summarised in Table 4.

Date	Process
8/2004	Accuracy Improvement Initiative (AII) completed, integrating 6 (eventually 14) NIMA GPS monitor stations into the current ground segment. The impact is to improve the user range error (URE) by 10% and to provide 100% dual visibility of the GPS constellation by the GPS operators (i.e. no more visibility gaps)
10/2005	AEP software version 5.2 available for test capability of L2C and L5

76 VOLPE

77 Garrett R P. *GPS Modernization Brief to the CGSIC*. Proc 41st CGSIC, Arlington VA, 19 March 2003.

78 Nagle T J. *GPS Joint Program Office (JPO) Civil Modernization Status*. Proc 42nd CGSIC, Portland OR, 8 September 2003.

2007	Civil signal monitoring being added to the AEP modernized monitor station receiver element (MMSRE) allowing civil signals to be monitored for the first time
12/2008	AEP software version 5.2 available for full operation of L2C and L5

Table 4 – Control segment modernisation through to 2008

H.2.3.2 Institutional

US GPS Policy

GPS is a US, publicly-owned system.

The 1996 Presidential Decision Directive (PDD) NSTC-6 establishes national policy for the management and use of the U.S. Global Positioning System and related U.S. Government augmentations.

Policy Goals

In the management and use of GPS, the US seeks to support and enhance our economic competitiveness and productivity while protecting its national security and foreign policy interests.

Its goals are to:

- Strengthen and maintain our national security.
- Encourage acceptance and integration of GPS into peaceful civil, commercial and scientific applications worldwide.
- Encourage private sector investment in and use of U.S. GPS technologies and services.
- Promote safety and efficiency in transportation and other fields.
- Promote international cooperation in using GPS for peaceful purposes.
- Advance U.S. scientific and technical capabilities.

Policy Guidelines

The US will operate and manage GPS in accordance with the following guidelines:

- It will continue to provide the GPS Standard Positioning Service for peaceful civil, commercial and scientific use on a continuous, worldwide basis, free of direct user fees.
- It is the US intention to discontinue the use of GPS Selective Availability (SA) within a decade[79] in a manner that allows adequate time and resources for its military forces to prepare fully for operations without SA. To support such a decision, affected departments and agencies will submit recommendations in accordance with the reporting requirements outlined in this policy.
- The GPS and U.S. Government augmentations will remain responsive to the National Command Authorities.

[79] Deactivated on 1 May 2000

- The US will cooperate with other governments and international organizations to ensure an appropriate balance between the requirements of international civil, commercial and scientific users and international security interests.
- The US will advocate the acceptance of GPS and U.S. Government augmentations as standards for international use.
- To the fullest extent feasible, the US will purchase commercially available GPS products and services that meet U.S. Government requirements and will not conduct activities that preclude or deter commercial GPS activities, except for national security or public safety reasons.
- A permanent Interagency GPS Executive Board (IGEB), jointly chaired by the Departments of Defense and Transportation, will manage the GPS and U.S. Government augmentations. Other departments and agencies will participate as appropriate. The GPS Executive Board will consult with U.S. Government agencies, U.S. industries and foreign governments involved in navigation and positioning system research, development, operation, and use.

This policy will be implemented within the overall resource and policy guidance provided by the President.

<u>Agency Roles and Responsibilities</u>

The *Department of Defense* will:

- Continue to acquire, operate, and maintain the basic GPS.
- Maintain a Standard Positioning Service (as defined in the Federal Radionavigation Plan and the GPS Standard Positioning Service Signal Specification) that will be available on a continuous, worldwide basis.
- Maintain a Precise Positioning Service for use by the U.S. military and other authorized users.
- Cooperate with the Director of Central Intelligence, the Department of State and other appropriate departments and agencies to assess the national security implications of the use of GPS, its augmentations, and alternative satellite-based positioning and navigation systems.
- Develop measures to prevent the hostile use of GPS and its augmentations to ensure that the United States retains a military advantage without unduly disrupting or degrading civilian uses.

The *Department of Transportation* will:

- Serve as the lead agency within the U.S. Government for all Federal civil GPS matters.
- Develop and implement U.S. Government augmentations to the basic GPS for transportation applications.
- In cooperation with the Departments of Commerce, Defense and State, take the lead in promoting commercial applications of GPS technologies and the acceptance of GPS and U.S. Government augmentations as standards in domestic and international transportation systems.
- In cooperation with other departments and agencies, coordinate U.S. Government-provided GPS civil augmentation systems to minimize cost and duplication of effort.

The *Department of State* will:

- In cooperation with appropriate departments and agencies, consult with foreign governments and other international organizations to assess the feasibility of developing bilateral or multilateral guidelines on the provision and use of GPS services.
- Coordinate the interagency review of instructions to U.S. delegations to bilateral consultations and multilateral conferences related to the planning, operation, management, and use of GPS and related augmentation systems.
- Coordinate the interagency review of international agreements with foreign governments and international organizations concerning international use of GPS and related augmentation systems.

Interagency GPS Executive Board

This was established as a result of the 1996 PDD. Its scope is to manage GPS and U.S. Government augmentations to GPS, consistent with national policy, to support and enhance U.S. economic competitiveness and productivity while protecting national security and foreign policy interests.

To accomplish its goals regarding the management of GPS and U.S. Government augmentations to GPS, the IGEB shall:

- Review status and plans for continued development, acquisition, and operation that affect dual use.
- Approve management policies that affect dual use.
- Resolve interdepartmental issues.
- Provide periodic status reports to the President through the Assistant to the President for National Security Affairs and the Assistant to the President for Science and Technology.
- Consult with U.S. Government agencies, U.S. industry, and foreign governments involved in navigation and positioning system research, development, operation, and use.

The Departments of Defense, Transportation, State, and Commerce (DOD, DOT, DOS, and DOC) are members of the IGEB by virtue of their specific responsibilities in the PDD. Other U.S. Government agencies that have responsibilities identified in the PDD, make substantial use of GPS, and/or provide GPS-related services are also members of the IGEB. The current membership of the IGEB includes:

- Department of Defense (co-chair)
- Department of Transportation (co-chair)
- Department of State
- Department of Agriculture
- Department of Commerce
- Department of Interior
- Chairman, Joint Chiefs of Staff

- National Aeronautics and Space Administration

Operations and Service Provision

The system is operated by the US Air Force's 2SOPS (Second Space Operations Squadron). GPS does not differentiate between operations and service provision.

Standardisation of Services

The civil Standard Positioning Service (SPS) is standardised through the four documents outlined in Section H.2.3.1.

Acceptance by User Bodies

International Maritime Organisation (IMO)

In 1996 the IMO recognised the GPS SPS as a component of the world-wide radio navigation system:

> *At its sixty-sixth session (38 May 1996) the Maritime Safely Committee, pursuant to operative paragraph 4 of resolution A.815(19) on the World-Wide Radionavigation System, recognized the Global Positioning System Standard Positioning Service (GPS-SPS), proposed by the United States Coast Guard, on behalf of the United States Administration in a letter written to the Secretary-General of IMO, as a component of the World-Wide Radionavigation System.*
>
> *The Committee's decision was based on the recommendation and assessment made by the Sub-Committee on Safety of Navigation at its forty-first session (18 to 22 September 1995). The NAV Sub-Cornminee assessed the offer of the. United States Coast Guard in accordance with the requirements of the Annex to resolution A.815(19). The NAV Sub-Committee had agreed that the GPS-SPS meets the operational requirements of the appendix to resolution A-815(19) for navigation in other waters (general navigation).*
>
> *Administrations should note that the static and dynamic accuracy of the system is 100 m (95%) and is therefore not suitable for navigation in harbour entrances and approaches, and other waters in which freedom to manoeuvre is limited.*
>
> *GPS-SPS does not provide instantaneous integrity warning of system malfunction Administrations may wish to note that Receiver Autonomous Integrity Monitoring (RAIM) can provide this facility. It should also be noted that the accuracy and integrity of the system can be greatly enhanced by the use of differential correction techniques using either local or wide area augmentations, or both.*
>
> *Member Governments are invited to bring this information to the attention of their maritime communities.*

International Civil Aviation Organisation

The US offered to make the GPS Standard Positioning Service available at the International Civil Aviation Organization's (ICAO) Tenth Air Navigation Conference, September 5, 1991. The Federal Aviation Administration's (FAA) Administrator, James Busey, promised that GPS would be available free of charge to the international community beginning in 1993 on a continuous, worldwide basis for at least 10 years. This offer was extended the following year at the 29th ICAO Assembly, when the United States offered SPS to the world for the foreseeable future and pledged to provide at least six years notice prior to termination of GPS operations or elimination of the GPS SPS.

Both offers were formally reiterated in a 1994 letter from the FAA's chief, David Hinson, to ICAO, reaffirming the U.S. government's intention to provide GPS SPS free of charge for at least 10 years. In 1995, President Clinton once again confirmed the government's commitment to provide GPS signals to international civil users in a statement that was released at an ICAO meeting in Montreal in March.

H.2.3.3 Service Delivery

General

GPS is a publicly owned system that provides position, velocity and timing. Receivers are widely available with prices ranging from a few tens of dollars for chipsets suitable for mobile telephones to a tens of thousands of dollars for state-of-the-art aviation receivers with embedded application software. Its users span the widest range of applications (see Section I). A GPS safety-case has not been developed.

Baseline Services

The L1-based SPS is currently available. New civil L2 signals will become available on the first Block IIR-M satellites to be launched in 2004. An Initial Operational Capability (IOC) is expected in 2009 and a Full Operational Capability is expected in 2012. The new civil L5 signals will become available on the first Block II-F satellites to be launched in 2006. L5 IOC is expected in 2011 and FOC is expected in 2015.[80]

Service Volume Variations

The service delivered by GPS varied as a function of latitude and longitude primarily due to constellation geometry (Figure 13). It also varies over an eleven-year period due to the solar sun-spot cycle.

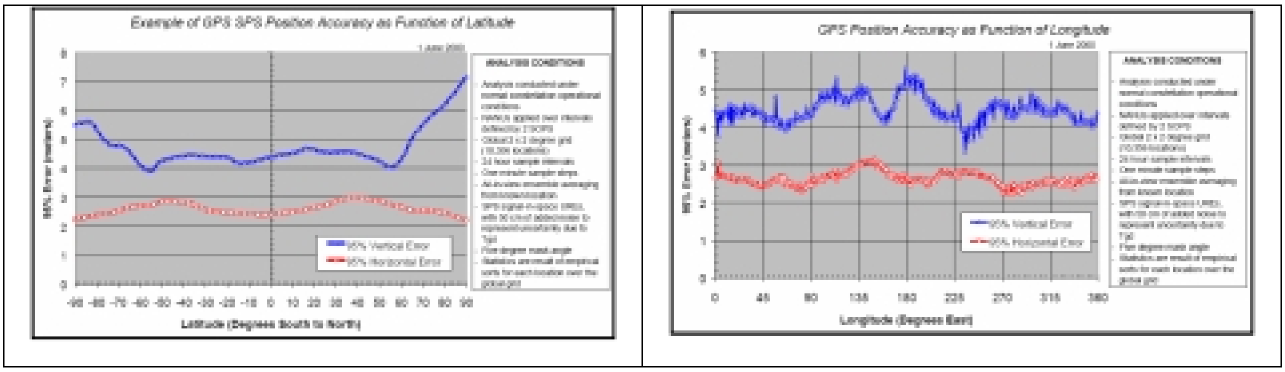

Figure 13 – Variation of GPS Service by latitude and longitude

Performance

US Policy Statement Regarding GPS Availability, March 21, 2003:

- The United States Government recognizes that GPS plays a key role around the world as part of the global information infrastructure and takes seriously the responsibility to provide the best possible service to civil and commercial users worldwide. This is as true in times of conflict as it is in times of peace.

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80 Garrett R P. *GPS Modernization Brief to the CGSIC*. Proc 41st CGSIC, Arlington VA, 19 March 2003.

- The U.S. Government also maintains the capability to prevent hostile use of GPS and its augmentations while retaining a military advantage in a theater of operations without disrupting or degrading civilian uses outside the theater of operations.
- We believe we can ensure that GPS continues to be available as an invaluable global utility at all times, while at the same time, protecting U.S. and coalition security requirements.

SPS Accuracy (Meters) 95%[81] Predictable	Service Availability	Coverage	Service Reliability[82]	Fix Rate	Fix Dimension	System Capacity	Ambiguity Potential
Horz ≤ 13 Vert ≤ 22 Time ≤ 40 ns	99%	Global Service Volume	99.94%	1-20 per second	3D - Time	Unlimited	None

Accuracy

SPS is the standard specified level of positioning, velocity and timing accuracy that is available, without restrictions, to any user on a continuous worldwide basis. SPS provides a global average predictable positioning accuracy of 13 meters (95 percent) horizontally and 22 meters (95 percent) vertically and time transfer accuracy within 40 nanoseconds (95 percent) of UTC. Decisions to change operational modes of GPS to include degrading GPS accuracy provided to civil users will be made by the National Command Authority.

Availability

The SPS provides a global average availability of 99 percent. Service availability is based upon the expected horizontal error being less than 36 meters (95 percent) and the expected vertical error being less than 77 meters (95 percent). The expected positioning error is a predictive statistic, and is based on a combination of position solution geometry and predicted satellite ranging signal errors.

Coverage

GPS coverage is worldwide. The coverage of the GPS SPS service is described in terms of a global terrestrial service volume, which covers from the surface of the earth up to an altitude of 3,000 kilometers.

Reliability

The probability that the SPS signal-in-space URE will not exceed 30 meters is 99.94 percent (global average).

Fix Rate

---

81 Accuracy and availability percentages are computed using 24-hour measurement intervals. Statistics are prepresentative for an average location within the global service volume. Predictable horizontal 95% error can be as large as 36 meters and predicted vertical 95% error as large as 77 meters at the worst-case location in the global service volume. Accuracy statistics do not include contributions from the single-frequency ionospheric model, troposphere, or receiver noise. Availability statistic applies for worst-case location predicted 95% horizontal or vertical position error values.

82 Reliability threshold of 30 meters for a not to exceed SPS signal-in-space User Range Error (URE), for any satellite. Reliability measurement interval is one year, averaged over the globe. Use 99.79% when daily averages are computed from the worst point on the globe.

The fix rate is essentially continuous, but the need for receiver processing to retrieve the spread-spectrum signal from the noise results in an effective user fix rate of 1-20 per second. Actual time to a first fix depends on user equipment capability and initialization with current satellite almanac data.

Integrity

The GPS system architecture incorporates many features including redundant hardware, robust software, and rigorous operator training to minimize integrity anomalies. The best response time, however, may be on the order of several minutes, which is insufficient for certain applications. For such applications, augmentations such as Receiver Autonomous Integrity Monitoring (RAIM), a receiver algorithm, may be required to achieve the requisite integrity.

Spectrum

GPS satellites broadcast at two L-Band frequencies: L1 in the 1559-1620 MHz aeronautical radionavigation/satellite service band and L2 in the 1215-1260 MHz band. The planned third civil signal, L5, is to be centered at 1176.45 MHz in the 1164-1215 MHz aeronautical radionavigation satellite service band.

H.2.3.4 Dependencies

GPS is an independent baseline radio-navigation system that is independent of other systems for data generation or data delivery.

H.2.4 GLONASS

H.2.4.1 Overview

GLONASS (Global'naya Navigatsionnaya Sputnikovaya Sistema = Global Navigation Satellite System) consists (like other GNSS) of three distinct segments: the Ground-based Control Complex (GCS – ground segment); the constellation (space segment) and user receivers (user segment).

The GCS is responsible for data generation and system management. It consists of the System Control Center (SCC) at Krasnoznamensk near Moscow and several Telemetry,Tracking & Control Stations (TT&C). The following figure shows the geographical distribution of the GCS.

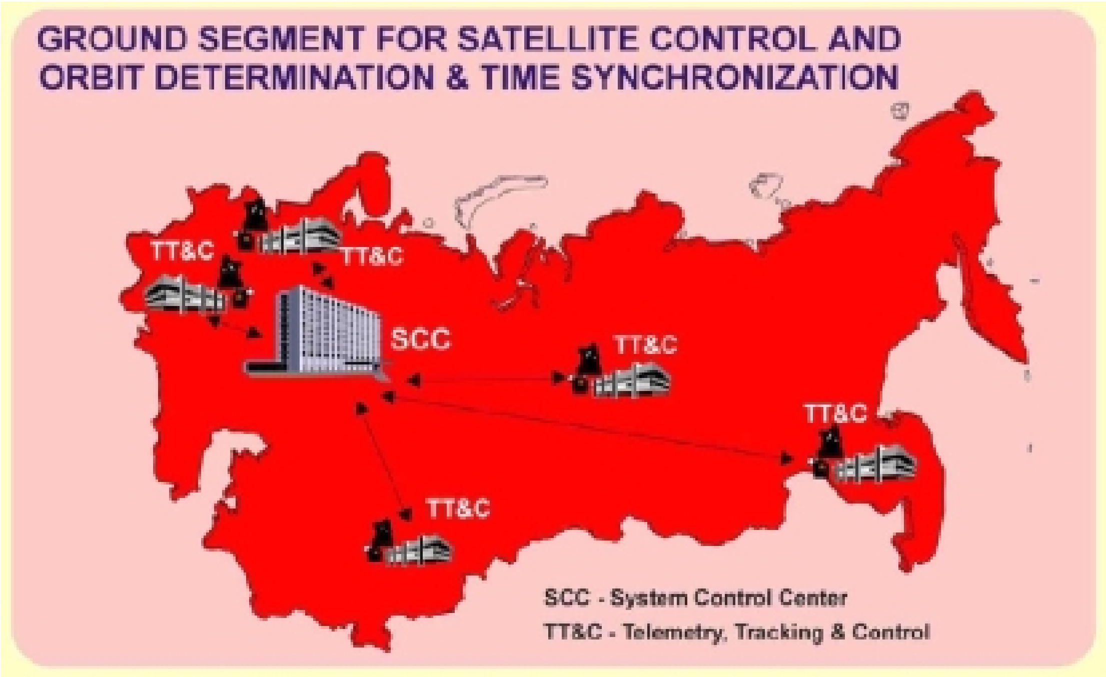

Figure 14 – GLONASS Ground Segment [83]

The TT&Cs track the GLONASS satellites in view and accumulate ranging data and telemetry from the satellites signals. The information from TT&Cs is processed at the SCC to determine satellite clock and orbit states and to update the navigation message of each satellite. This updated information is transmitted to the satellites via the TT&Cs, which are also used for the transmission of control information. The TT&Cs ranging data is periodically calibrated using a laser ranging devices at the Quantum Optical Tracking Stations which are within TT&C system. Each GLONASS satellite specially carries laser reflectors for this purpose. There is the Central Synchronizer within GCS to meet this requirement. The Central Synchronizer is based on a high-precise hydrogen atomic clock which forms the GLONASS system time scale. The onboard time scales (cesium atomic clocks) of all the GLONASS satellites are synchronized with the State Etalon UTC (CIS) in Mendeleev near Moscow, through the GLONASS System Time scale.

The nominal constellation comprises of 24 space vehicles (SV) in inclined medium earth orbits (MEO). The constellation parameters are summarised in the following table:

Constellation Parameter	GLONASS
Number of SV (nominal)	24
Current Number of SV (February 2004) [84]	10
Orbital Planes	3 (equally spaced)
Orbital Height	19 100 km

83 Source: G. M. Polischuk et al, THE GLOBAL NAVIGATION SATELLITE SYSTEM GLONASS: DEVELOPMENT AND USAGE IN THE 21ST CENTURY, 34th Annual Precise Time and Time Interval (PTTI) Meeting, 2002

84 http://gibs.leipzig.ifag.de/cgi-bin/glo_status.cgi?en

Orbital Inclination	64,8°
Orbital Period	11 h 15 min

Table 5 – GLONASS Constellation Parameters

GLONASS satellites currently (February 2004) transmit two types of signal: the Standard Precision (SP) and High Precision (HP) signals. The SP signal L1 has a frequency division multiple access within the L-band: L1= 1602MHz + n0.5625MHz. "n" stands for a frequency channel number (n=0,1.2...). This means that each satellite transmit signals on its own frequency, which differs from the other satellites. Satellites, which are placed in antipodal slots, have the same frequencies, but they do not appear at the same time in the user's view. The next generation of SVs called GLONASS-M will differ from current SVs:

- the frequency band will be shifted to the left: L1 = (1598.0625 – 1605.375) ± 5,11 MHz, L2 = (1242.9375 – 1248.625) ± 5,11 MHz
- the transmission power will be doubled on L2
- previously reserved bytes will be used for additional information, such as divergence between GPS and GLONASS time scales, validity flags (transmitted every 4 seconds), time corrections, and information on navigation data age
- filters will be installed to reduce out-of-band emission in 1610.6 – 1613.8 MHz and 1660.0 –1670.0 MHz frequency ranges down to the level specified in Recommendation 769 of the International Consulting Radio Committee
- on both frequencies L1 and L2, civil and special signals will be transmitted that contain digital data and ranging codes for pseudorange measurements.

The follow-up generation of SVs called GLONASS-K will provide additional features beyond the GLONASS-M capabilities:

- a third frequency in the L-band
- increased satellite life-time (10 years)
- reduction of satellite mass by ~50%
- SAR payload.

H.2.4.2 Institutional

Since the beginning of the GLONASS system development, the State Enterprise of Applied Mechanics (NPO PM) has been the main system contractor. NPO PM is responsible for the system’s general development and implementation; development and manufacturing of the navigation satellite and facilities for launch preparation; and development of its automated control system. The main subcontractors are:

- the Russian Scientific-Research Institute of Space Industry (RNII KP): responsible for the development of satellite radio equipment; monitoring and control subsystems; and receivers for nautical and space users
- the Russian Institute of Radionavigation and Time (RIRV): responsible for the development of precise satellite and ground frequency standards, as well as for synchronization, and receivers for air and ground users

In March 1995, the Russian Federation Government Resolution offered GLONASS services for civil use to ICAO and IMO for a long term period.

Several directive documents were approved by the Russian President and Government and aimed at unconditional maintenance and development of the GLONASS system. Probably the most important is the federal dedicated and mission-oriented program “Global Navigation System.” Approved by the Government of the Russian Federation on 20 August 2001 by the Government Decision N 587 the program’s duration is scheduled from 2002 to 2011. The main goals of the program are:

- successive development and effective use of GLONASS, applying advanced GNSS-technology to provide state social and economy development and state security
- saving the role of Russia in the GNSS sector by guaranteed service provision for Russian and international users

The main program tasks are:

- development and implementation of Space Segment and Ground Control infrastructure for GNSS
- GLONASS constellation maintenance at the required level
- GLONASS geodetic system improvement
- fulfilment of international commitments of Russia in the field of satellite navigation
- development of international cooperation
- participation in international projects
- development and manufacturing of competitive user equipment to be provided for the Russian and international markets
- creation of a new geodetic network structure implementing a highly accurate geocentric reference
- creation and development of a scientific, technical, and technological basis for further GNSS

The program customers are:

- Russian Aviation and Space Agency (Rosaviakosmos) – Program Coordinator
- Ministry of Defence of Russian Federation (MoD) – Coordinator of program tasks for Russian Federation defence and security
- Ministry of Industry, Science, and Technology of the Russian Federation (MoIST)
- Ministry of Transport of the Russian Federation (MoT)
- Russian Agency of Control Systems (RACS)
- Russian Federal Mapping Service (Roskartographia).

The contents of the program are:

- Subprogram 1: Provision of GLONASS operation and development. (Rosaviakosmos and MoD)
- Subprogram 2: Development, industry preparation, and manufacture of user equipment for civil users(RACS)

- Subprogram 3: Implementation and use of GNSS for transportion (MoT)
- Subprogram 4: Use of GNSS for geodetic provision of Russia (Roskartographia)

H.2.4.3 Service Delivery

The GLONASS system has two types of navigation signal: standard precision navigation signal (SP) and high precision navigation signal (HP). SP positioning and timing services are available to all GLONASS civil users on a continuous, worldwide basis and provide the capability to obtain horizontal positioning accuracy within 57-70 meters (99.7% probability), vertical positioning accuracy within 70 meters (99.7% probability), velocity vector components measuring accuracy within 15 cm/s (99.7% probability) and timing accuracy within 1 ųs (99.7% probability).

Source: http://www.glonass-center.ru/int.html

H.2.4.4 Dependencies

GLONASS is an independent system.

H.2.5 Loran-C

H.2.5.1 Overview

Loran-C is a terrestrial long wave Radionavigation system, providing 2D position information using either the hyperbola mode, based on measurements of Time Differences (TD) between stations within one transmission-chain, or using the all-in-view mode, based on Time of Arrival (TOA) measurements to all transmitters received. A frequency of 100 kHz was chosen for the Loran-C carrier wave to take advantage of propagation of the stable ground wave to long distances.

Loran-C transmitters are organised into chains of 3 to 5 stations. Within a chain one station is designated Master (M) and the others secondary stations identified by the letters W, X, Y and Z. The Loran-C navigation signal is a structured sequence of pulses on a carrier wave centred at 100 kHz. All secondary stations radiate pulses in groups of eight, whereas the Master signal, for identification purposes, has an additional ninth pulse. The sequence of signal transmissions consists of a pulse group from the master station followed at precise time intervals by pulse groups from the secondary stations. The time interval between the reoccurrence of the Master pulse is called the Group Repetition Interval (GRI). Each Loran-C chain has a unique GRI. Since all Loran-C transmitters operate on the same frequency, the GRI is the key by which a receiver can identify and isolate signal groups from a specific chain. The hyperbolic method is visualised in the next figure.

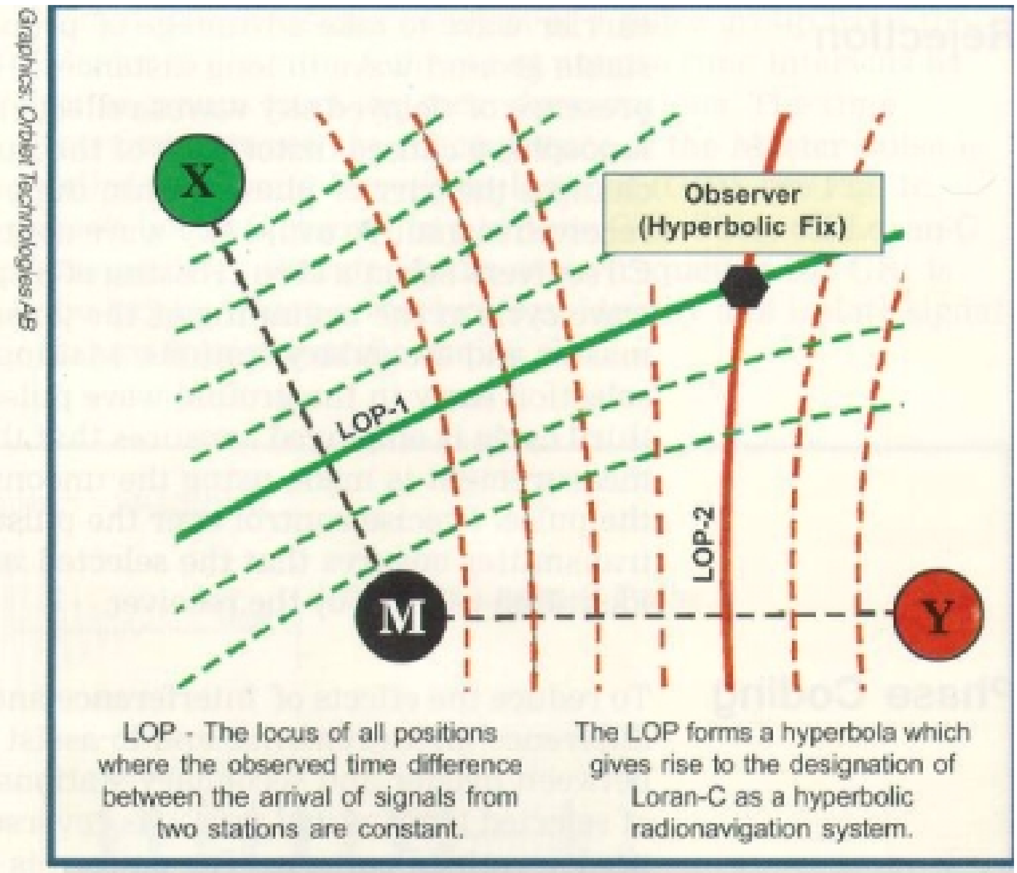

Figure 15 – Loran-C – Hyperbolic Mode [85]

To perform TOA-measurements the Loran-C transmitters have to be synchronised. There are two basic methods for monitoring and adjusting the clocks in Loran-C systems. The most commonly used method up to now is to measure the time difference between Loran-C signals received from a master and a secondary at a fixed location in the coverage area. Timing control includes making adjustments to the clock of the secondary station so that the measured TD is kept at a predetermined value. The measurement equipment at the fixed location is called a System Area Monitor (SAM); hence this method of timing control is referred to as SAM control. In the other method for timing control, used by NELS, there are no SAMs. Instead, arrival times of signals from adjacent transmitters are measured relative to the local clock at each transmitter station. The measurements from all stations in the system are sent by permanent data-link to the control station where they are combined so that the time deviation of each transmitter's clock can be calculated. Computed adjustments are returned to the individual transmitter sites where they are used for clock synchronisation. This results in a common time reference for the Time Of Emission (TOE) of the Loran-C pulses from all transmitters and is called TOE control.

H.2.5.2 Institutional

Loran-C was introduced in Europe by the United States Coast Guard (USCG) in the 1950s to meet U.S. naval requirements. At the beginning of the 1980s, the USCG made it known to the host nations that Loran-C in Europe would no longer be required by the U.S. military after 1994 and the host nations would be offered the option to take over the stations on their own territory. This resulted in consultations among interested nations leading to a recommendation to maintain Loran-C in Northwest Europe. On this basis an International

85 http://www.nels.org/images/loran_system3.jpg

agreement concerning the establishment and operation of the civil Loran-C system in Northwest Europe and the North Atlantic was signed in 1992 by representatives from Denmark, France, Germany, Ireland, the Netherlands and Norway. France made its two already established Loran-C stations available for full integration into the new system and offered to establish and operate a TOE-based Control Centre for the entire system in Brest, taking advantage of experience gained in TOE control of their national Loran-C chain. Under the signed agreement each member nation of NELS owns the facilities on its own territory and appoints a National Operational Agency (NOA) to manage these facilities and look after its national interests. The overall control of NELS rests with a Steering Committee (SC) composed of representatives from all participating nations and observers from interested nations and organisations. Everyday co-ordination of NELS operations is left to a Co-ordinating Agency (CA). Norway has accepted the role as CA, and a Norwegian Government organisation has been tasked to be responsible for the functions given the CA in the NELS agreement. The following figure shows the NELS organisational structure.

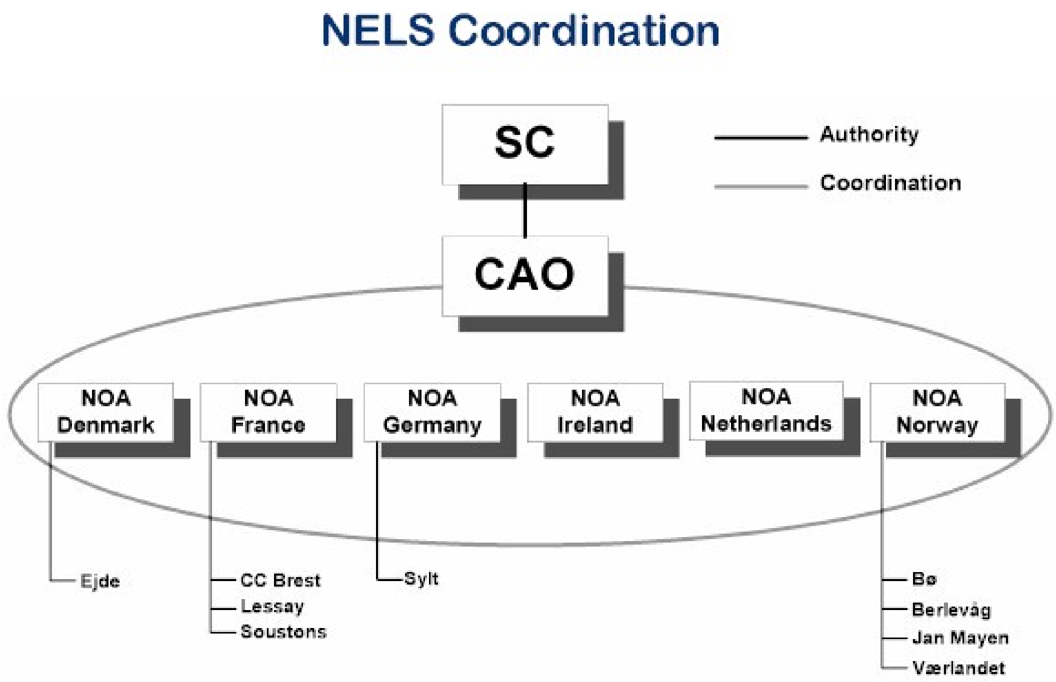

Figure 16 – NELS organisational structure

Beside the member states of NELS, the following states and organisations have the status of an observer:

- Austria
- Italy
- Russia
- U.K.
- USA
- Arab Institute of Navigation (AIN)
- European Commission (EC)
- Far East FERNS

- IALA

The Czech Republic and Poland have addressed their interest to participate to NELS and potential supporters are:

- Greece
- Hungary
- Slovakia
- Slovenia
- Switzerland

The future development of NELS is under consideration at the moment. The decision will be final till October 2003 since the nations have to inform the NELS Depositary in the period April - September 2004 if they want to withdraw from the NELS Agreement. If no information is received by the Depositary then the Agreement will be prolonged for another seven years.

The current situation (February 2003) is the following: Denmark, Germany and Norway want to withdraw from NELS and have had their decision confirmed by the Parliament. Ireland and the Netherlands want to withdraw from NELS, but have not had their decision confirmed by the Parliament. The UK has not decided whether or not they would like to join NELS. Only France has stated that they want to continue Loran-C, either within NELS, but France is also open to other alternatives. France has offered to take responsibility and cover the operational costs for the stations Ejde and Sylt and in addition erect 1-2 new stations in France and later on maybe further stations in case the NELS Agreement will not be continued. The German approach to continue Loran-C operation in Europe is based on private investments to fund Loran-C activities.

H.2.5.3 Service Delivery

The coverage area of the European Loran-C system is shown in the following figure.

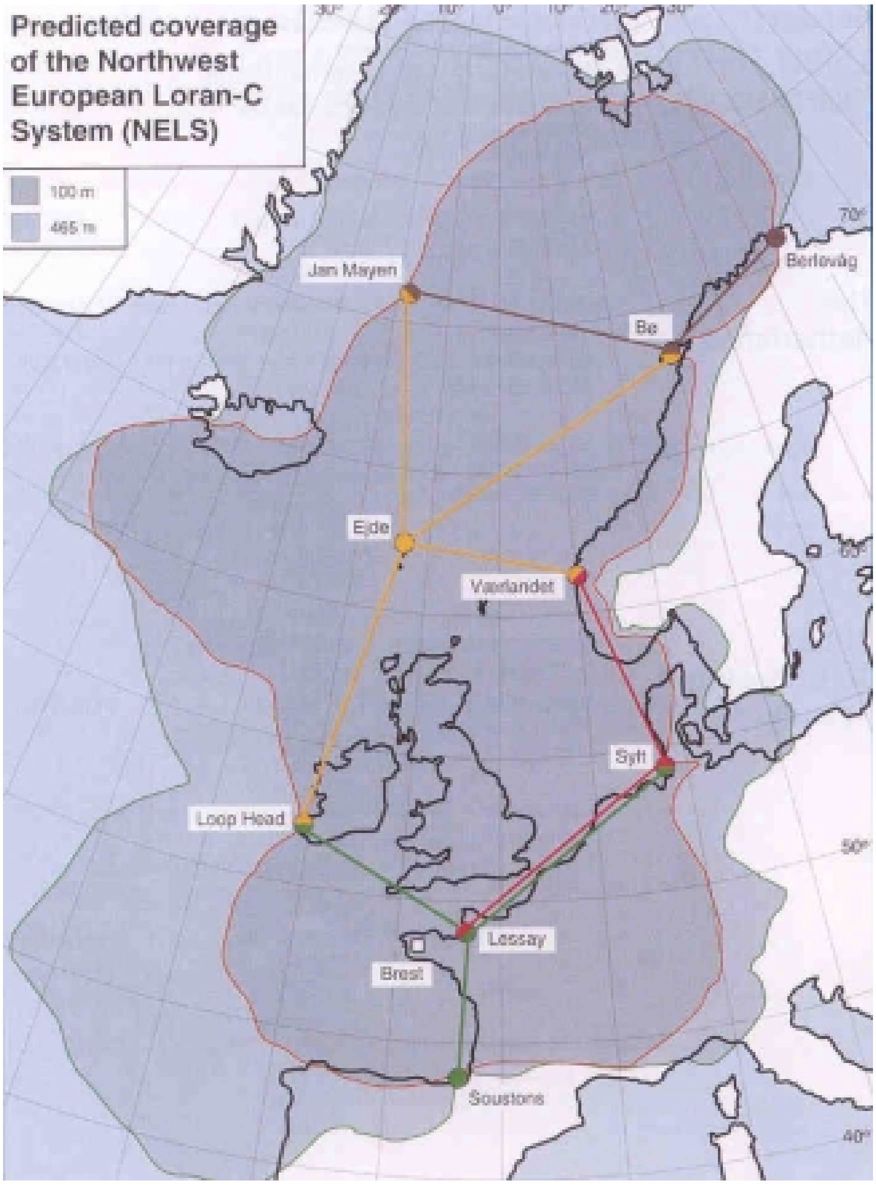

Figure 17 – NELS Coverage

A Loran-C receiver computes distances from Loran-C transmitting stations using the time of arrival measurements and the propagation velocity of the radio ground wave to determine position. Small variations in the velocity of propagation between that over sea water and over different land masses are known as the Additional Secondary Factor (ASF). Corrections may be applied to compensate for this variation. Such corrections may improve the absolute accuracy of the Loran-C service in positions where the received Loran-C signal passes over anything but sea water on its way from transmitter to receiver. The values of ASF depend mainly on the conductivity of the earth's surface along the signal paths. Sea water has high conductivity, and the ASFs of sea water are, by definition, zero. Dry soil, mountains or ice generally have low conductivity and radio signals travel over them more slowly, giving rise to substantial ASF delays and hence degradation of absolute accuracy. Fortunately, ASFs vary little with time, and it is possible to compensate the ASF influence. This could either be done by calibrating the Loran-C position (e.g. by using GNSS), determine the local ASFs and compensate their influence, or include ASF models into the position calculation. A program for mapping of ASFs in northern Europe was carried out by NELS and an ASF electronic database is available.

Loran-C stations are constantly monitored to detect signal abnormalities which would render the system unusable for navigation. Blinking the Loran-C signal is the prime means by which the user is notified that the transmitted Loran-C signal does not comply with the system specifications. Blink also indicates that the Control Centre cannot ensure that the signal complies with these specifications, for instance, as a result of discontinuation of data communications linking the Control Centre to the stations. Blink is a distinctive change in the group of eight Loran-C pulses that can be recognised automatically by a receiver so the user is notified instantly that the Loran-C chain blinking should not be used for navigation. Blink starts at a maximum of 60 seconds after detection of an abnormality. Automatic blink initiated within 10 seconds of a timing abnormality may be added where Loran-C is extensively used for aviation purposes.

In the USA the FAA and USCG are conducting a joint evaluation to determine whether Loran can support non-precision instrument approach operations for civil aviation and harbour entrance and approach operations for maritime users. It is envisioned that minor changes in the transmitted signal and equipage with modern all-in-view receivers will be required to achieve these levels of performance. These changes are not currently anticipated to adversely affect legacy Loran-C receivers. The resulting capability is referred to as Enhanced Loran.

	Accuracy	Availability	Integrity	Continuity
Current Loran-C	**0.25 nm (460 m)**	**0.997**	**10 sec alarm (25 m error)**	**0.997**
Aviation Enhanced Loran	0.16 nm (296 m)	0.999	0.9999999	0.999 – 0.9999
Maritime Enhanced Loran	0.004 – 0.01 nm (8-20 m)	0.997	10 sec alarm (25 m error)	0.9985 – 0.9997 (3 hours)
Enhanced Loran Timing	UTC +/- 30 ns Frequency 10^{-11}	NA	NA	NA

Figure 18 – Loran-C System Performance [86]

Note: The figures given in the table above refer to absolute accuracy. Several studies have demonstrated that the repeatable horizontal accuracy of Loran-C is in the order of 10-20m.

H.2.5.4 Dependencies

Loran-C is an independent system.

H.2.6 Chayka

H.2.6.1 Overview

Chayka (Russian for “seagull”) is a terrestrial radionavigation system very similar to Loran-C. It was established by the former Soviet Union and is still used in Russia and surrounding territories and seas. Like Loran-C Chayka consists of chains made up of a master station and a number of secondaries.

Chayka works with a pulse-modulated frequency of 100 kHz. Receivers measure the time difference between the arrivals of a given wave form from the master and any particular secondary station. Those time differences can be converted into position, velocity, and time and frequency reference information.

86 Radionavigation Systems: A Capabilities Investment Strategy - A Report to the Secretary of Transportation, Radionavigation Systems Task Force, Overlook Systems Technologies, Inc., 2004.

Each station in the Chayka networks transmits pulses with standard characteristics. All secondary stations transmit signals in packets of eight impulses at intervals of 1000 µs. For identification purposes the master emits a ninth impulse 1890 µs after the eighth. The transmission restarts after a chain-specific group repetition interval (GRI) between 40.000 and 100.000 µs.

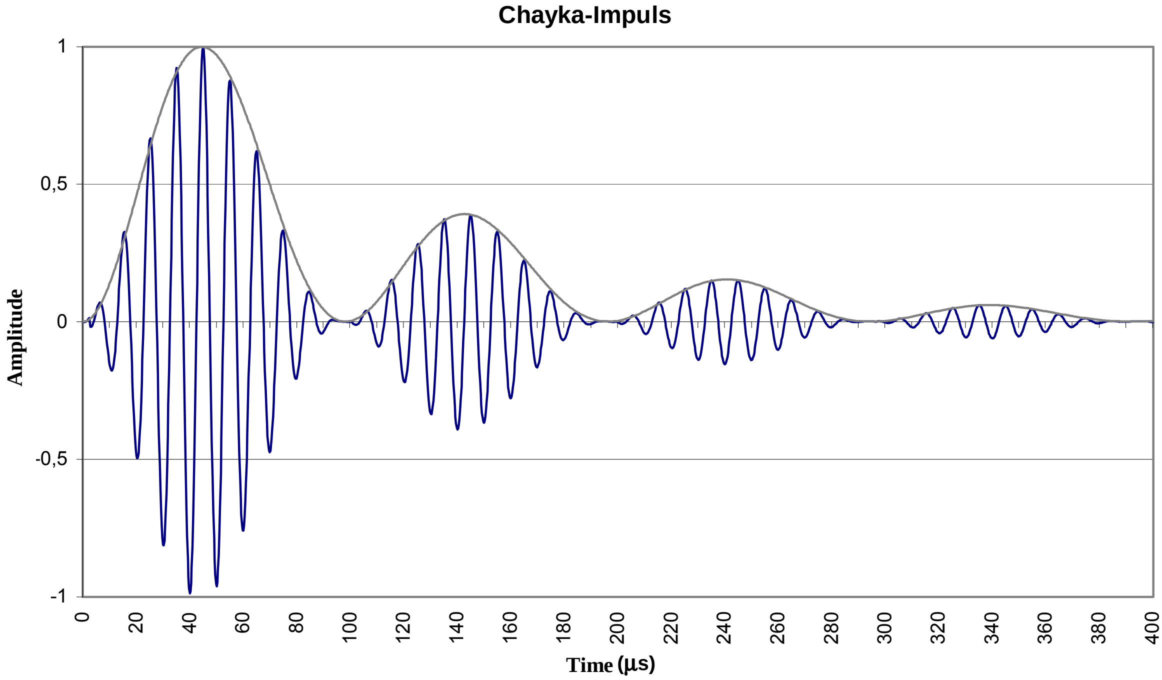

Figure 19 – Chayka Impulse (carrier wave and upper envelope)

In order to allow automatic detection and identification of the signals and to reduce the influence of multiply reflected signals, the signals are phase-coded. Each secondary transmits with its own specific code delay relative to the master signal. Those delays are selected such that the order of reception of secondary signals is identical everywhere within the assigned network operation area.

H.2.6.2 Institutional

Russia strongly supports its Chayka system and will continue Chayka operations regardless of the future of GLONASS. Russia currently works on transmission of a Eurofix-like signal from some of their Chayka stations. Additionally, the work on an integrated Chayka/GNSS/DGPS receiver has started. The Russian Federation-controlled Chayka networks will not be considered for phasing out until at least the year 2010.

H.2.6.3 Service Delivery

The figures below indicate the coverage areas of the Chayka chains and some chains which are co-operated with American Loran-C stations or with the Far East Radio Navigation Service (FERNS)[87].

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87 taken from: Internavigation RTC (Interstate Navigation and Information Center), Organization of navigation and information maintenance of the consumers in Russia and CIS, http://user.cityline.ru/~vkntc/

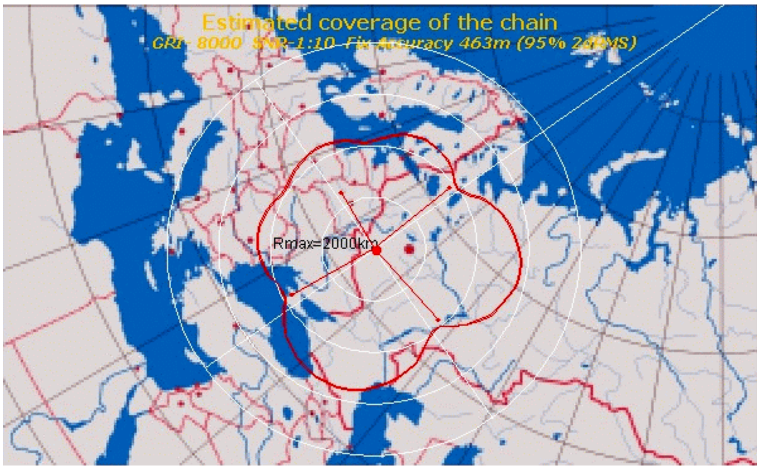


Figure 20 – Coverage of the European Chayka Chain (GRI 8000)

Figure 21 – Coverage of the North West Chayka Chain (GRI 4970)

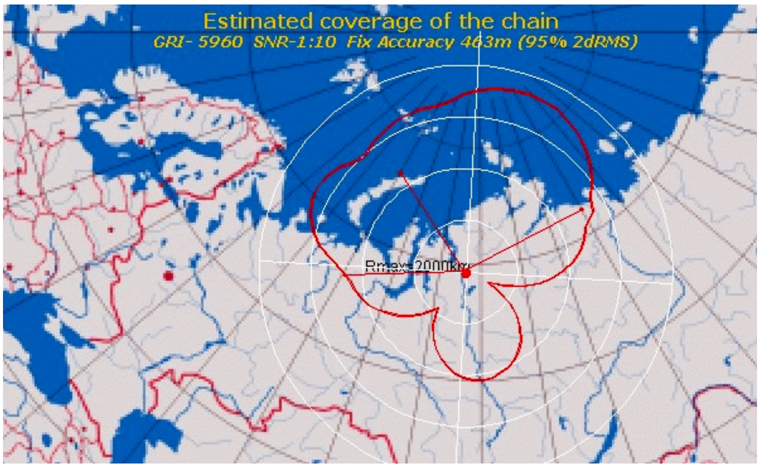


Figure 22 – Coverage of the Northern Chayka Chain (GRI 5960)

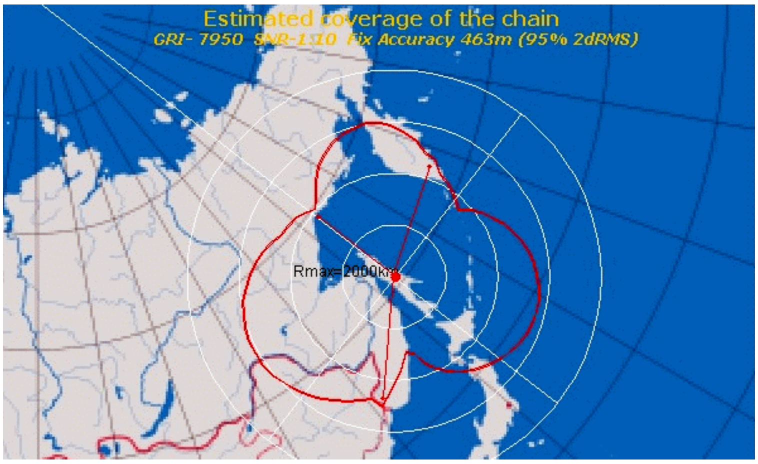


Figure 23 – Coverage of the Eastern Chayka Chain (GRI 7950)

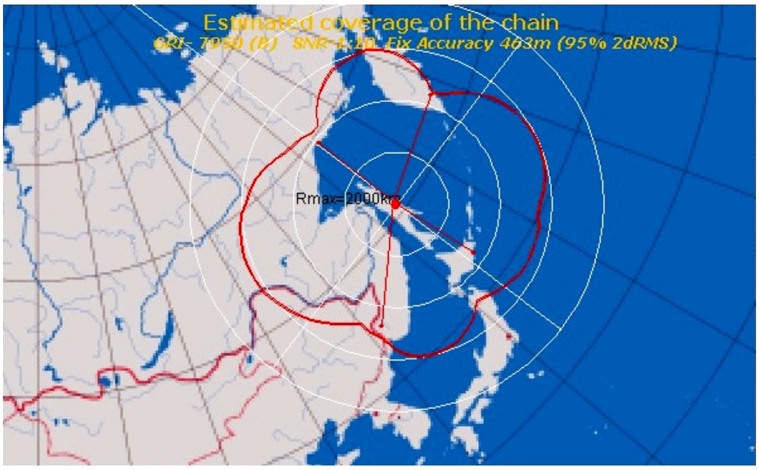


Figure 24 – Coverage of the Russian Japan Chain (7950B)

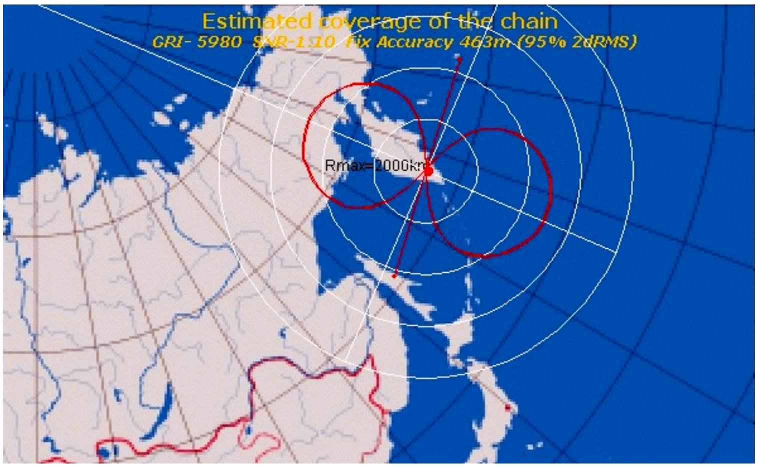


Figure 25 – Coverage of the Russian American Chain (GRI 5980)

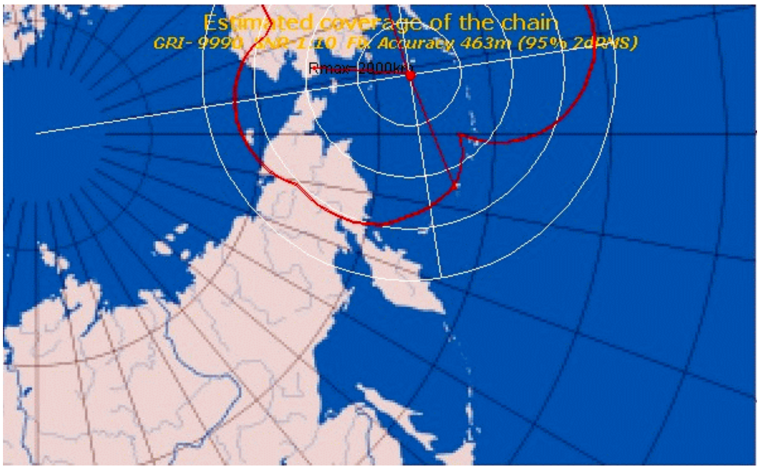


Figure 26 – Coverage of the North Pacific (American) Chain (GRI 9990)

H.2.6.4 Dependencies

Chayka is an independent system.

H.2.7 NDB

H.2.7.1 Overview

The main purpose of non-directional beacons is to provide navigation to aviators and mariners. Though not as complex and expensive as some of the newer NAVAIDS, the NDB still provides basic navigation capabilities.

Non-directional beacons (NDBs) act as omnidirectional radio transmitters, which are used to provide craft bearing with respect to the beacon. Aircraft make use of radio beacons to aid in finding the initial approach point of an instrument landing system as well as for non-precision approaches at low traffic airports without convenient non-precision or precision approach systems.

NDB's are unlikely to be used at major international airports, which have other systems in profusion. Maritime and aeronautical NDBs exist, with the latter being the most predominant. The maritime NDB's are situated at prominent points along coastlines, often near other marine navigational devices such as lighthouses, jetty lights, and foghorns. The aeronautical NDB's are situated in the vicinity of airports, under inbound flight paths, and may also be known as outer, middle, or inner markers

NDBs are connected to a single vertical antenna. The vertical pattern produced is shown in the diagram below:

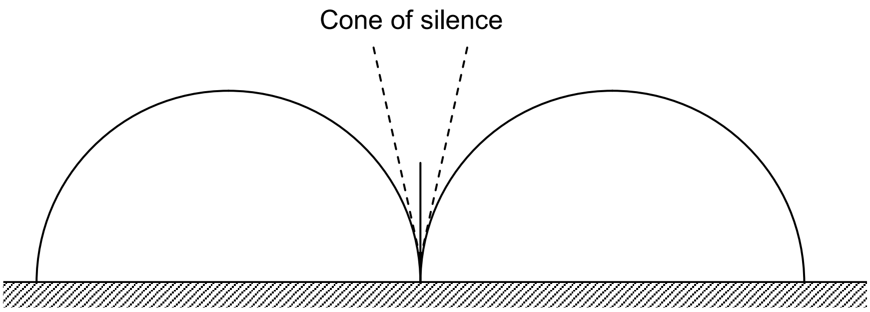


Figure 27 – CAPTION REQUIRED

The sharp reduction in signal strength as the aircraft flies directly over the beacon enables a specifically defined fix. The accuracy of such a fix produced by the "cone of silence" is dependant on the airborne antenna.

NDBs have remained popular since:

- They are inexpensive;
- They are omnidirectional;
- They place responsibility for accuracy on the airborne receiver.

NDB Signals

- Maritime NDBs transmit primarily in the LF and MF frequency band (283.5 – 315 kHz).
- Aeronautical NDBs also transmit in the LF and MF band (190-1750 kHz), although most European NDBs use the 325-405 kHz band.
- Transmission of the Morse code for identification of the station either interrupts the carrier, which is called Coded Continuous-Wave (CCW) or is modulated on a 1020 Hz or a 400 Hz tone, which is called Modulated Continuous-Wave (MCW).

For reception and bearing measurement a radio direction finder is required. This device is also known as an Automatic Direction Finder (ADF). The purpose of the ADF is to point to a non-directional beacon.

NDBs are often easily accessible and therefore prone to physical damage. Fortunately, many stations simultaneously are often in reach of an aircraft using the system which yields a rather high level of redundancy in the spatial domain.

One potential source of interference within the NDB frequency range (255kHz to 526.5kHz) is the xDSL.

Failures of both maritime and aeronautical NDBs are notified through navigational warnings on communications and broadcast frequencies, for instance Broadcast Notice to Mariners. Beacons used for non-precision approach will shut down within 15 seconds after the occurrence of the anomaly.

H.2.7.2 Institutional

The local civil aviation authorities control the aeronautical NDBs. They are responsible for the service and maintenance of all ground components (i.e. the transmitters). The airline operators are responsible for receivers onboard their aircraft.

Signal format is standardized by ICAO.

H.2.7.3 Service Delivery

All air carriers, most military, and many general aviation aircraft carry automatic direction finders (ADF). However, the importance of ADF is expected to decline with the increasing popularity of GPS. Decommission of stand-alone NDBs is expected to start in 2008.

NDBs provide position information with respect to the beacon.

Range

- Aeronautical beacons cover an omnidirectional radius varying between 45 and 280 km (25 and 150 nmi)

- Maritime beacons have a nominal range between 45 and 360 km (25 and 200 nmi).

Accuracy

- Maritime beacons have an accuracy of around ±5 degrees
- Aeronautical beacons have an accuracy of around ±3 to ±10 degrees

Bearing measurements may be influenced by skywaves, land/sea transitions, transmitter siting, static discharge, thunderstorms and noise. Positioning accuracy is influenced by the angle of cut between the LOPs, which is the geometry factor, the accuracy of the compass heading and the accuracy of the bearing measurements.

Fix Rate

Aeronautical NDBs provide continuous fixes. Maritime NDBs also provide continuous fixes, except when a group of beacons timeshare the same frequency, i.e. transmit sequentially. This group is maximally 6 in size and has time slots of 1 minute per beacon. Independent fixes may then be obtained every six minutes.

Fix Dimension

Bearing with respect to the beacon. This can also be interpreted as a line of position. Two of these lines provide two-dimensional position.

Availability

Better than 99%

Reliability

Better than 99%

Capacity

Unlimited.

H.2.7.4 Dependencies

None.

H.2.8 VOR/DME

H.2.8.1 Overview

VOR/DME is the basic aircraft continental en-route navigation aid and provides guidance for all continental airways. VOR gives the azimuth towards the beacon and DME provides the distance to the beacon. Terminal VOR/DME stations are used for terminal and non-precision approach. The daily operational control over the system lies in the hands of the national governments.

As each component performs a different function, they are best dealt with separately

VOR (Very High Frequency Omnidirectional Range)

VOR is the most common radio navigation aid in use today. Its primary use is in defining airways (aircraft corridors), and as such remote VORs (not associated with an airport) will usually be sited so as to define major airways between airports. Airport VORs usually have an additional use: they provide the pilot with lateral (azimuth) guidance during final approach in inclement weather, known as the 'VOR approach'. VORs represent a significant advancement from older forms of navaids (e.g NDBs). Their use of VHF radio signals virtually eliminates interference by atmospheric events such as thunderstorms and precipitation static. The use of a phase-difference technique enables the pilot to know the bearing of his aircraft from the station.

The VOR operates in the 108MHz to 118MHz band, with channels spaced 100kHz apart (x-channel). Only until present low-sensitivity airborne receivers can be served by better channel arrangements, channels will be spaced 50kHZ (y-channel) apart to double the availability. VOR stations also transmit a Morse code every ten seconds for identification. VOR frequencies are coupled to DME frequencies.

The VOR signal consists of two components from which the azimuth towards the station can be determined. The two components are:

- 30 Hz reference signal.
- 30 Hz rotating signal.

The phase difference of the two signals can be measured and used to find the angle with respect to the magnetic north.

To the pilot, this information is displayed in the form of a needle showing him which radial his aircraft is on, and how close to the centre of that radial it is. As such, direct tracks to and from the VOR station can be accurately flown, and any sideways drift (due to wind, for example) is quickly brought to the attention of the pilot, who can then act to correct it.

At VHF frequencies, the line of sight (LOS) needs to be clear of obstacles whose size is 1 metre or larger. The transmitter site also needs to be cleared, because the system is very sensitive to reflections from these. To overcome such problems, the Doppler VOR was developed, which comprises of a larger number of antennas (50). The same level of obstacle clearance is not required using DVOR due to the larger size of the antenna structure. DVOR is completely compatible with normal VOR.

The receiver derives the direction of the station by phase comparison of the two signals. It can combine the information of VOR and DME to determine the position in polar co-ordinates, or by knowing the azimuth to two VOR stations, which is known as theta-theta positioning.

The quality of the data available is adversely influenced by factors such as radio noise, antenna masking, terrain interference, signal strength, and phase shift variations. The coupler also has to struggle with behavioural anomalies caused by geometry and distance, since VOR is associated with angles.

VORs are often easily accessible and therefore prone to physical damage. Fortunately, many stations simultaneously are often in reach of an aircraft using the system which yields a rather high level of redundancy in the spatial domain.

The VOR station is constantly monitored. The signal is removed within 10 seconds in the event that it is out of tolerance. The monitoring function is independent of the transmitter function.

DME (Distance Measuring Equipment)

Such equipment is used to measure the direct distance between the aircraft and the antenna, which is then presented to the pilot. When the DME is co-located with the VOR, the pilot will know:

- The aircraft's bearing from the station.
- The distance from the station.

This allows a position fix to be made.

Signal

DME is an internationally standardized pulse-ranging system for aircraft, operating in the 960-MHz to 1215MHz band. This band is divided into 126 channels, with a separation of 1 MHz. Every DME channel is coupled to a VOR channel, with which the DME station forms a combined VOR/DME station. However, not every DME facility is co-located with a VOR station.

The aircraft carries an interrogator which actively transmits signals, that are returned by a ground based transponder. The DME equipment on the aircraft transmits pulses on one of the 126 frequencies, spaced 1MHz apart. The pulses are in pairs, 12 µs apart, with each pulse lasting 3.5µs. The pulse pair repetition rate can range from 5 to 150 pulse-pairs per second. Pulsed pairs are used to reduce interference with other pulse systems.

The transponder receives these pulses and retransmits them back to the aircraft on a frequency 63MHz below or above the transmitting frequency, after a fixed 50µs delay. The airborne interrogator compares the elapsed time between transmission and reception, takes into account the 50µs delay, and displays the result on a meter calibrated in nautical miles. To be able to recognise the reply of the ground transponder to its own transmitted pulse-pairs, the interrogator uses a unique "jitter" of the pulse-pair spacing.

Interference

DMEs are often easily accessible and therefore prone to physical damage. Fortunately, many stations simultaneously are often in reach of an aircraft using the system which yields a rather high level of redundancy in the spatial domain.

Integrity

The DME station is constantly monitored. The signal is removed in case it is out of tolerance within 10 seconds. The monitoring function is independent of the transmitter function.

H.2.8.2 Institutional

The local civil aviation authorities control both the VOR and DME. They are responsible for the service and maintenance of all ground components (i.e. the transmitters). The airline operators are responsible for receivers onboard their aircraft.

Signal format is standardized by ICAO, and is protected by ICAO agreement to January 1, 2010.

H.2.8.3 Service Delivery

VOR is the primary radio navigation aid in the National Airspace System and is the internationally designated standard short-distance radio navigation aid for air carrier and general aviation IFR operations. It is easy to use and is generally liked by pilots. Because it forms the basis for defining the airways, its use is an integral part of the air traffic control procedures.

Both VOR and DME provide position information.

The current VOR/DME network will be maintained until 2008 to enable aircraft to become equipped with WAAS avionics and to allow the aviation community to become familiar with the system.

VOR:

Accuracy

For the ground station contribution:

- VOR accuracy around 2 degrees
- DVOR accuracy around 0.5 degrees

Receiver contribution:

- Between 1 and 5 degrees. With modern equipment, more closer to 1 degree.

ICAO requires a maximum ground station contribution of 2 degrees (95 percent).

Availability

For the solid state equipped transmitters, the availability comes close to 100 percent.

Range

- For low altitudes (< 1500 m or 5000 ft) the LOS limits the range, due to the curvature of the earth. The range is approximately 56 km (30 nmi).
- For medium altitudes (< 6000 m or 20000 ft) the range is approximately 185 km (100 nmi), and for higher altitudes, the VOR range can be as much as 370 km (200 nmi).

Fix Rate

VOR enables continuous measurement of the azimuth angle.

Fix Dimension

The VOR receiver gives the magnetic bearing from the VOR station towards the aircraft and also the angular course deviation from the desired track.

Capacity

Unlimited.

DME:

Accuracy

Operating on the line-of-sight principle, DME furnishes distance information with a very high degree of accuracy. Reliable signals may be received at distances of up to 199nm at the line-of-sight altitude with an accuracy of better than $^1/_2$ mile or 3 percent of the distance, whichever is greater. Distance information received from DME equipment is slant range distance and not actual horizontal distance.

Availability

Close to 100%

Range

DME is limited to line-of-sight, and is the limiting factor in the coverage of the DME station beyond 56 km (30 nmi). At higher altitudes (> 1500 m or 5000 ft) the range is 185 km (100 nmi), and for the terminal area VOR/DME stations, the range is assumed enough to cover the entire terminal area.

Reliability

Close to 100%.

Fix Rate

Fix rate DME is limited to line-of-sight. DME allows 10 fixes per second.

Fix Dimension

DME provides the aircraft's slant range to the DME ground station.

Capacity

Each beacon is designed to handle at least 50 aircraft simultaneously, with 100 being a more typical number.

Ambiguity

There is no ambiguity in the range measurement.

H.2.8.4 Dependencies

The DME and VOR depend on one another for effective operations.

H.2.9 ILS

H.2.9.1 Overview

The instrument landing system is a collection of radio transmitting stations used to guide aircraft to a specific airport runway, especially during times of limited visibility. High-density airports may be equipped on more than one runway.

Typically, an ILS includes:

a) The localizer transmitter, which is centred on the runway beyond the stop end to provide lateral guidance.

b) The guide slope, which is located beside the runway near the threshold to provide vertical guidance.

c) Marker beacons, which are located at discrete positions along the approach path; to alert pilots of their progress along the guide path.

d) Radiation monitors, which, in the case of ILS failure alarm the control tower, may shut-down a Category I or II ILS, or switch a Category III ILS to backup transmitters.

Increasingly, DMEs are located with the ILS, and distance readouts in the cockpit are used instead of marker beacons.

Signal

The localizer, glide slope and marker beacons radiate continuous wave, horizontally polarized, radio frequency energy. The bands of operation are:

Localizer: 40 channels from 108-112MHz

Glide slope: 40 channels from 329-335MHz

Marker beacons: all on a single frequency of 75MHz.

An audible Morse code identification signal is transmitted on the localizer frequency, and a voice channel from the control tower may also be provided

The localiser and glide slope form narrow guidance beams with an antenna array. When the number of elements is increased, the antenna aperture becomes wider and the beam becomes narrower. The two angle functions use 90 Hz and 150 Hz AM modulation on the RF carrier and have 40 channels.

A typical localizer is an array of antennas usually located 600 to 1000ft beyond the stop end of the runway. The array axis is perpendicular to the runway centreline, and the course is aligned with this centreline. Localizer arrays range from 40 to 130ft in length on which are mounted from 6 to more than 20 antennas.

The frequencies of the localiser and glide slope are paired. The glide slope antenna is normally placed at 300 meters from the approach end of the runway next to the touch down point. The glide slope antennae is a vertical array, using the images of the element through ground reflection. The glide slope is therefore very sensitive to the flatness of the terrain in front of the antenna. Snow also influences the radiation pattern.

The ILS angle functions are affected by the surrounding environment through multipath from buildings and structures. This causes bending of the beams. Stringent siting requirements are therefore imposed by ICAO to guarantee good performance.

Measurement of the course deviation with respect to the nominal glide path and course line is performed by measuring the difference in depth of modulation (DDM) between the 90 and 150 Hz modulations.

Marker beacons provide pilot alerts along the approach path. The outer marker (OM) is placed under the approach course near the point of glide path intercept around 4-7 nmi from the threshold. The middle marker (MM) is placed near the point where a missed-approach decision would need to be made for a Category I approach procedure (around 3000ft from the threshold). The inner marker (IM) may be required at runways certified for Category II and III operations and is placed near the point where the glide path is 100ft above the runway (around 1000ft before threshold).

A unique Morse code and light display in the cockpit identify the marker beacons

Interference

ILS installations at airports are protected against intruders. This is not always the case with the outer and inner markers that are often in installed at non-protected properties.

The localizer is subject to interference from strong FM stations. This is a particular problem in congested Northern Europe. The ICAO has issued standards for ILS receivers with improved FM rejection characteristics.

The use of an ILS in its promulgated Category is subject to the “signal-in-space” being adequately protected from interference due to the reflection from objects “illuminated” by the Localizer or Glide Path beam. Moving objects, particularly large ones like aircraft manoeuvring in close proximity to the runway, may disturb the ILS guidance signals. ATC will apply increased separation and such other methods considered necessary to prevent interference particularly during Low Visibility operations. Such measures may also be applied, at the discretion of ATC, when requested by pilots wishing to use Low Visibility Procedures when meteorological conditions do not necessitate them.

The ILS uses a line-of-sight signal from the localizer antenna and marker beacons and a reflected signal from the ground plane in front of the glide slope antenna. ILS antenna systems are susceptible to signal interference sources such as power lines, fences, metal buildings, etc. Since ILS uses the ground in front of the glide slope antenna to develop the signal, this area should be graded to remove surface irregularities.

Integrity

ILS is continuously monitored. It has dual redundancy, and for CAT III even triple redundant monitoring equipment.

H.2.9.2 Institutional

The local civil aviation authorities control the ILS. They are responsible for the service and maintenance of all ground components (i.e. the transmitters). The airline operators are responsible for receivers onboard their aircraft.

Signal format is standardized by ICAO.

H.2.9.3 Service Delivery

ILS is the ICAO standard landing system, and is used extensively by air carrier and general aviation aircraft of many countries.

ILS provides position information.

The phase-down of Category I ILS is expected to begin in 2008. Category II/III ILS systems will not be phased out prior to 2015

Accuracy

The position accuracy of the ILS system depends on the category of use. ICAO Annex 10 defines ILS accuracy by specifying allowable noise levels, which Annex 10 calls maximum bends in the course line, and by course alignment accuracy (bias error). The size of the allowable error is dependent on the category and is specified for the full range extent of the ILS coverage. The ILS coverage volume is separated by several points along the runway, called ILS points A to E, plus the ILS reference datum which is at a specified height (usually 50 ft) above the intersection of the runway threshold (TH) and the runway centreline.

Availability

Availability is approximately 99 percent.

Range

The localiser has a beam width of 4 degrees, therefore providing accurate guidance in ±2 degrees around the extended runway centreline. Its range extends to 46 km (25 nmi). The total ILS coverage is ± 10 degrees within 46 km (25 nmi) and ± 35 degrees within 32 km (17 nmi).

The glide slope typically has a 2.5 to 3.5 degree angle with the local horizontal. Its angular coverage is about ± 8 degrees in azimuth and between 0.45 x q and 1.75 x q in elevation (q = nominal glide slope angle). The range extends to at least approximately 18 km (10 nmi).

The marker beacons have a coverage of ± 40 degrees in approach direction and ± 85 degrees across.

Reliability

Close to 100%. Reliability factors include snow, terrain factors and other taxiing aircraft in the beam of ILS.

Fix Rate

Localiser, glide slope and marker beacons provide continuous fixes.

Fix Dimensions

Course deviation angles and distance to threshold.

Capacity

Unlimited. The existing limitations in capacity of ILS equipped runways are caused by procedures and ATC.

Ambiguity

There are ambiguities in the glide slope, though they are not a significant problem in practice.

H.2.9.4 Dependencies

The marker beacons place dependencies on NDBs, which are required to alert pilots of their progress along the guide path. Increasingly DMEs are being used with instrument landing systems, and hence depend on them for data generation.

H.2.10 MLS

H.2.10.1 Overview

During the late 1960's, the requirements of civil aviation were forecast to exceed the capabilities of the ILS. In 1974, the ICAO solicited proposals from member states for a new guidance system to replace the ILS as the international standard for civil aviation, and in 1977 adopted the Time-Reference Scanning Beam (TRSB) technique, proposed by the US.

MLS provides precision navigation guidance for alignment and descent of aircraft on approach to a landing by providing azimuth, elevation and distance.

MLS was developed to enhance the capacity of the landing systems, and to provide all-weather operations capability to locations where geographical or physical constraints prevented this. MLS is based on a single accuracy standard, which means that every installation category provides the same accuracy. MLS requires no extensive obstacle-free terrain as ILS does, it has small aerial structures and provides the capability for curved approaches. Finally, MLS allows steep glide path approaches for airports in mountainous terrain and facilitates short field operations for short and/or vertical takeoff and landing (STOL and VTOL) aircraft.

The DME/P was intended to be used in conjunction with MLS to provide accurate ranging which would be required for advanced flight procedures such as curved approaches.

Within the coverage, the basic MLS provides azimuth and elevation with respect to the runway centreline, which, together with the range from the DME/P, provides a 3D position.

The system may be divided into five functions:

1. **Approach azimuth:** The approach azimuth antenna normally provides a lateral coverage of 40º either side of the centre of scan. The antenna is normally located about 1000 feet beyond the end of the runway.

2. **Back azimuth:** The back azimuth antenna provides lateral guidance for missed approach and departure navigation.

3. **Approach elevation:** The elevation station transmits signals on the same frequency as the azimuth station. The elevation transmitter is normally located about 400 ft from the side of the runway between the threshold and the touchdown zone.

4. **Range:** Range guidance, consistent with the accuracy provided by the azimuth and elevation stations, is provided by the MLS precision DME (DME/P).

5. **Data communications:** The azimuth ground station includes data transmission in its signal format, which includes both basic and auxiliary data. Basic data may include approach azimuth track and minimum glide path angle. Auxiliary data may include additional approach information such as runway condition, wind-shear or weather.

Signal

A basic MLS consists of azimuth and elevation ground stations and a conventional DME for 3D positioning on approach courses to 40^{O} either side of the centre line and to 15^{O} elevation above the runway.

The MLS ground stations transmit angle and data functions on one of the 200 frequencies between 5031MHz and 5190.7MHhz. The basic MLS functions are transmitted on the same frequency in several specified sequences interleaved by the Basic and Auxiliary data words. The format of the sequences is chosen to avoid synchronous blocking of any function by an aircraft propeller.

The Time-Referenced Scanning Beam (TRSB) principle is used for angle functions. The azimuth angle of the aircraft is calculated by positioning an antenna behind the end of the runway. By transmitting a narrow beam, which sweeps across the coverage area at a fixed scan rate, both azimuth and elevation may be calculated by an airborne receiver that measures the time interval between sweeps.

Integrity

Integral and far-field monitors provide MLS integrity. The level of integrity depends on the category of the installation.

Interference

- MLS installations at airports are protected against intruders.
- Elimination of ILS/FM broadcast interference problems.
- MLS is not particularly susceptible to signal interference as a result of buildings, trees, power lines, metal fences, and other large objects. However, when these objects are in the coverage area, they may cause multipath (signal reflection) or shadowing (signal blockage) problems

H.2.10.2 Institutional

The local civil aviation authorities control the MLS. They are responsible for the service and maintenance of all ground components (i.e. the transmitters). The airline operators are responsible for receivers onboard their aircraft.

Signal format is standardized by ICAO.

H.2.10.3 Service Delivery

The phase-down of MLS is expected to begin in 2008.

Accuracy

The MLS provides precision three-dimensional navigation guidance accurate enough for all approach and landing manoeuvres. MLS is based on a single accuracy standard, such that every installation provides CAT III accuracy.

Availability

Close to 100%.

Range

- Provision of all-weather coverage up to $\pm 60^{O}$ from runway centerline.360^{O} coverage is available, but accuracy is reduced outside $\pm 60^{O}$.
- Elevation coverage ranges from 0.9^{O} to around 15^{O}.
- The minimum usable range is around 20nmi.

Reliability

Close to 100%.

Fix Rate

A standard azimuth ground installation supports 13 independent fixes each second, while a high-rate azimuth provides three times as many (39). The elevation ground installation always supports 39 independent fixes each second.

Fix Dimensions

Azimuth and elevation angles are measured relative to runway centreline. Range information is measured relative to the DME transponder, normally (but not required to be) collocated with the azimuth antenna.

Capacity

Unlimited.

H.2.10.4 Dependencies

The DME/P is used in conjunction with the MLS to provide accurate ranging which is required for advanced flight procedures, and enables MLS to provide 3D position.

H.2.11 GBAS

H.2.11.1 Overview

The Ground Based Augmentation System (GBAS) is a safety-critical system consisting of the hardware and software that augments the GPS Standard Positioning Service (SPS) and provides enhanced levels of service supporting all phases of approach, landing departure and surface operations within its area of coverage.

The GBAS system is part of the GNSS. It can be divided into 3 sections:

- **The satellite sub-system:** Provides the aircraft GBAS receiver and GBAS ground station with ranging information.
- **The ground station sub-system:** This uses two or more GNSS reference receivers. They calculate pseudoranges for all satellites within view and the ground station calculates differential corrections for each pseudorange, based on its surveyed reference receiver positions. The ground station also monitors the quality and integrity of the ranging signals using the redundant measurements and signal processing techniques.
- **The aircraft sub-system:** This uses differentially corrected aircraft position, integrity information and FAS data to supply navigation guidance signals (vertical and lateral deviations, distance to threshold crossing point, and validity flag) to the pilot’s display and to the autopilot.

The GBAS ground sub-system consists of two or more GNSS receivers, the GBAS housing unit containing ground processing functionality, data broadcast functionality and integrity monitoring functionality, and one or more VDB antenna to transmit ranging corrections and other information to the aircraft.

The GBAS airborne sub-section has the following functions (MMR):

- A GNSS Receiver Function that receives, tracks and decodes the GNSS satellite signals.
- A VDB Receiver Function that receives and decodes the messages broadcast by the GBAS ground subsystem.
- A Navigation Processing Function that receives the measurement of the pseudoranges from the GNSS receiver function, applies the differential corrections received from the VDB receiver function and calculates the differentially corrected aircraft position.

Non-MMR architectures are expected to provide the same GBAS functionality as MMR architectures.

GBAS uses a VHF Data Broadcast (VDB) in the band 108MHz to 117.975MHz. The separation between assignable frequencies is 25KHz. Pseudorange corrections are broadcast by the transmitter, together with integrity parameters, and other relevant data.

H.2.11.2 Institutional

The local civil aviation authorities own and operate GBAS. They are responsible for the service and maintenance of all ground components. The airline operators are responsible for receivers onboard their aircraft.

ICAO SARPs have been developed and amended to reflect safety and interoperability requirements of the application.

H.2.11.3 Service Delivery

CAT I, CAT II and CAT III precision approaches are due to be implemented at various stages. CAT I approaches will be operational in early 2006, whereas CAT II and CAT III approaches are planned to operational around 2012. The following additional and longer-term applications will become available:

- **Near-term GDPS applications -** SIDs, STARs, non-precision approach, AVP1, AVP2 and missed approach procedures.
- **Advanced procedures** - Curved approaches and independent parallel runway operation.
- **A-SMGCS and ADS-B -** A-SMGCS navigation and guidance and ADS-B surveillance.

Each GBAS approach has a service volume that is defined as the region within which the system meets the accuracy, integrity and continuity requirements.

The service volumes (for CAT I) are:

- **Laterally** - beginning at 137m each side of the Landing Threshold Point/Fictitious Threshold Point (LTP/FTP) and projecting out $\pm 35^{O}$ either side of the final approach path to 28km and $\pm 10^{O}$ either side of the final approach path to 37km.

- **Vertically** - within the lateral region, up to the greater of 7^{O} or 1.75 times the promulgated glide path angle (GPA) above the horizontal with an origin at the Glide Path Intercept Point (GPIP) and 0.45 GPA above the horizontal or to such lower angle, down 0.30 GPA, as required to safeguard the promulgated glide path intercept procedure. This coverage applies between 30m and 3000m HAT.

The coverage required to support the GBAS positioning service is dependent upon the specific operations intended. The range of CAT I and CAT II approach procedures will inevitably be different.

The GBAS guidance material will be based on ILS instrument approach criteria, on the assumption that GBAS will meet or exceed ILS accuracy.

A safety case for GBAS is still under development.

H.2.11.4 Dependencies

GBAS relies on GPS for ranging information for both the aircraft receivers and the GBAS ground station. Future development of CAT II and CAT III approaches may introduce dependencies on EGNOS and Galileo, which will enhance accuracy.

GBAS uses VHF Data Broadcast (VDB) to transmit pseudo-range corrections, integrity parameters, and various locally relevant data, such as atmospheric model, Final Approach Segment (FAS) data that are referenced to the World Geodetic System (WGS 84) co-ordinate system, defining the path in space to enable the precision approach operations.

H.2.12 Network based positioning

H.2.12.1 Overview

Network based location (GSM, UMTS) is the provision of the geographic position of a mobile unit/handset using specialised equipment and software within the network. To locate the mobile unit, location determination systems use a variety of methods and technologies, for example, cell of origin (the network simply positions the mobile unit based on the cell it is currently occupying), angle of arrival, assisted GPS and time-based methods.

Currently, this technology is being studied to be used in railways for fleet management applications and passengers' information services and some railways administrations have already launched prototypes using this technology.

Nowadays, this system and the services are not widely deployed and routinely used by many users. Therefore, the challenge for location-based services is to achieve critical mass and wide usage.

There are a number of alternatives for locating mobile phones, including network-based or mobile-based solutions. The accuracy of the position information depends of the technology used.

- Cell Of Origin (COO): The location information provided is the cell where the mobile is located. Depending on the size of the cells (for example in cities where pico-cells are used) the location information would be more or less accurate, ranging from around 150 meters to several kilometres.

- Enhanced observed Time Difference (E-OTD): It uses the difference in the Time of Arrival of the signal from different base stations in the cellular network. As the position of the base stations is known, the time differences are used to produce intersecting hyperbolic lines from which the location is estimated. The performance level in terms of accuracy would range from 100 to 500 meters.

- Angle of Arrival (AOA): Using complex directional antennae at the cell sites, the direction of the mobile can be determined by the angle of arrival of the signal. When several cell sites make this determination then the location of the mobile can be established by the intersection of the obtained directions. As the magnitudes involved are angular, with larger cells the performance can be significantly lower, although a reasonable range would be from 100 to 500 meters.

- Assisted-GPS is a combination of GPS position technology and network-based techniques to improve accuracy, availability and coverage of the solution at a reasonable cost. A-GPS consists of:

    - A wireless handset with a partial GPS receiver,

    - An A-GPS server with a reference GPS receiver that can simultaneously "see" the same satellites as the handset, and

    - A wireless network infrastructure consisting of base stations and a mobile switching centre.

The network can accurately predict the GPS signal the handset will receive and convey that information to the mobile, greatly reducing search space size and shortening the TTFF from minutes to a second or less. In addition, an AGPS receiver in the handset can detect and demodulate weaker signals than those than conventional GPS receivers require. Because the network performs the location calculations, the handset only needs to contain a scaled-down GPS receiver.

A-GPS provides a natural fit for hybrid solutions because it uses the wireless network to supply assistance data to GPS receivers in handsets. This feature makes it easy to augment the assistance-data message with low accuracy distances from handset to base stations measured by the network equipment. Such hybrid solutions benefit from the high density of base stations in dense urban environment, which are hostile to GPS signals. Conversely, rural environments provide ideal operating conditions for AGPS because GPS works well there.

The performance attainable with A-GPS would be in the range of 5 to 50 meters.

The only technology that it is widely deployed today in wireless networks is cell of origin information.

H.2.12.2 Institutional

Position information and location related products are the next class of services to be offered by mobile network operators to their customers, not only new services, but improved current services

Public mobile networks (GSM, UMTS) are suitable for some applications in railways, mainly non-safety related. These networks are private or public owned and operated by public or private companies.

Railways administrations are potential users of location services, through special commercial agreements or just using normal level of services.

In case of Assisted-GPS (or A-GNSS in the future) final service provider (to end-user) will be the mobile network operator, who in turn, can have service agreements with GNSS service providers.

The European Telecommunications Standards Institute (ETSI) have recently decided (together with the ANSI) to standardise location finding services using Enhanced Observed

Time Difference (E-OTD), Time of Arrival (TOA) and Assisted GPS in addition to Cell Of Origin (OOO).

H.2.12.3 Service Delivery

Depending on the technology used, network based positioning services are suited for different types of applications with different performance and overhead requirements. For instance, some non-demanding applications could very well work with a Cell of origin based positioning service.

In principle, railways could be users of all this kind of services. Safety-related applications (ATP) are not likely to use them, although it may be suitable for Management of Emergencies and rescue teams. Depending on the application and/or or service operator, raw position data or complete elaborated position information (matched position in the track and the line) could be delivered to the user.

Products and receivers are both for professional users or mass-market users.

Summary of accuracy and product prices are:

Technology	Information provided	Precision	TTFF	Cost
A-GPS	Speed/ Position	5 - 50m	5 - 10 s	Low
COO	Position	150 m urban areas 5 Km in rural areas	1 s	Low
E-TOD	Position	100 - 500m	5 s	High
AOA	Position	100 - 500 m	5 s	High

H.2.12.4 Dependencies

Local components are needed for some of the technologies described in addition to conventional mobile network elements.

Assisted-GPS technology depends also of GPS constellation for data generation.

H.2.13 Regional Augmentation Services

GPS suffers from a number of error sources, some of which are correlated, i.e. they behave in a similar way over a large area during a certain period of time. This property has been exploited to develop differential GPS (DGPS).

DGPS is based on the accurate knowledge of the x-y-z co-ordinates of the antenna(s) of a reference receiver or of a set of reference receivers. The reference receiver determines corrections for the measured ranges, using its capability of calculating the correct range to the satellite based on the knowledge of its own position and the position of the desired satellite. These errors are transmitted to the users who can adjust their measurements with the transmitted corrections.

Two DGPS methods have been developed:

- ***Wide Area DGPS***: Wide area DGPS is becoming operational in Europe as the European Geostationary Navigation Overlay Service (EGNOS). In the US, the Wide

Area Augmentation System (WAAS) is already operational. EGNOS is described in detail in Section G.2.1, while WAAS is described in detail in Section G.2.2.

- ***Local Area DGPS***: operational in Europe since the late 1980s. Local area DGPS systems are described in detail in Section G.2.4.

H.2.14 EGNOS

H.2.14.1 Overview

EGNOS is one of a number of Satellite Based Augmentation Systems (SBAS) being developed to augment the US Global Positioning System (GPS) and Russian Federation GLONASS system. Each SBAS broadcasts a GPS look-alike signal modulated with Wide Area Differential (WAD) corrections and integrity data from dedicated geostationary satellites that provide dual coverage over the SBAS region. The additional GPS look-alike signals improve availability, the WAD corrections improve accuracy and the integrity messages improve integrity (safety or quality of service).

Support for user applications

EGNOS will provide a European-wide, standardised and quality-assured positioning system suitable for a diverse range of applications. Its high compatibility with GPS, means that a single antenna and receiver can process both the GPS and EGNOS signals, eliminating the need for a separate radio to receive differential corrections. This will allow many users to dispense with their current local-area differential or commercial services.

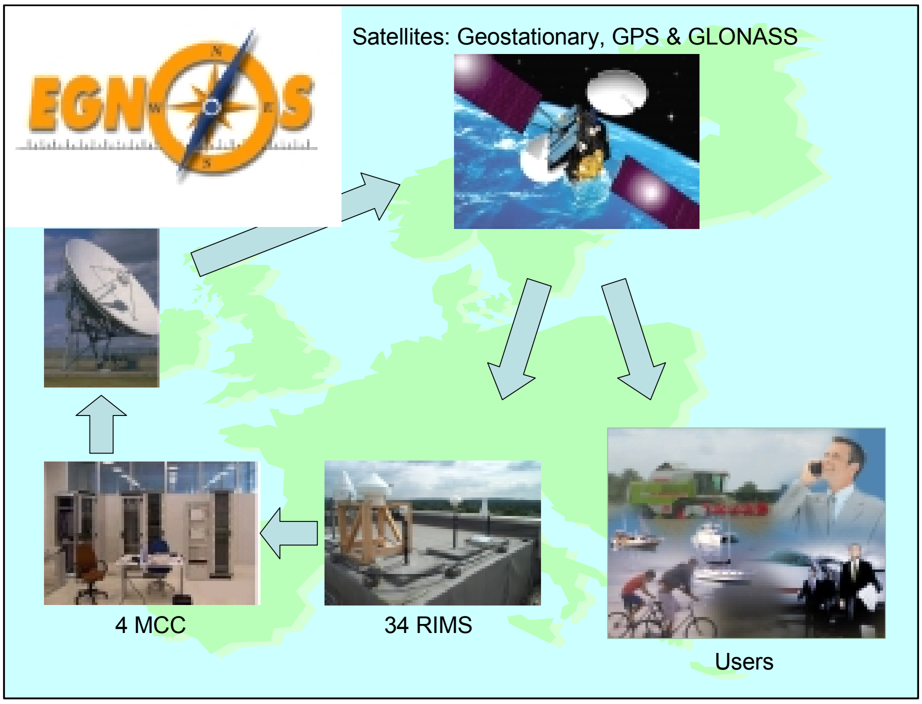
EGNOS has been designed to meet the demanding performance requirements for landing aircraft, as well as having the performance potential to support a number of maritime and mass-market applications:

- Accuracy is improved (relative to GPS or GLONASS) to about 2-3 m vertical and 1-2 m horizontal through the broadcast of WAD corrections;
- Integrity (safety) is improved both through the high degree of redundancy in the system and by alerting users within 6 seconds if something goes wrong with EGNOS, GPS or GLONASS;
- Availability is improved by broadcasting GPS look-alike signals from three geostationary satellites.

EGNOS architecture

The EGNOS architecture (Figure G-1) is highly redundant, generating wide-area differential corrections and alerting users within six seconds if something goes wrong with EGNOS, GPS or GLONASS.

Figure G-1 – EGNOS Architecture



H.2.14.2 Institutional

EGNOS is the first step of Europe's Global Navigation Satellite System (GNSS) policy that culminates in Galileo. EGNOS is being developed by the European Space Agency (ESA), together with both the European Commission (EC) and Eurocontrol.

EGNOS has been developed over a seven-year period based on an ESA System Requirements Document (SRD) that was written in December 1998 at a time when the international standards had not been concluded. The resulting SRD refers to:

- the ICAO Standards and Recommended Practices, Draft version 7A (R16);
- and the RTCA Minimum Operational Performance Standards (MOPS) Change 3.

The current versions of these standards (R17, R18) differ from those referred to in the SRD despite ESA's inclusion in the SRD of additional requirements that were intended to anticipate their future evolution.

H.2.14.3 Service Delivery

The EGNOS ground segment mimics GPS to deliver WAD corrections and integrity. Thirty-four RIMS monitor the GPS, GLONASS and geostationary satellites and each satellite has to be monitored by multiple RIMS before correction and integrity messages are generated. Four Mission Control Centres (MCC) process the RIMS data to generate the WAD corrections and integrity messages for each satellite. Only one of these MCCs is active and operational at any time, the remaining MCCs are hot spares that can be activated if a problem occurs. Navigation Land Earth Stations (NLES) upload the corrections and integrity messages to the satellites for onward broadcast to the users. Two NLESs (one acting as primary and one as backup) will be deployed for each of the three geostationary satellites (6 operational NLES). A further (seventh) NLES will be deployed for test and validation purposes.

The EGNOS space segment is composed of three geostationary satellites with global earth coverage. The EGNOS operational system is based on the use of two INMARSAT-3 satellites stationed at 15.5ºW (Atlantic Ocean Region East (AOR-E) and at 25ºE (Indian Ocean Region-West (IOR-W), as well as the ESA ARTEMIS satellite, launched in 2001 and stationed at 21.5ºE. These have been positioned to:

- maximise the contribution to user/satellite geometry and hence to system availability;
- maximise GEO-visibility angle diversity and hence to minimize the risk of signal blocking;
- provide dual GEO coverage (minimum) within the core service area.

The geostationary broadcast areas (GBA) of these three satellites are illustrated in Figure G-2 together with the core European Service Area. EGNOS users in the core European service area should be able to track at least two geostationary satellites. It takes less than six seconds to notify users about a problem occurring with any of the satellites (GPS or GEO) once it has been detected by the RIMS network.

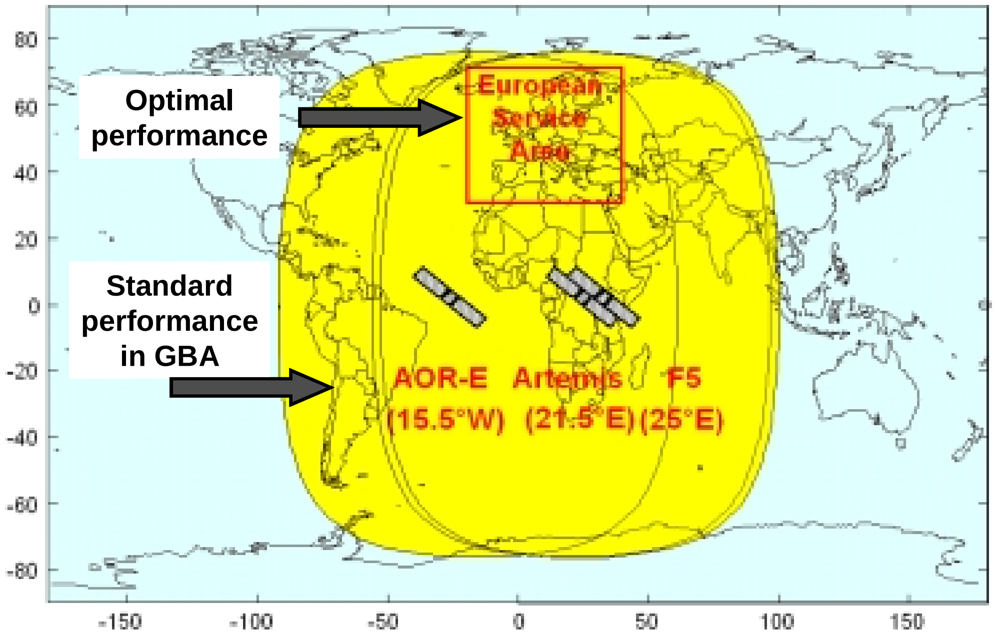


Figure 28 – EGNOS Coverage Area

Coverage

A plot of Europe showing the expected 95% horizontal accuracy is presented in Figure G-3. This is believed to be pessimistic based on the 1 m (95%) accuracies already possible using the ESTB (Figure G-4) and available from the WAAS. This will be confirmed once actual performance data become available. EGNOS services delivered through GEOs or other communications links (e.g. SISNeT) will offer real benefits to the mass market.

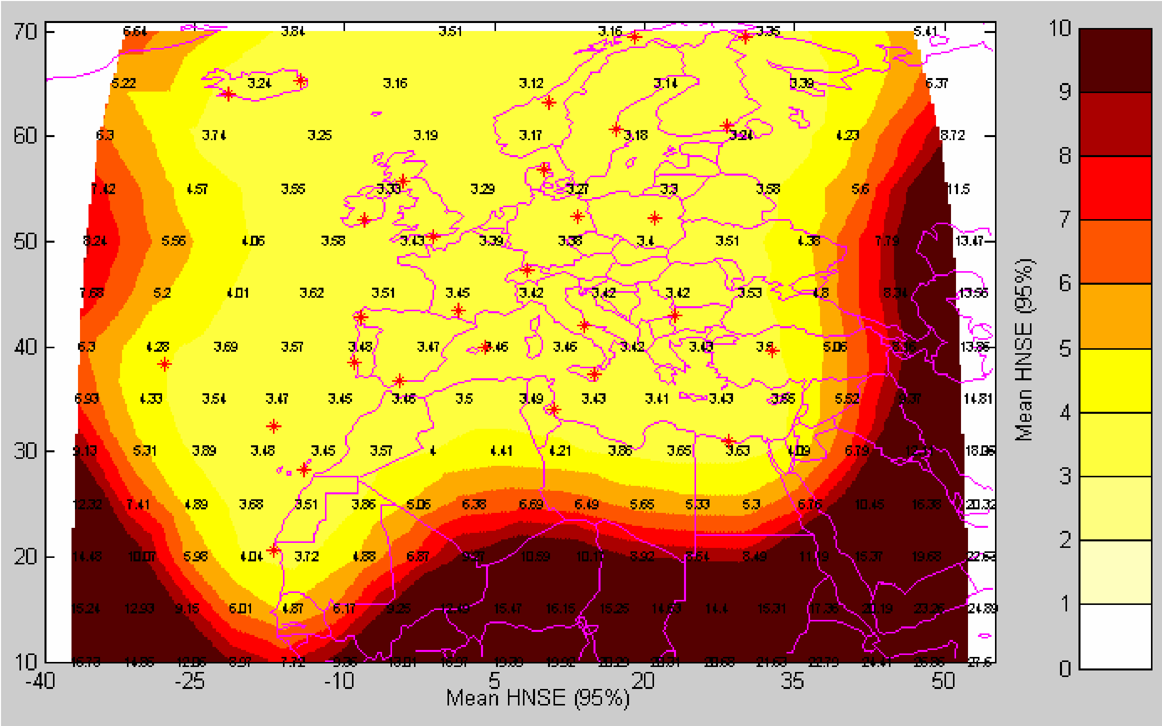


Figure 29 – Horizontal Accuracy (95%, m)

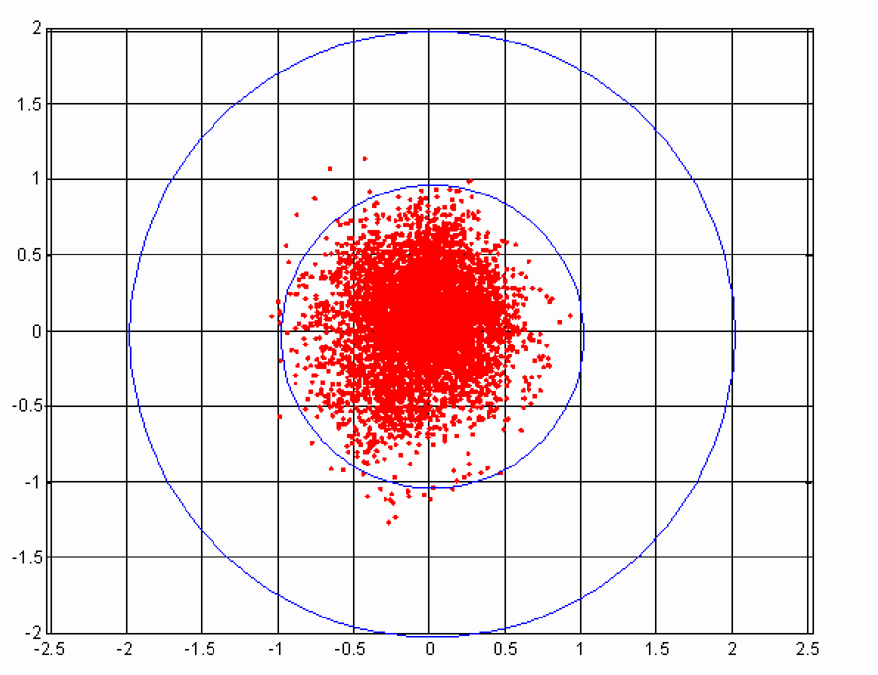


Figure 30 – ESTB Horizontal Accuracy (95%, m)

EGNOS Service levels

EGNOS provides different levels of service at different parts of the area covered by the geostationary satellites. Optimum performance (Level 2 or Level 3) is obtained within the core coverage area. Standard performance (Level 1) is available in other parts of the geostationary broadcast areas although there is some potential for improvement through interoperability with other SBAS systems. The core coverage area may also be expanded.

EGNOS will support several levels of GNSS-1 Navigation services. These services have been labelled EGNOS services even though their characterisation in terms of performances can only fully be done at GNSS-1 level (i.e. based upon the combination of GPS, GLONASS and EGNOS signals). In particular, the EGNOS AOC system will support the following three Service Levels:

- Level 1 (Ranging Service) - will provide an enhanced navigation function to GPS users based on the transmission of additional GPS look alike signals through the Inmarsat AOR-E and IOR-W and the ESA Artemis geostationary satellites. This will improve the availability of the navigation service (positioning and RAIM) at user level. Receivers will process these ranging signals in combination with the GPS signals in the positioning and RAIM algorithms. Level 1 does not provide support to GLONASS users;
- Level 2 (Integrity Service or Non-Precision WAD) - will provide the same service as Level 1 with an enhanced Integrity function based on additional clock and orbit integrity data for the GPS, GLONASS and GEO satellites; and
- Level 3 (Precision WAD) - will provide the same service as level 2 with additional ionospheric data to support, with improved accuracy, two sub-levels of the Navigation System performances:
    - Level 3A when only GPS and GEO satellites are used by the receiver;
    - Level 3B when GPS, GEO and GLONASS satellites are used by the receiver.

All these services will be supported when EGNOS is declared operational in 2004. The different levels of performance are defined in Table G-1.

Parameter	**Level 1**	**Level 2** [3]	**Level 3A**	**Level 3B**
Navigation System Error (95%)	100m	100m	7.7m (Vertical)	4m (Vertical)
Protection Limit		556m	20m (Vertical) 20m (Horizontal)	10m (Vertical) 10m (Horizontal)
Integrity Risk	10^{-7} /h [1]	10^{-7} /h	2×10^{-7} /approach	2×10^{-7} /approach
Time to Alarm	10s [2]	10s [2]	6s [4]	6s [4]
Continuity Risk	10^{-4} /h	10^{-5} /h	8×10^{-7} /approach	8×10^{-7} /approach
Availability	0.98	0.999	0.95 (0.99) [5]	0.95 (0.99) [5]
Service Volume	Any location where there is dual GEO coverage	ECAC	ECAC land masses	ECAC land masses

Notes

1 *Integrity risk is specified here at GPS+EGNOS SIS+RAIM level without taking into account the risk associated to the avionics assembly.*

2 *The time to alert of 10 seconds is apportioned between 8 sec (SIS) and 2 sec (receiver). This requirement will most likely be superseded by the more stringent requirement for Level 3A and 3B*

3 *The EGNOS system requirements indicated in this Table shall be met considering only the EGNOS ground integrity monitoring function and disregarding any additional benefit that may be achieved by the use of RAIM.*

4 *The time to alert of 6 seconds is apportioned between 5.2 sec (SIS) and 0.8 sec (fault free receiver).*

5 *The availability performance objective is in line with the last ICAO GNSS requirements (SARPS). The actual availability requirements are indicated in parentheses.*

Table 6 – EGNOS Performance Requirements

EGNOS Signal-in-space

The EGNOS System Test-Bed has been broadcasting a pre-operational EGNOS signal since February 2000. EGNOS uses the same frequency (L1 1575.42 MHz) and ranging codes as GPS, but has different data message format.

A combination of both 'fast' and 'slow' wide area differential corrections are transmitted, which model the temporal decorrelation of the different error sources (see Figure G-5). The fast corrections allow for rapidly changing error sources including satellite clock errors. The slow corrections allow for more slowly changing error sources including long-term satellite clock drift and ephemeris errors.

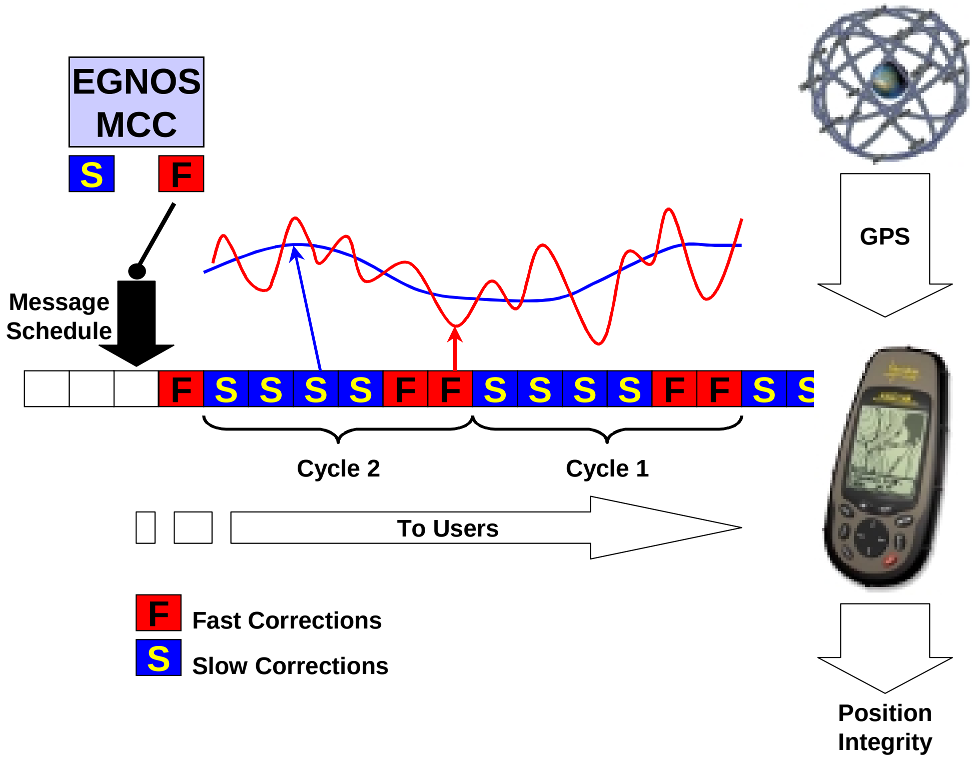


Figure 31 – The EGNOS Signal

Eighteen different message types have so far been defined to broadcast integrity data and WAD corrections (Table 2). There is a 6-second duty cycle in the message schedule to meet integrity requirements (e.g. time-to-alert). Other data messages have their own duty cycle and are arranged between the integrity messages.

Type	Description	Type	Description
0	Don't use this SBAS signal	17	GEO satellite almanacs
1	PRN Mask assignments	18	Ionospheric grid point mask
2 – 5	Fast corrections	24	Mixed fast/slow error corrections
6	Integrity information	25	Slow satellite error corrections
7	Fast correction degradation factor	26	Ionospheric delay corrections
9	GEO navigation message	27	SBAS service message

10	Degradation parameters	63	Null message
12	SBAS Network Time/UTC offsets		

Table 7 – EGNOS Message Types

Processing the corrections is quite complex both because the messages have been designed to minimise the bandwidth requirements and because they need to account for updated GPS navigation information.

The receiver estimates corrections for satellite clock and ephemeris errors using the fast and slow satellite data message.

EGNOS receivers compute a certified error bound for the position solution based on data broadcast by the GEO satellites, the user/satellite geometry, and the probability of integrity non-detection.

EGNOS Service guarantees

The EGNOS SIS is currently provided without any warranties regarding availability, continuity, accuracy, and reliability. The EGNOS SIS is provided on an "as is" and "as available" basis. Until further notice, messages associated with the EGNOS SIS are not certified for Civil Aviation or other safety critical purposes.

SISNeT

ESA has been assessing the use of complementary transmission links to optimise service delivery. SISNeT is an EGNOS internet service that aims to provide access to the EGNOS messages over the Internet. Among the benefits are that an EGNOS receiver is no longer necessary to obtain the EGNOS WAD and integrity messages – only a connection to the internet is required; and the EGNOS signal is available even if GEOs are not visible.

H.2.14.4 Dependencies

The EGNOS system is dependent on there being a GNSS service in existence, such as GPS, GLONASS, or in the future, GALILEO. The EGNOS service does not however require 100% availability or integrity of a GNSS service, since EGNOS is designed to fill in the gaps in the GNSS service and warn of integrity or availability failures.

H.2.15 WAAS

H.2.15.1 Overview

The US Wide-Area Augmentation System (WAAS) consists of equipment and software that augments the DoD-provided GPS Standard Positioning Service (see Figure 3-4). The signal-in-space provides three services:

1. integrity data on GPS and GEO satellites;
2. wide area differential corrections for GPS satellites;
3. an additional ranging capability.

After receiving an upgrade to meet strict safety-related integrity requirements, WAAS will support aviation navigation for the en-route through Category 1 precision approach phases of flight.

The GPS satellites' data are received and processed at widely dispersed sites, referred to as Wide-area Reference Stations (WRS). These data are forwarded to data processing sites, referred to as Wide-area Master Stations (WMS), which process the data to determine the integrity, differential corrections, residual errors, and ionospheric information for each monitored satellite and generate GEO satellite navigation parameters. This information is sent to a Ground Earth Station (GES) and uplinked along with the GEO navigation message to GEO satellites.

These GEO satellites then downlink these data on the GPS Link 1 (L1) frequency with a modulation similar to that used by GPS. In addition to providing GPS integrity, the WAAS verifies its own integrity and take any necessary action to ensure that the system meets performance requirements. The WAAS also has a system operations and maintenance function that provides information to FAA Airway Facilities personnel.

The WAAS user receiver processes:

1. the integrity data to ensure that the satellites being used are providing in-tolerance navigation data;
2. the differential correction and ionospheric information data to improve the accuracy of the user's position solution;
3. the ranging data from one or more of the GEO satellites for position determination to improve availability and continuity.

H.2.15.2 Institutional

The WAAS service is funded and operated by the US FAA. Standards for WAAS are covered by ICAO standards for SBAS. The ICAO GNSS SARPs, including SBAS, are contained in Amendment 76 to Annex 10, Volume I, of the ICAO Convention on International Civil Aviation.

H.2.15.3 Service Delivery

Signal characteristics

The WAAS collects raw data from all GPS and WAAS GEO satellites that support the navigation service. WAAS ground equipment will develop messages on ranging signals and signal quality parameters of the GPS and GEO satellites. The GEO satellites broadcast the WAAS messages to the users and provide ranging sources. The signals broadcast via the WAAS GEOs to the WAAS users are designed to require minimal standard GPS receiver hardware modifications.

The GPS L1 frequency and GPS-type modulation, including a C/A PRN code, are used for WAAS data transmission. In addition, the code phase timing is synchronized to GPS time to provide a ranging capability.

Accuracy

WAAS is delivering horizontal accuracy of 2 to 3 metres (95 percent) throughout the CONUS. The accuracy requirements are based on aviation operations. For the en route through nonprecision approach phases of flight, unaugmented GPS accuracy is sufficient. For Category I precision approach, the horizontal and vertical requirement is 7.6 metres (95 percent). These accuracy requirements are under review.

Availability

The WAAS availability for the en route through nonprecision approach phases of flight is at least 0.99999. For the precision approach phase of flight, the availability is at least 0.999.

Coverage

The WAAS full service volume is defined from the Category I decision height up to 100,000 feet for the airspace of the 48 contiguous states, Hawaii, Puerto Rico, and Alaska (except for the Alaskan peninsula west of longitude 160 degrees West or outside of the GEO satellite broadcast area).

At present, there are two geo-stationary satellites serving the WAAS area. These are Inmarsat IIIs: POR (Pacific Ocean Region) and AOR-W (Atlantic Ocean Region-West).

The European area will eventually be served by two Inmarsats, AOR-E (Atlantic Ocean Region-East) and IOR (Indian Ocean Region) and the European Space Agency satellite, ARTEMIS.

Reliability

The WAAS will provide sufficient reliability and redundancy to meet the overall NAS requirements with no single point of failure. The overall reliability of the WAAS signal-in-space will approach 100 percent.

Fix Rate

This system provides a virtually continuous position update.

Fix Dimensions

The WAAS provides three-dimensional position fixing and highly accurate timing information.

System Capacity

The user capacity is unlimited.

Ambiguity

The system provides no ambiguity of position fixing information.

Integrity

Integrity augmentation of the GPS SPS by the WAAS is a required capability that is both an operational characteristic and a technical characteristic. The required system performance levels for the integrity augmentation are the levels necessary so that GPS/WAAS can be used for all phases of flight.

Integrity for the WAAS is specified by three parameters: probability of hazardously misleading information (PHMI), time to alarm, and the alarm limit.

For the en-route through to non-precision approach phases of flight, the performance values are:

Probability of hazardously misleading information (PHMI)	10^{-7} per hour
Time to Alarm	8 seconds
Alarm Limit	Protection limits specified for each phase of flight

For the precision approach phase of flight, integrity performance values are:

Probability of hazardously misleading information (PHMI)	10^{-7} per approach
Time to Alarm	5.2 seconds
Alarm Limit	As required for Category I operation

The WAAS will provide the information such that the user equipment can determine the integrity to these levels.

Spectrum

The WAAS operates as an overlay on the GPS L1 link in the 1559-1610 MHz ARNS/RNSS frequency band.

H.2.15.4 Dependencies

The WAAS system is dependent on a GPS service being in existence. The WAAS service does not however require 100% availability or integrity of a GNSS service, since EGNOS is designed to fill in the gaps in the GNSS service and warn of integrity or availability failures.

H.2.16 EUROFIX

H.2.16.1 Overview

Eurofix is an integrated radionavigation and communication system which is proposed and developed by Delft University of Technology. Loran-C or Chayka stations are upgraded to broadcast low-speed data reliable over ranges up to 1,000 km. Data are separated into 8 channels which are assigned to DGPS, DGLONASS, DLoran-C/DChayka, navigation integrity messages and short message services. Three channels are reserved for future applications.

Figure 32 – Eurofix System Architecture[88]

The normal navigation operational mode of Loran-C and Chayka respectively is preserved which gives the Eurofix user, next to accurate DGPS positions, improved navigation reliability. As the Loran-C and Chayka infrastructure are already available, the upgrading to Eurofix is a minor and low-cost operation.

88 http://www.eurofix.tudelft.nl

The principle of Eurofix is based on the modulation of the last 6 impulses of every Loran-C 8-impuls-group. Navigating with Loran-C is done by measuring the arrival times of the impulses. The idea of Eurofix is to slightly shift those arrival times, but without deteriorating the performance of Loran-C navigation. A slight time shift is not harmful if another impulse is equally time shifted in the other direction, so that the average timeshift is zero. This is called balanced modulation. On the average nothing can be noticed about the Loran-C impulses.

The time shifts of 1 microsecond represent digital bits. In previous concepts of Eurofix only an advanced (-) and a delayed (+) pulse were used to modulate. In the final concept also the non-shifted pulse contribute to Eurofix. It is called a prompt (0). So there are three states the pulse can be modulated in. The combination of the 6 modulated impulses represents 7 bits of data. One can calculate the number of possible balanced modulation patterns:

Modulation Pattern Combination			Example	Number of Combinations
6 x zero (0)	0 x plus (+)	0 x minus (-)	0 0 0 0 0 0	1
4 x zero	1 x plus	1 x minus	0 0 + 0 – 0	30
2 x zero	2 x plus	2 x minus	0 + - + 0 -	90
0 x zero	3 x plus	3 x minus	+ + - - - +	20
			Total =	141

Table 8 – Total number of balanced modulation patterns in Eurofix 3-level modulation[89]

H.2.16.2 Institutional

Eurofix is operated by NELS. The service is free of charge for all users.

H.2.16.3 Service Delivery

The coverage of Eurofix is estimated to be at least 1000 km from each equipped Loran-C transmitter. Fully implemented an absolute accuracy of better than 5 m and an availability of better than 99,9996% per month is achievable in most areas. At the moment four Loran-C stations broadcast Eurofix data:

89 http://www.eurofix.tudelft.nl

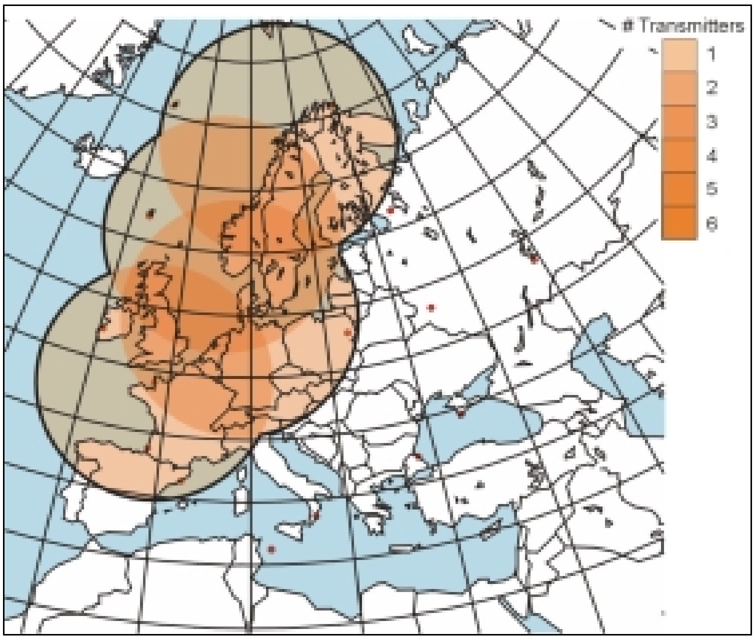


Figure 33 – Eurofix Coverage 2004

The Eurofix coverage area could be extended by implementing Eurofix to all NELS stations and to Russian Chayka stations:

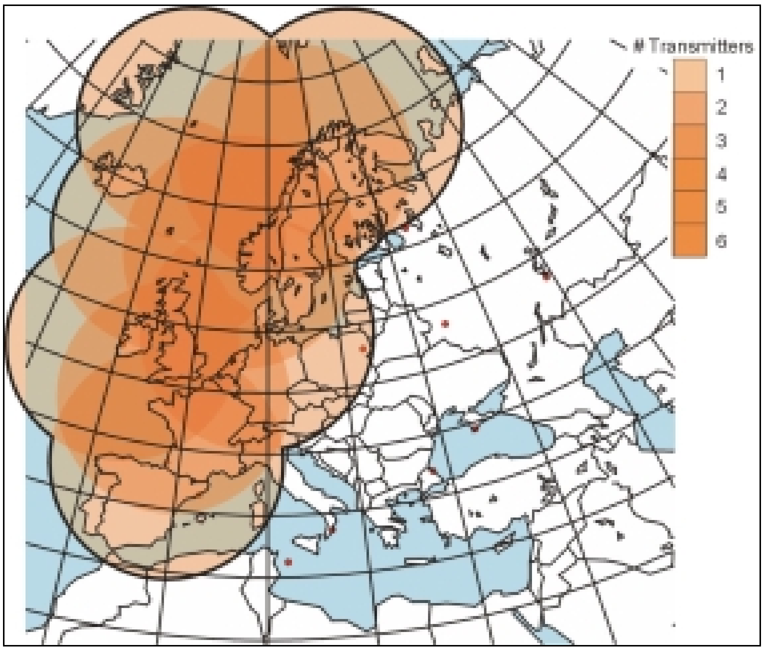


Figure 34 – Eurofix Extension (all NELS stations[90])

90 including the proposed Loran-C station Loop Head (Ireland)

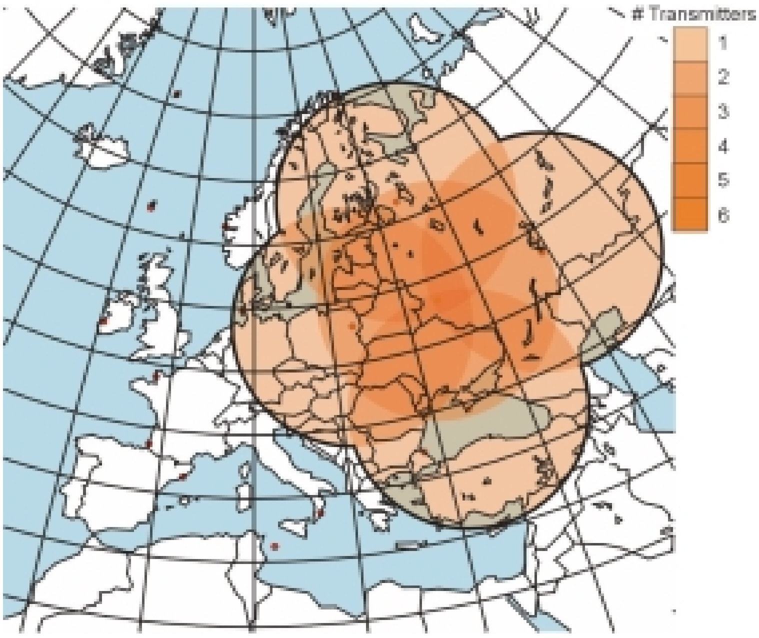


Figure 35 – Potential DGNSS coverage by the European Chayka chain

H.2.16.4 Dependencies

As Eurofix modulates the Loran-C or Chayka signal to broadcast the data, those systems are essential for the maintenance of Eurofix.

H.3 National Augmentation Services

H.3.1 SA*POS* (Germany)

H.3.1.1 Overview

The satellite positioning service SA*POS* makes available the official reference system at a nation-wide level by modern methods. A system of GPS reference stations forms the basis of this system. This service is available with high reliability.

SA*POS* comprises four service areas with different characteristics and accuracies:

- SA*POS* EPS Real Time Positioning Service
- SA*POS* HEPS High-Precision Real Time Positioning Service
- SA*POS* GPPS Geodetic Precision-Positioning Service
- SA*POS* GHPS Geodetic High-Precision Positioning Service

Standard components enable the user to have easy access via modern communication links. EPS and HEPS can be used in real time.

Service	Format	Communication Media	Update Rate	Charge	Charging Unit
EPS	RTCM 2.0	VHF/LW	3 - 5 seconds	Once (included in price of device)	-

		2m-Band	1 second	150,- Euro	1 year
HEPS	RTCM 2.3 [91]	2m-Band	1 second	0,10 Euro	1 minute
		GSM	1 second	0,10 Euro	1 minute
GPPS/GHPS	RINEX 2.0 [92]	phone/internet	<= 1 Hz	0,20 Euro	1 minute
		phone/internet	> 1 Hz	0,80 Euro	1 minute

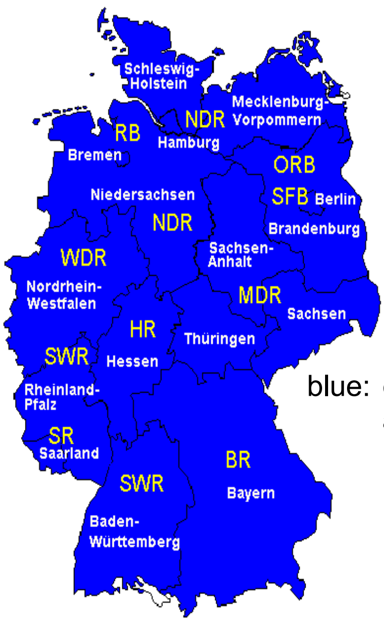
Table 9 - Service fees of SA*POS*[93]

SA*POS* EPS

SA*POS* EPS offers real time positioning with an accuracy of 1 to 3 meters. Reference stations permanently measure distances to the GPS satellites from which they determine correction values. The correction data are available to the user in real time (in standardized format). It is possible for him to correct the measured GPS position to 1 to 3 meters with little instrumental input.

The correction data are transmitted in cooperation with the radio stations of the German television and radio broadcast organisation ARD (VHF), with the German Telekom AG (long wave), and via the stations of the National Survey (2 m band). The RTCM SC-104 format (US Technical Commission for Maritime Services Special Committee No. 104), version 2.0, which has been introduced internationally, is used.

To be able to use SAPOS EPS a simple GPS receiver and a VHF/LW receiver available on the market or a 2 m band receiver with decoder are required.



blue: coverage area

91 additional fee of 250,- EUR for Germany-wide clearing

92 data access by user

93 http://www.sapos.de

Figure 36 – SA*POS* EPS transmission via German radio broadcast (ARD) as of September 1999[94]

Figure 37 – SA*POS* EPS Long-wave transmission via German Telekom AG (ALF)[95]

94 http://www.sapos.de

95 http://www.potsdam.ifag.de/alf/

Figure 38 – SA*POS* EPS transmission via 2-meter-band sender (as of January 2004)[96]

SA*POS* HEPS

SA*POS* HEPS offers real time positioning with an accuracy of 1 to 5 centimetres. The user may, in addition to the EPS correction, also have recourse to the carrier phase correction data of the satellite signals in real time (in standardized form), which supports precise positioning.

The correction data are transmitted in the 2 m band via the National Survey's own stations. The data can be received via telephone too. The internationally introduced RTCM SC-104, version 2.1 standard is used. The data are transmitted at intervals of a second. A decoder module of the AdV is required.

In different areas an extended service will be offered in the future. Several GPS reference stations work on an interlinked basis and can thus record site-dependent error influences.

96 http://fhh.hamburg.de/stadt/Aktuell/weitere-einrichtungen/landesbetrieb-geoinformation-und-vermessung/service/satelliten-positionierungsdienst/

Specific, position-dependent correction values are supplied to the user, which means a further increase in reliability and accuracy.

While offering a Germany-wide standard HEPS distinguishes between a compulsory service and optional add-ons (which can be offered several federal states or regionally).

The compulsory service specifies:

- the transmission of unencrypted, uncompressed data via GSM
- linking-up of the reference stations
- the provision of network modelled corrections.

The optional service may provide additionally:

- the data transmission via transmitters of the federal surveying agency
- data encryption and compression
- the “virtual reference station” technique.

SA*POS* GPPS

SAPOS GPPS offers one centimetre-accuracy “near online” as well as in post processing. The continuous observations of the reference stations are available to the user (in standardized form). The reference stations permanently record the signals of the GPS satellites and make them available to the user in RINEX format (Receiver Independent Exchange Format). The data can be received “near online” via mobile telephone and data carrier.

To obtain accuracies in the cm range two high-quality receivers were necessary until now; with SA*POS* GPPS a single instrument is sufficient on the user side.

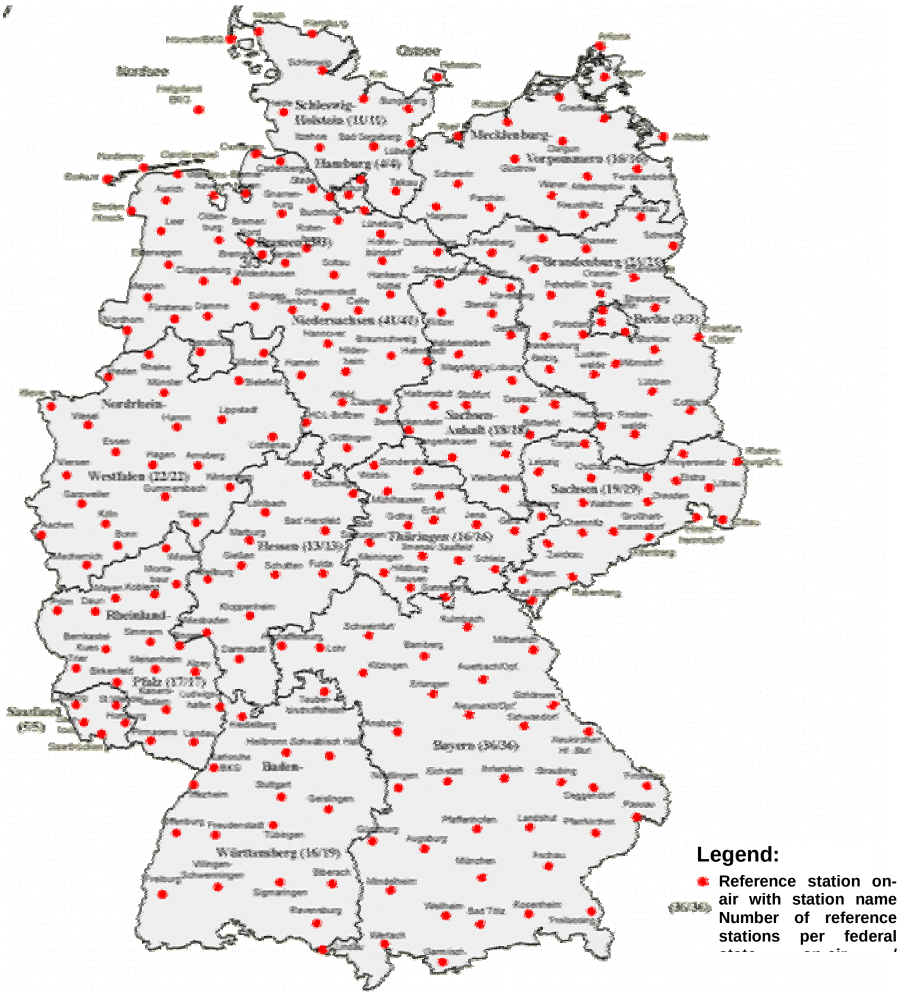


Figure 39 – SA*POS* reference stations (as of January 2004)[97]

SA*POS* GHPS

SAPOS GHPS offers positioning in the millimetre range. The continuous long-term measurements of the reference stations are available (in standardized format) to the user.

The reference stations continuously record the signals of the GPS satellites and provide them in RINEX format. Evaluation is performed in the post processing mode. It is appropriate to make use of the precise orbit data of the International GPS Service for Geodynamics (IGS).

Ntrip

Networked Transport of RTCM via Internet Protocol (Ntrip) stands for an application-level protocol streaming Global Navigation Satellite System (GNSS) data over the Internet. Ntrip is a generic, stateless protocol based on the Hypertext Transfer Protocol HTTP/1.1. The HTTP objects are enhanced to GNSS data streams.

Ntrip is designed for disseminating differential correction data (e.g. in the RTCM-104 format) or other kinds of GNSS streaming data to stationary or mobile users over the Internet, allowing simultaneous PC, Laptop, PDA, or receiver connections to a broadcasting host. Ntrip supports wireless Internet access through Mobile IP Networks like GSM, GPRS, EDGE, or UMTS.

97 http://fhh.hamburg.de/stadt/Aktuell/weitere-einrichtungen/landesbetrieb-geoinformation-und-vermessung/service/satelliten-positionierungsdienst/

Ntrip is meant to be an open none-proprietary protocol. Major characteristics of Ntrip's dissemination technique are:

- Based on the popular HTTP streaming standard; comparatively easy to implement when having limited client and server platform resources available.
- Application not limited to one particular plain or coded stream content; ability to distribute any kind of GNSS data.
- Potential to support mass usage; disseminating hundreds of streams simultaneously for up to thousand users possible when applying modified Internet Radio broadcasting software.
- Considering security needs; stream providers and users don't necessarily get into contact, streams often not blocked by firewalls or proxyservers protecting Local Area Networks.
- Enables streaming over any mobile IP network because of using TCP/IP.

H.3.1.2 Institutional

SA*POS* (Satellite Positioning Service of the German National Survey) is a service of the Working Committee of the Surveying Authorities of the States of the Federal Republic of Germany (AdV) to support the official reference system and offer DGPS services for commercial applications. This is part of the legal responsibility of the German National Survey, which includes the provision of basic infrastructural facilities.

H.3.1.3 Service Delivery

H.3.1.4 Dependencies

The SA*POS* services depend on GPS

H.3.2 ascos – ruhrgas positioning services (Germany)

H.3.2.1 Overview

The Ruhrgas AG provides real time correction data for GPS and GLONASS positioning under the brand name ascos. Data for post processing are available as well. In close co-operation with the SAPOS reference stations the service can be provided Germany-wide.

Correction data are transmitted via GSM in RTCM format at a rate of 1 second. The data are neither compressed nor encrypted.

H.3.2.2 Institutional

The ascos service is operated by a private company.

H.3.2.3 Service Delivery

ascos disposes of two services:

- PED - Precise real-time service, Accuracy ≥ 2 cm
- ED - Real-time service, Accuracy ≥ 30 cm

Figure 40 – ascos coverage, PED (as of April 2003)[98]

H.3.2.4 Dependencies

The ascos services depend on GPS.

H.3.3 AMDS (Germany)

H.3.3.1 Overview

The AMDS DGPS Service is operated by EuroNav Service GmbH to meet the requirements of real time applications in the 0,5-2 m accuracy level. Three long wave transmitters broadcast corrections at a rate of 3-5 seconds in RTCM 2.0 format. The user needs an AMDS/dGPS-Box II and a licence.

98 http://www.ascos.de

H.3.3.2 Institutional

The AMDS service is operated by a private company.

H.3.3.3 Service Delivery

AMDS provides 0,5-2 m accuracy within the following area:

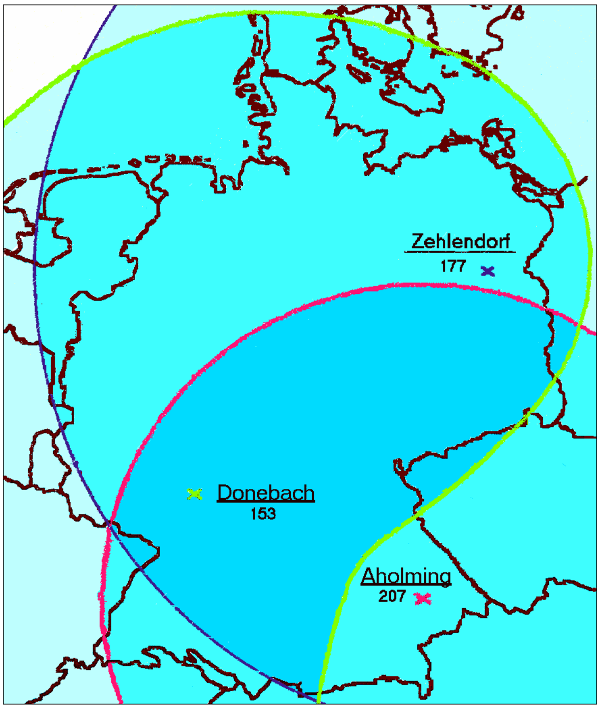


Figure 41 – AMDS coverage (as of October 1998)

H.3.3.4 Dependencies

AMDS service is depends on GPS.

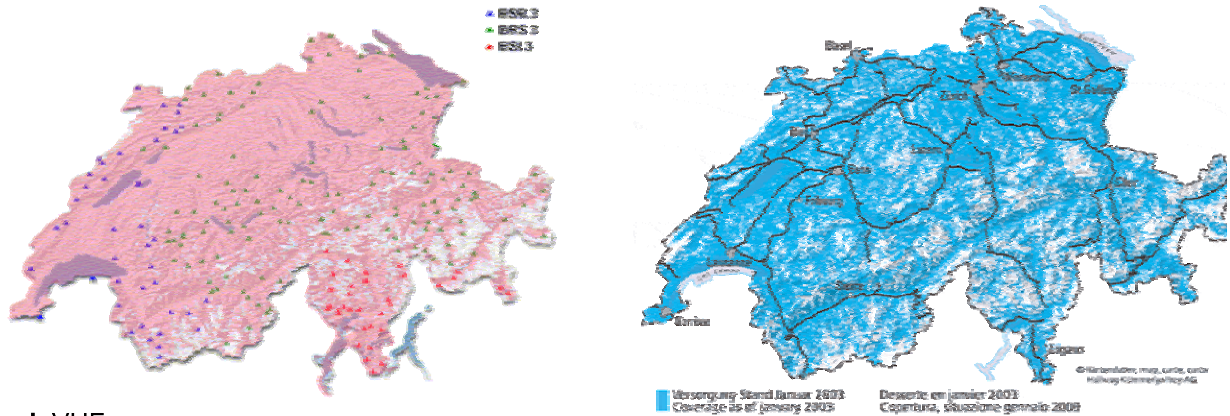
H.3.4 swipos (Switzerland)

H.3.4.1 Overview

Swipos is operated by the Swiss Federal Office of Topography which is offered at two service levels.

***swipos*-NAV**

swipos-NAV is a positioning service via VHF/RDS (until end of 2004) or GSM for applications at the accuracy level of meters. Access via internet is available, too (NTRIP format). Correction data are calculated from the automated Swiss GPS network AGNES. The data (RTCM 2.3) are free of charge; the user has to pay for communication costs only.



red: VHF coverage

Figure 42 – swipos-NAV coverage via VHF (left, as of November 2002)[99] and via GSM (right, as of January 2003)[100]

The user needs a GPS receiver with integrated GSM module or – when using an external GSM connection – a receiver which supports the GSM interface.

swipos-GIS/GEO

swipos-GIS/GEO is a positioning service for applications at the accuracy level of centimetres. It is based on the data of the 29 AGNES stations. Data for real time (RTCM 2.3) or post processing (RINEX) are generated using the method of the virtual reference station and transmitted via GSM.

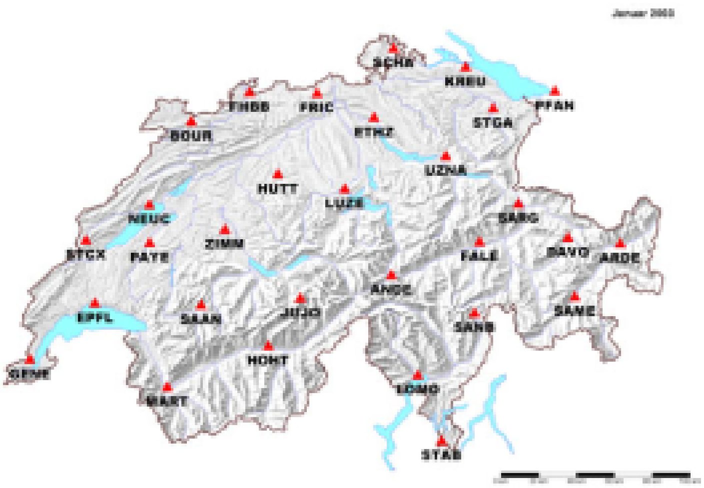


Figure 43 – Swiss reference station network AGNES (as of January 2003)[101]

H.3.4.2 Institutional

The swipos service are operated by the national surveying administration (Swiss Federal Office of Topography).

99 http://www.swisstopo.ch/

100 http://www.swisscom-mobile.ch/sp/BEAAAAAA-xsp-en.jsp

101 http://www.swisstopo.ch/

H.3.4.3 Service Delivery

Service	Format	Communication Media	Update Rate	Charge	Charging Unit	Accuracy (2σ)
swipos-NAV	RTCM 2.3	VHF[102]		communication only		1 .. 2 m
	NTRIP	internet		communication only		
swipos-GIS/GEO	RTCM 2.3	GSM		0.70 CHF	1 minute	2.4 cm (horizontal) 4 cm (vertical)
				5500 CHF	1 year	
	RINEX 2.0	internet	1 .. 60 seconds	60 .. 15 CHF[103]	1 hour	
				0.0167 .. 0.25 CHF	1 epoch	

Table 10 - swipos services[104]

H.3.4.4 Dependencies

The swipos services depend on GPS and are based on the Swiss Automated GPS Network (AGNES).

H.3.4.5 Local Augmentation Services

H.3.4.6 Overview

Different standards exist for local area DGPS. The general principle of operation is equal for these standards, but the way of implementation is different. A local area DGPS architecture consists of a reference receiver on a very precise surveyed position on the ground. Differential corrections are transmitted by the reference receiver over a datalink to the user equipped with a datalink receiver. The user applies the corrections to the measurements in the mobile GPS receiver.

Current local area DGPS standards transmit corrections for the measured pseudoranges and not for the position. The main reason for this is that the set of visible satellites at the reference site can differ from the one at the mobile. By transmitting pseudorange corrections the user can select the ones which are useful.

All pseudorange corrections are generated and transmitted at the same instant in time. The user receives a data string containing the time tag of the corrections t0 followed by, for every satellite, the satellite ID, a pseudorange correction (PRC) and a pseudo range rate correction (RRC). The user can calculate the correction at the desired time "t" for satellite i:

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102 data transmission via VHF ends by end of 2004

103 plus service charge each

104 http://www.swisstopo.ch

$$PRC_i(t) = PRC_i(t_0) + RRC_i \cdot [t - t_0]$$

The measured pseudorange PRm at the mobile can then be corrected by adding the PRC:

$$PR_i(t) = PR_{m,i}(t) + PRC_i(t)$$

The reference station, using a single frequency GPS receiver, does not apply any corrections for ionosphere and troposphere, but leaves that up to the mobile user to provide maximum freedom in the selection of ionospheric and tropospheric models.

Carrier Phase DGPS

The length of the carrier wave is much shorter than the code chips and therefore higher accuracy can be obtained from the use of the carrier phase. However, the carrier has an unambiguous range of only 20 cm and the resolution of the ambiguity is far more difficult. Different techniques have been invented to solve this problem, both static and dynamic (also known as On-the-Fly). Most techniques employ double differencing to eliminate satellite and user clock errors. After that, satellite redundancy and changing of the satellite constellation are used to identify the correct GPS carrier cycle.

Signal Characteristics – The RTCM SC-104 Standard

The RTCM SC-104 standard has been originally designed for maritime use with the assumption that the most probable datalink would be maritime radio beacons. The standard provides a general data format and standard user interface which can be used in conjunction with any datalink.

The RTCM standard basically defines message content and format, assuming a minimum data rate of 50 baud. The format is very similar to the GPS data format with some modifications. Every message is preceded by a header, containing message type and time tag. The message type is necessary as the RTCM format is capable of supporting 64 different message types of which 26 are defined in RTCM-SC 104 V. 2.1. Of the defined types 8 are fixed. The most important are "Message Type-1" and "Message Type-9."

Message Type 1 – Differential GPS corrections:

The Type 1 message contains data for all satellites in view of the reference station. For every satellite a PRC, a RRC, an Issue of Data (IOD) and User Differential Range Error (UDRE) is transmitted. The UDRE is a signal quality indicator, providing a 1s estimate of the uncertainty in the pseudorange correction as estimated by the reference station. The IOD is transmitted in the GPS satellite messages and indicates for which set of GPS orbital and clock parameters the transmitted corrections are valid. This is necessary as the satellites could start transmitting a new set of data during the transmission interval of the corrections to the mobile..

Message Type 9 – Partial Satellite Set Differential Corrections:

Type 9 messages do not include a full set of pseudorange corrections. This requires a very stable clock as corrections will be transmitted at different instances in time. Reference station clock drift will induce different clock biases in the corrections, which the mobile receiver can no longer remove. The advantage is that the average latency per correction can be reduced.

European Local Area DGPS systems

The following table summarises known information concerning national DGPS systems in Europe.

Country	System title	Institution	No of ref stations	Type of solution	Services	Service provider	Channel type	Accuracy	Service charge	Notes
Sweden	Swepos		25	RINEX	Post processing service			< 10 cm		Long term goal is that users fee will cover operational cost
				DGPS	EPOS	Cartesia	FM RDS	1 - 2 m		
				WADGPS	Omnistar	Omnistar	L-band Geo	1 - 2.5 m		Omnistar uses data from Swepos
Germany	SAPOS			DGPS	Real-time Positioning (EPS) Service		LW (2 m band), UKW	1 - 3 m		
				VRS / DGPS	High Precision Positioning Service (HEPS)		LW (2 m band), GSM	1 - 5 cm		
				RINEX	Geodetic Precise Positioning Service (GPPS)		Internet, CD-ROM, GSM	1 cm		Post-processed
				RINEX	Geodetic High Precision Positioning Service (GHPS)		Internet, CD-ROM	mm		Post-processed
	ASCOS	Private company		DGPS	Precise real-time service (PED)	Ruhrgas AG	GSM	> 2 cm		See Section G.3.2
					Real-time service (ED)	Ruhrgas AG		> 30 cm		
	AMDS	Private company		DGPS		EuroNav Service GmbH		0.5 - 2 m		User requires AMDS/DGPS-Box II and a licence
UK	National GPS Network	Ordnance Survey							Service is free	
Denmark	National Survey & Cadastre	TU Denmark		DGPS	Service 1 (public)	National Survey & Cadastre				
		National Survey & Cadastre			Service 2 (public)					
				RTK / VRS	Service 1 (private)	GPSnet.dk	GSM	cm	Initial charge of 10,000 Dkr	

									plus 8,500 Dkr annual charge	
					Service 2 (private)					
					Service 3 (private)	Andelsforeningen GPS-Referencen				
Austria	DARC	Austrian Broadcasting Corporation	270	RTCM						
Switzerland	SWIPOS	Swiss Federal Office of Topography		DGPS	Swipos -NAV		VHF/RDS	1-2 m	Free of charge (except communicatio n cost)	
				VRS/RTK	Swipos - GIS/GEO		GSM	2.4 cm hor 4 cm vert	5,000 CHF annual charge or 0.70 CHF per minute	
Netherlands	LNR Globalcom	Private company		GPS-RTK		LNR Globalcom	GSM			
				GPS-RTK		LNR Globalcom	439.6 MHz TDMA			
	06-GPS	Private company		GPS-RTK		06-GPS	GSM			
	Fugro-Commetius	Private company		VRS-RTK		Fugro-Commetius	GSM			System in test phase only
	RWS LRK	Private company		GPS-RTK		RWS LRK	410-470 MHz UHF			
	NS Rail Infra Beheer			GPS-RTK		NS Rail Infra Beheer	439.8-439.9 MHz			
Italy	GeoData			DGPS		TIM (Telecom Italia Mobile)	GSM			

H.3.5 OmniSTAR

H.3.5.1 Overview

The OmniSTAR system is a global real-time differential GPS broadcast system delivering corrections from an array of base stations. OmniSTAR uses a network of reference stations (or base stations) to measure Ionospheric interference and other errors inherent in the GPS system.

This reference data is then transmitted to both global network control centres where it is checked for integrity and reliability and is then up-linked to geo-stationary satellites, which distributes the data over their respective footprints.

The satellite broadcast is received at the user's location by an Omni-directional antenna. It is then demodulated, and passed to a processor that reformats the data into corrections for use in either an internal or external differentially capable GPS receiver. The way that the data is processed inside the user equipment depends on the type of OmniSTAR receiver that is used. The raw data complies with RTCM - SC -104, Version 2.

Network Control Centre NCC

The OmniSTAR Global Network Control Centres are located in the USA and Australia. Both centres are interlinked via the OmniSTAR Data Network, providing integrity monitoring on a 24 hour basis. The centres provide the management, command and control functions, gather data from the reference station networks and apply Quality Control and Quality Assurance checks before transmitting the data via the uplink sites.

System reliability is ensured by built in redundancy in the system. System Integrity is monitored 24 hours a day at the Network Control Centres. DGPS correction data is logged and archived on a routine basis providing a capability for post-processing and data analysis.

Network of Reference Stations

OmniSTAR has around 100 reference stations globally. OmniSTAR coverage is claimed to be over 90% of the world. New reference stations are being set up to improve coverage further. Each reference station is equipped with low noise, 12 channel GPS receivers.

H.3.5.2 Institutional

The OmniSTAR service is operated by Fugro.

H.3.5.3 Service Delivery

OmniSTAR VBS

The OmniSTAR Virtual Base Station (VBS) technology provides users with metre-level positioning with a correction message.

Performance: accuracy to within one metre.

OmniSTAR-HP

The OmniSTAR-HP (High Performance) solution is a dual frequency GPS augmentation service.

OmniSTAR-HP provides a decimetre level DGPS service. It uses dual frequency GPS receivers to measure the true ionosphere at the reference and user locations, thus largely eliminating this error.

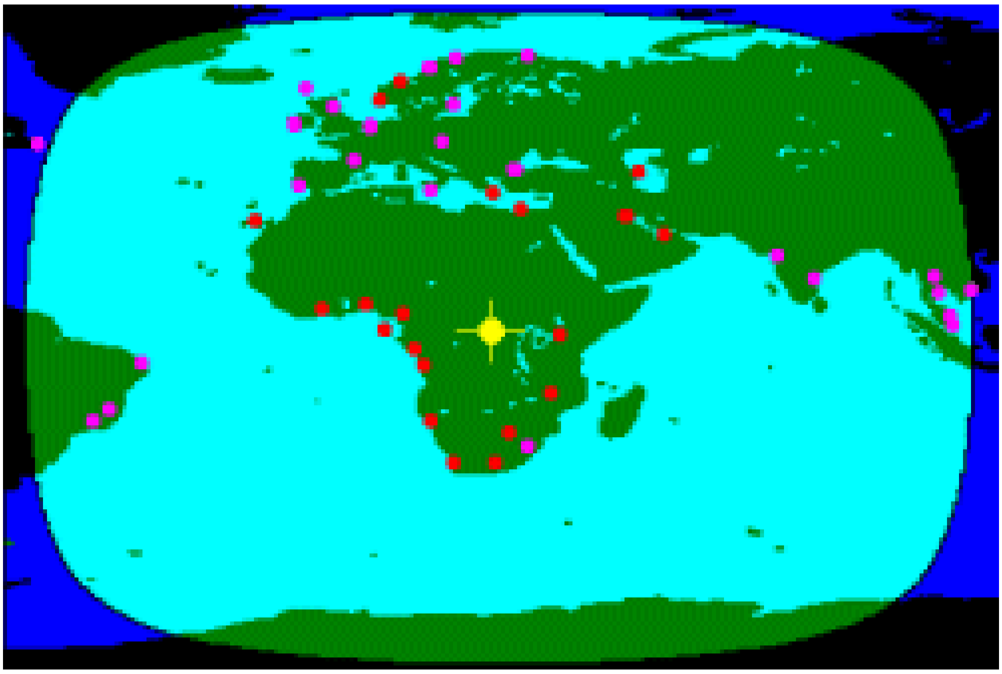
Performance

Horizontal Accuracy	10 cm
Vertical Accuracy	20 cm

These accuracies are obtained up to 1000 km from the reference station.

European coverage

OmniSTAR European coverage is shown in the figure below.



Frequencies

The following table shows the satellite frequencies used by OmniSTAR.

Satellite	Frequency (MHz)	Symbol rate	Baud rate	Status
EA-SAT (Europe)	1535.1525 MHz	2438	1200	use instead of EMS
ASAT S. America	1541.7050	-	2400	inactive
AMSC (N. America) East	1556.8250	2438	1200	active
AMSC Central	1554.4970	2438	1200	active
AMSC (N. America) West	1551.4890	2438	1200	active
Optus Austr./ N.Z.	1558.5100	2438	1200	active
GPS signal	1575.4200	-	-	active

AP-Sat (Asia)	1535.1375	2438	1200	active
AM-Sat (America)	1535.1375	2438	1200	active
AF-Sat (Africa)	1536.2150	1219	600	active

User base

OmniSTAR supports applications across a wide range of industries from agriculture (Precision Farming), mining and land survey to aerial applications such as Crop Spraying, Photogrametry and geophysical surveys:

H.3.5.4 Dependencies

The Omnistar system is dependent on the existence of GPS.

H.3.6 SkyFix

H.3.6.1 Overview

The main elements of the SkyFix system are:

- A network of more than 85 permanent DGPS reference stations
- A communication network with data relays via X25 and VSAT
- Two permanently manned Network Control Centres
- Satellite downlinks via geostationary communication satellites
- Satellite terminals and data decoders
- Multi-reference station positioning and QC hardware and software

The network of reference stations comprises 85 permanent GPS installations worldwide, tied into large Geodetic Networks. Each reference station has dual redundant sets of GPS receivers, antennas and data processing and communications interfaces, and can be fully remotely controlled from the Network Control Centres. The GPS instrumentation used throughout the SkyFix Reference Stations Network is based on Trimble 4000 series of single frequency, 9 channel, GPS receivers. The Pseudo Range Corrections (PRC) are generated using DGPS RTCM SC-104 V2 format.

The SkyFix data communications network delivers the stream of GPS Pseudo Range Corrections from each reference station to the control centres by a variety of data links, which include leased lines, X25 packet networks, and VSAT systems. As the two Control Centres are also linked, the whole system can operate as one contiguous network.

The two Network Control Centres, in Singapore and Scotland, deal with the Network Management and Quality Control and perform system quality control and monitoring functions. These include checks on reference station and observation performance, data link delay and reliability, overall system latency, DGPS positioning performance, and satellite broadcast power and continuity. In addition, SkyFix uses two sub-NCCs in Houston, USA and Perth, Australia.

Correction messages

Correction Message broadcast is achieved using pre-assigned leased capacity on each of the four INMARSAT marine and on the regional High Power beam communication satellites. All these downlinks use Frequencies on the L-band at data rates between 1200 and 2400 bps.

H.3.6.2 Institutional

The SkyFix service is operated by Fugro.

H.3.6.3 Service Delivery

SkyFix DGPS Service

The standard SkyFix DGPS is suitable for many applications including positioning for seismic exploration, DP, rig moves and construction projects. It has the performance characteristics shown below:

Accuracy	< 2 metres
Range	2000+ km
Frequency	L-Band
Message Protocol	RTCM SC-104 V2
Update Rate	< 5 seconds
Network Management	Full quality control and data integrity monitoring

SkyFix XP Service

SkyFix-XP is a more accurate DGPS service that allows users to derive positions with decimetre level precision. The service is based around corrections to the broadcast GPS orbit and clock information. This technique is therefore called Satellite Differential GPS (SDGPS) as the differential corrections are for the actual satellites, as opposed to a geographical area.

The standard Differential GPS services use the fixed location of a single reference station to measure the ranges to all GPS satellites in view. These measurements are then compared to the computed ranges at that location and the resulting differences in the observations are transmitted as pseudo-range corrections. This technique introduces some inaccuracies as the distance from the reference station grows. SkyFix XP removes this range limitation by using a completely new technique known as Satellite Differential GPS (SDGPS). Orbit and clock corrections are determined for each GPS satellite continuously utilising Thales' global network of reference stations. These corrections are then broadcast to the user and can be used at any location, regardless of distance to any reference station, making the system truly global.

The satellite corrections are derived from a global network of reference stations, in real-time, and they are transmitted to the user via the existing SkyFix satellite communication infrastructure.

Key features of SkyFix XP are:

- Truly global coverage with no range restrictions from stations
- Dual delivery satellite beams
- Extensive QC monitoring in line with UKOOA standards

- Real-time system performance information available on-line
- Compatible with existing SkyFix hardware

Performance

SkyFix XP performance is shown below:

Horizontal Accuracy	10 cm
Vertical Accuracy	15 cm

Coverage

SkyFix coverage in Europe is shown in the following figure.

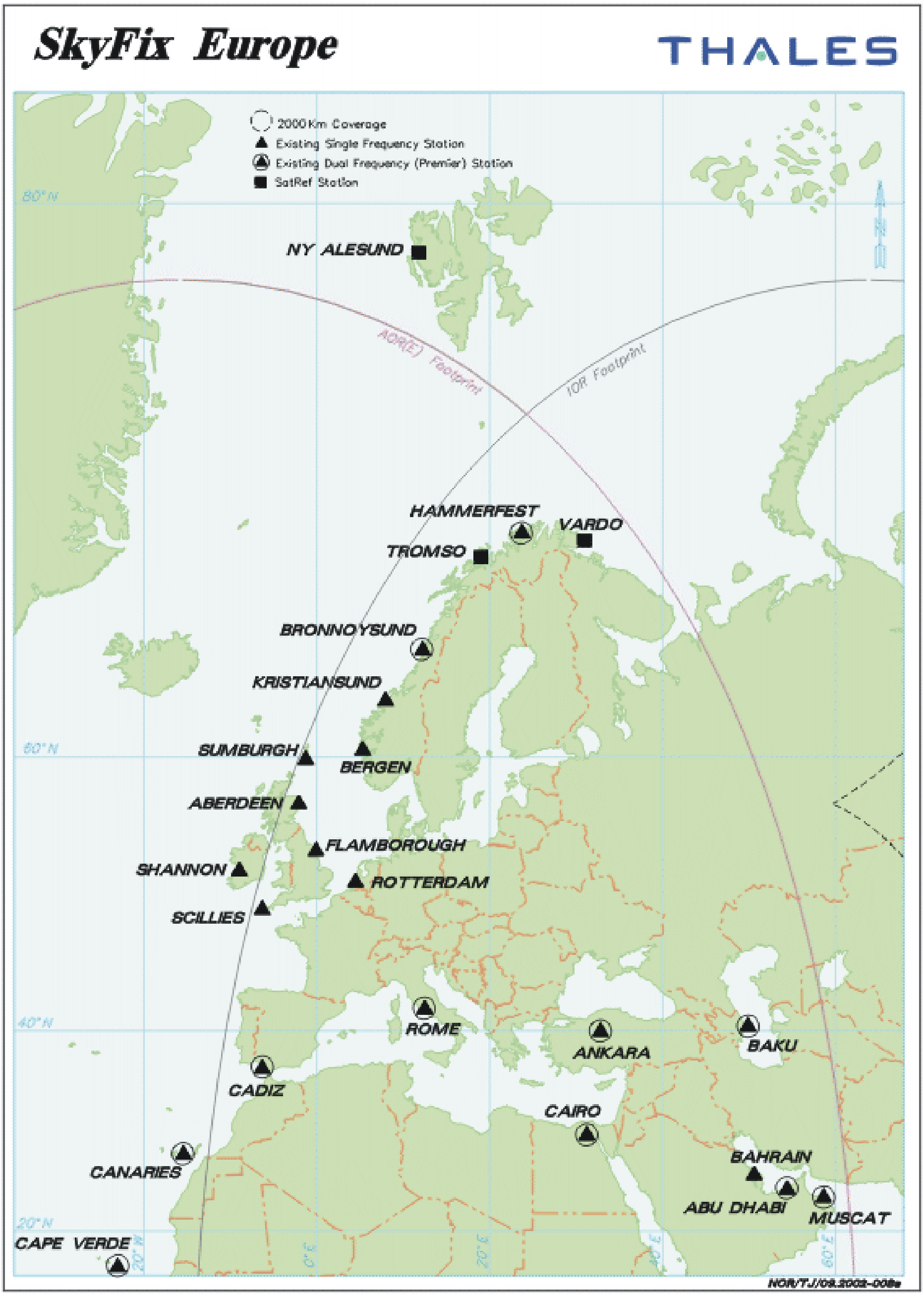


Figure 44 – European SkyFix Coverage

Receivers

The user accesses the SkyFix signals by either existing Inmarsat A equipment, or by using a special receive only L-Band terminal supplied by Fugro. The SkyFix High Power can be received via a smaller, omni-directional High Power Beam Antenna.

Purpose-designed SkyFix decoders are used to decode the DGPS data. The station enabling and data decoding is controlled by the Network Control Centres. Two types of SkyFix decoders are available: the 90938 and the 2403.

H.3.6.4 Dependencies

The Skyfix system is dependent on the existence of GPS.

H.3.7 StarFire

H.3.7.1 Overview

The StarFire WADGPS has been developed from a set of regional DGPS networks over independent continental areas. Now combined, these provide a high accuracy service forming a global network. The system provides sub-decimeter real time service worldwide. It is based on technology called RTG (Real Time GIPSY) developed by the Jet Propulsion Laboratory (JPL) for NASA.

The StarFire system consists of a global network of dual frequency GPS reference receivers. These send data to two network processing centres at Torrance and Moline in the US. GPS satellite orbit and clock corrections are calculated and then transmitted via Inmarsat satellite links to StarFire user receivers.

Unlike DGPS positions that are relative to the reference station location, StarFire produces absolute, ITRF positions. Accuracy is independent of the distance to the nearest reference station.

The StarFire system has the following characteristics:

- GPS measurement data from a global network of dual frequency reference receivers
- Orbit calculations using JPL's RTG technology
- Modelling of significant error sources
- Dual frequency mobile receivers
- Redundant measurement data, processing structures, and communications links.

H.3.7.2 Institutional

The StarFire DGPS service is operated by NavCom.

H.3.7.3 Service Delivery

Receivers

StarFire receivers are available as fully integrated units or modular systems. StarFire receivers use a dual frequency GPS receiver that measures the ionospheric delay for each satellite. Tropospheric zenith delays are calculated from a multi-state time and position model aided by redundant satellite observables. Typical applications include:

- Land Survey
- Offshore Positioning
- Precision Agriculture
- Aerial Photogrammetry and LIDAR
- GIS and Asset Mapping
- Machine Control

Performance

StarFire performance is shown below:

Horizontal Accuracy	10 cm
Vertical Accuracy	15 cm

Coverage

StarFire coverage extends from 75 degrees North to 75 degrees South and is shown by the red outline in the figure below.

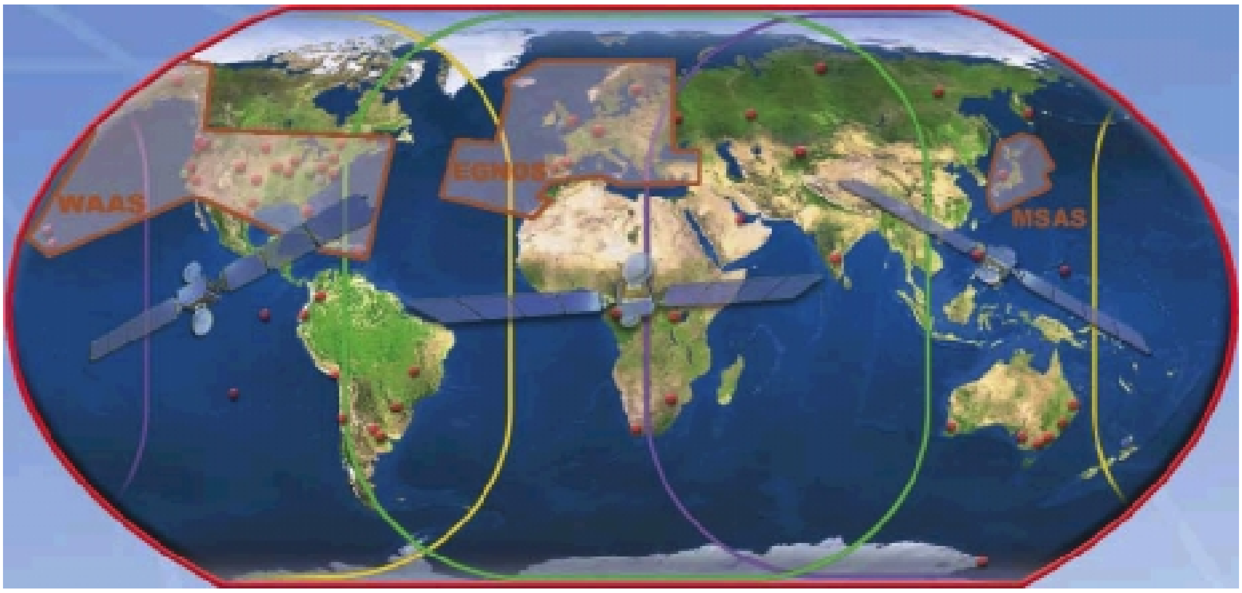


Figure 45 – Global StarFire Coverage

H.3.7.4 Dependencies

The StarFire system is dependent on the existence of GPS.

H.3.8 IALA Marine Radiobeacon DGPS

H.3.8.1 Overview

The internationally accepted method of providing DGNSS (effectively DGPS at present) corrections to maritime users is by local broadcast stations transmitting “free-to-air” corrections on frequencies within the maritime radionavigation band (285 to 325 kHz). The systems use a local augmentation architecture, as illustrated in Figure 1. The system was originally conceived to enhance the accuracy from GPS when selective availability (SA) was applied. Following the termination of SA, the GNSS system continues to improve accuracy above that available from GPS alone but also fulfils the vital integrity monitoring and dissemination function .Other than for frequency coordination, control and monitoring, and coverage purposes, each system currently operates independently of all other systems, i.e. there is no networking.

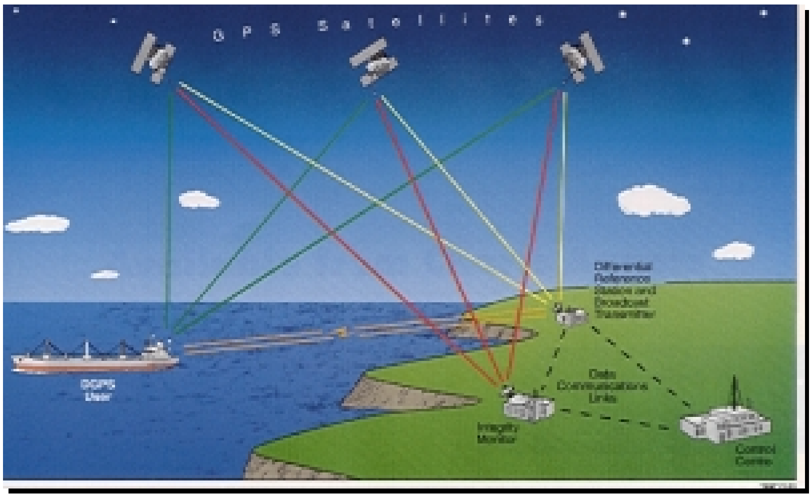


Figure 1 – Illustration of the architecture used by the IALA DGNSS system

The system provides extensive coverage within the European Maritime Area, as illustrated in Figure 2, as well as in other regions. In addition to maritime users, the IALA DGNSS service is available to users for other sectors and some States, e.g. the UK, have implemented inland stations to provide complete terrestrial as well as coastal coverage.

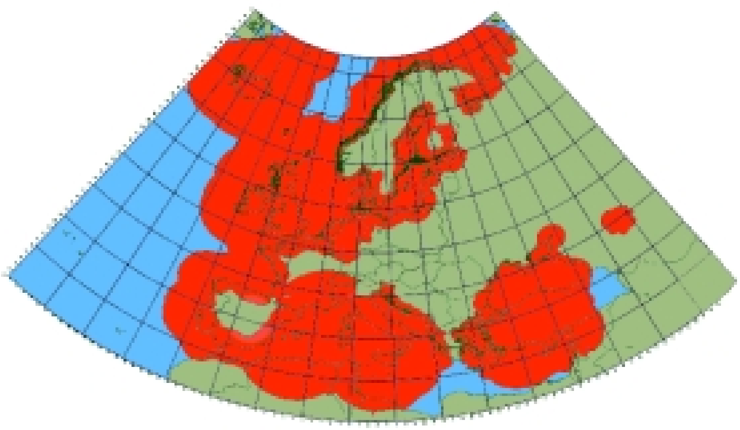


Figure 2 – The European coverage of the IALA DGNSS system

Correction and integrity data is generated using monitoring stations, usually collocated with the transmitters. The monitoring stations consist of survey quality, dual frequency GPS receivers at very accurately surveyed positions. These receivers are used to generate differential corrections and integrity flags for all GPS and/or GLONASS satellites in view. In addition, local integrity and far-field monitoring is provided to check the transmitted signal and data content. These integrity monitors are usually, but not always, connected directly to a central control centre for real-time performance monitoring. Data is archived for performance monitoring, audit and legal reasons.

Augmentation data is broadcast, unencrypted and free-to-air, on a point-to-multipoint basis to all users that have suitable receiving equipment. In Europe, signals are transmitted in the maritime radiobeacon band 283.5 to 315KHz using a minimum shift keying (MSK) modulation scheme. The 283.5 to 315KHz frequency band is sub-divided into 64 channels, each of 0.5KHz bandwidth. Data can be broadcast at 50bps, 100bps or 200bps, with most European stations broadcasting at 100bps. The maximum range of European transmitting stations depends on the transmitter power, as well as interference from other stations. Service providers publish the nominal ranges of stations at stated signal powers, e.g. 50, 75 or 100µV/m. IALA maintains a database of DGNSS stations including the reference and transmitter identification numbers and transmitter characteristics[105],[106].

The data format and transmission characteristics are defined in ITU-R Recommendation M.823 which incorporates the data format defined in RTCM SC-104 version 2.3. IALA Recommendation R-121[107] further refines the data to be transmitted to a subset of the message types defined in RTCM SC-104. This data includes pseudorange corrections, and integrity messages and can also include special text messages. Typically, corrections are rebroadcast at least every thirty seconds[108] to ensure that temporal decorrelation is not problematic and service providers publish service volumes such that the impact of spatial decorrelation is controlled.

Transmissions from MF beacons are subject to a variety of interference effects:

- over-the-horizon interference from other beacons operating on the same or nearby channels
- skywave fading, especially at night
- atmospheric noise
- precipitation static
- man-made noise.

These factors are taken into consideration when determining the nominal range of stations. In particular, interference from other beacons is minimised through a frequency plan coordinated by IALA.

In addition, the broadcasts could be vulnerable to intentional interference although MF transmitters are not portable and the size of the masts needed to transmit effective jamming signals may be sufficient to ensure that this threat is not significant. In theory, spoofing could be achieved by gradually increasing pseudorange corrections. However, the threat to DGNSS broadcasts is likely to be relatively low as it is much easier to jam the core GNSS system itself.

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105 "Information and guidance on allocation of identification numbers for Differential Global Navigation Satellite system (DGNSS) reference and transmitting stations in the maritime radionavigation (radiobeacon) band", IMO Circular SN/Circ.223, 6 November 2002

106 http://www.iala-aism.org/web/index.html

107 "Recommendation on the performance and monitoring of DGNSS services in the frequency band 283.5KHz – 325KHz", IALA Recommendation R-121, June 2001

108 Corrections were broadcast at least every ten seconds prior to the termination of selective availability (SA)

H.3.8.2 Institutional

The IALA DGNSS service is provided to meet each State's obligations under the SOLAS Convention. However, in Europe, States meet this obligation in a variety of ways ranging from direct service provision by the government (e.g. as in France) through to delegation of service provision to private institutions (e.g. as in the UK). The mechanism for service provision is usually enshrined in primary national legislation and there is no single service provision model applicable throughout Europe. However, in the majority of cases the infrastructure is owned and operated by the service provider – the marine aids to navigation provider, with the exception of some maintenance activities which are outsourced. The majority of DGNSS service providers are either unregulated or self-regulating (with specific regards to the DGNSS service) although all comply with international recommendations and guidelines.

The IALA DGNSS service is standardised globally, coordinated through IALA but utilising the instruments of the competent standards bodies, particularly ITU and RTCM as appropriate. The system is not explicitly recognised as part of the World Wide Radio Navigation System (WWRNS) by the International Maritime Organisation but is noted as necessary in the Resolutions recognising both GPS and GLONASS.

H.3.8.3 Service Delivery

The IALA DGNSS service provides the user with differential corrections (pseudorange corrections) and integrity messages for the GNSS satellites in view, principally GPS at present. The service is operational throughout Europe providing coastal coverage as illustrated in Figure 1. The service will continue to be provided for the foreseeable future.

The service performance parameters are specified by IALA[109] to be at least:

- 10m absolute accuracy to the 95% level within the specified coverage area, noting that several service providers specify an accuracy level considerably better than this minimum performance requirement. The accuracy at the broadcast site is specified to be 1m at the 95% level and the spatial decorrelation effects causing a 1m degradation for every 150km distance from the reference site
- for integrity, the minimum specification is for a warning to be provided to the user within 10 seconds of a position error of 10m persisting for more than 20 seconds (i.e. in the worst case the user is warned within 30 seconds of the onset of a 10m position error)
- availability of the DGNSS system is required to be 99.5% over a period of two years in low risk areas and 99.8% over a period of two years in high risk areas
- continuity of the DGNSS system is required to be 99.85% for single beacon coverage in low risk areas and 99.97% over three hours with dual beacons coverage in high risk areas.

DGNSS is widely used in the maritime community by the whole range of users from commercial through to leisure. The vast majority of GPS receivers are capable of utilising RTCM SC-104 corrections and interfacing easily to an MF radio receiver. Receiver costs are relatively low and receivers are widely available.

The IALA DGNSS service is provided primarily for safety purposes at performance levels promulgated by individual service providers, compliant with IALA recommendations, above.

109 "Recommendation on the performance and monitoring of DGNSS services in the frequency band 283.5KHz – 325KHz", IALA Recommendation R-121, June 2001

The service is provided as part of a bundled set of services that also includes traditional aids to navigation – DGNSS is not a sole means service. There is no formal service level agreement between the service providers and users and, as yet, the overall service has not been subject to formal certification. However, the service provider sub-systems are subject to formal testing and validation and the user equipment is subject to type approval against international standards.

H.3.8.4 Dependencies

The IALA DGNSS system is wholly dependent on the core GNSS systems – GPS and GLONASS. It only provides augmentation to those systems and cannot function in isolation.

H.3.9 Radar Beacons (RACONS)

H.3.9.1 Overview

A RACON is defined as a receiver/transmitter associated with a fixed navigational mark which when triggered by a shipborne radar, automatically returns a distinctive signal (identification) which appears (is painted) on the display of the triggering radar correlated with the return generated by the associated navigational mark. Together the primary radar and RACON signals provide range, bearing and identification information[110].

RACONs are always associated with navigational marks and may be devices mounted on fixed structures, or on floating aids anchored at fixed positions, for navigational purposes. The RACON itself is considered a separate aid to navigation[111]. RACONs can be used for

- ranging and identification of positions on coastlines
- identification of aids to navigation, both seaborne and land based
- landfall identification
- indicating centre and turning point in precautionary areas or traffic separation schemes
- marking hazards
- indicating navigable spans under bridges
- as a leading line.

Of the two types of RACON, the swept frequency variety is now obsolescent. The frequency-agile RACON responds on the frequency at which it is interrogated and the response can be re-painted on each radar sweep. However, to avoid masking other features on the radar screen the RACON response is usually switched on and off on a preset cycle, usually with the off:on ratio being around 20:40. Frequency-agile RACONs can also be made user-selectable so that the radar operator may choose whether to suppress display of either the RACON response or other radar echoes.

RACONs operate in the 9GHz (X) band in the range 9320MHz to 9500MHz with horizontal polarisation, and/or in the 3GHz (S) band in the range 2900MHz to 3200MHz with horizontal and, optionally, vertical polarisation. Dual frequencies are provided because during bad weather, many vessels use 3GHz band radars in preference to 9 GHz band radars because

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110 ITU Radio Regulation 4.40

111 "*Radar beacons, transponders and reflectors*", IMO Resolution A.615 (15), 19 November 1987

of better clutter rejection. Despite this better performance at 3 GHz in adverse conditions there are concerns regarding the future of RACONs in this band as proposed IMO performance standards would not require RACONS to operate at 3GHz and there is a potential threat to the band from other services.

The performance of RACONs is often monitored remotely by their providers using remote control and monitoring systems.

The pulse transmitted from the RACON has a length of approximately 25µs and is delayed by up to 7µs following the receipt of the radar pulse. The pulse can be coded with a Morse code for identification purposes. The symbol *D* is reserved for danger signals and cannot be over-ruled by user selection. The following figure illustrates a radar display with the RACON character "R".

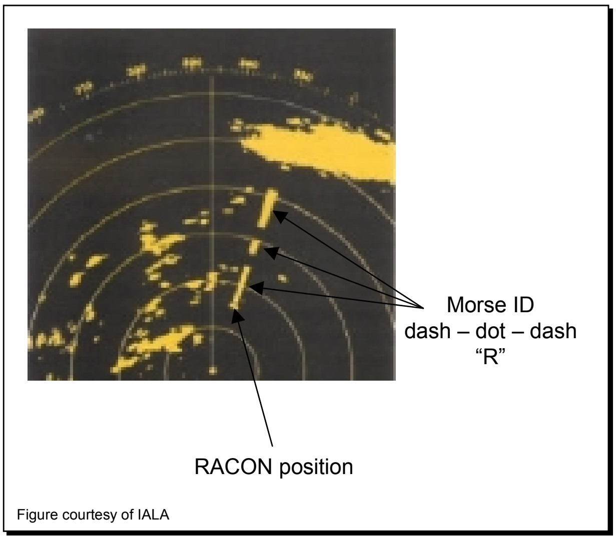

Figure 3 – A radar display illustrating a RACON character

H.3.9.2 Institutional

RACONS are owned and operated by the marine aids to navigation service provider which, in addition to the national providers, can be provided by local providers, such as port and river authorities. RACONS are operated under the normal regulatory regime in place, which can vary from State-to-State. In general, national authorities are self-regulating whereas local authorities can be inspected and audited by the national authority in line with the normal procedures in place for aids to navigation.

RACONs are accepted internationally and fully standardised through the IMO and IALA processes. These standards are promulgated through IMO Resolution A.615(15)[112], IALA Recommendation R-101[113] and the IALA Guideline on RACON range performance.

H.3.9.3 Service Delivery

The coverage provided by a RACON depends on its purpose, location and also on line of sight between the RACON and the vessel. Typically, a RACON mounted on a bouy is expected to have an operational range of around 6 nautical miles whereas the range of a

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112 112 "*Radar beacons, transponders and reflectors*", IMO Resolution A.615 (15), 19 November 1987

113 *"Recommendation on marine radar beacons (RACONs)*", IALA Recommendation R-101r1, December 2000

RACON mounted on a lighthouse would be expected to be much greater, up to around 30 nautical miles. Multipath effects can impair the range performance of RACONs.

The range accuracy depends on both the radar and the RACON, measured from the primary return or the start of the RACON flash. The bearing accuracy depends only on the radar and is usually around 0.3°. Angular accuracy can be degraded by returns triggered from the radar sidelobes but RACONs employ sidelobe suppression techniques to mitigate this effect.

RACON availability is required, by IALA, to be greater than 99.6% although many aids to navigation providers exceed this target.

List of RACONs are promulgated in the appropriate official maritime publications, e.g. by hydrographic officies in list of radio signals. The lists include the name of the station, the location of the station, the station reference number, the frequency of operation, the sector within which signals may be received, the maximum range of operation, the Morse identification character and the overall length on the radar screen of the RACON flash.

H.3.9.4 Dependencies

RACONs operate cooperatively with ship's radar. They are also generally collocated with other navigation marks, which may require radar target enhancers (RTEs) or radar reflectors to ensure that they are visible on the vessel's radar display.

H.4 Non-Radionavigation Systems

H.4.1 MSF

H.4.1.1 Overview

System overview

MSF is a 60 kHz standard-frequency and time radio signal which broadcasts the national time standard for the UK. The MSF service broadcast from Rugby is the principal means of disseminating the UK national standards of time and frequency which are maintained by the National Physical Laboratory. Transmission is 24 hours a day, and the carrier frequency is maintained at 60 kHz to within 2 parts in 1012.

The letters MSF are a call sign which uniquely identifies the broadcast. M is one of three prefixes (2, G or M) allocated to the UK by international agreement for station identification. There is speculation that SF was intended to represent the words 'standard frequency'.

Signal characteristics

The modulation is a simple switching on and off of the 60 kHz carrier, with the boundary between the on and off states acting as a time marker. The beginning of the first second of a UTC minute is indicated by an off-period of 500 ms, with the remaining 500 ms of this second as an on-period. The remaining 59 seconds of the minute are used to carry time and date data at the rate of two bits per second. The duty cycle of the MSF signal is shown in Figure H-1 below.

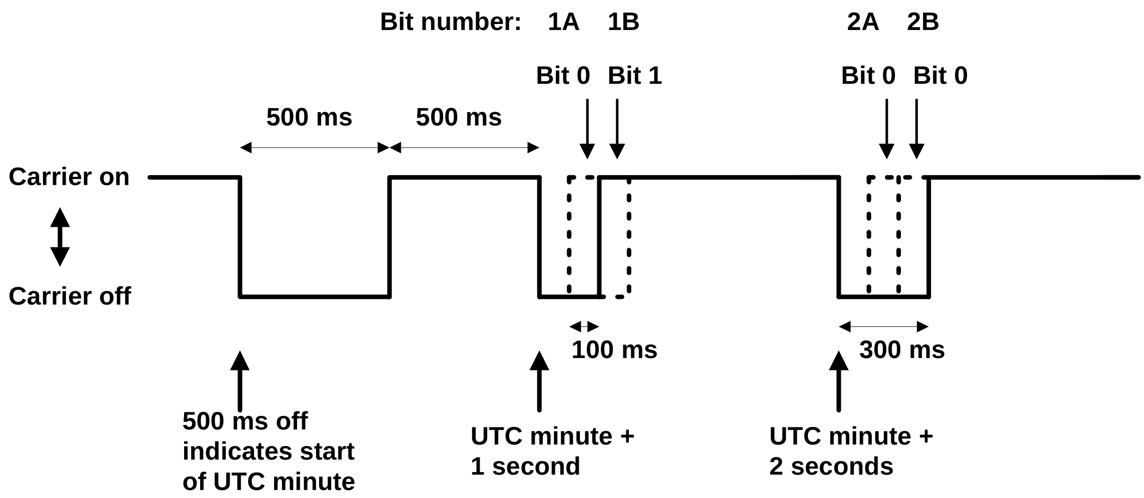

Figure H-1: MSF carrier modulation

The first 100 ms of each of the remaining 59 seconds is marked by an off-period. The two bits in each remaining second are denoted by whether the carrier is off or on in the second and third 100 ms periods of the second. Theses two bits are denoted A and B. Thus the available bits range from 1A to 59A and from 1B to 59B. The last eight A-bits of the minute are used to transmit the sequence ‘01111110’ as a marker to indicate that the following second is the first second of the next UTC minute.

H.4.1.2 Institutional

The MSF 60 kHz standard time and frequency service is funded by the Department of Trade and Industry (DTI) as part of its provision of time and frequency measurement standards in the UK.

H.4.1.3 Service Delivery

Signal coverage

The horizontal radiation pattern is substantially omnidirectional. The signal provides a field strength exceeding 100 µV/m throughout the UK and up to 1000 km from the transmitter, and can therefore be satisfactorily received throughout much of north and west Europe. A diagram illustrating the coverage is shown in Figure H-2. The main cause of reception difficulties are local interference and screening due to nearby metalwork, for example in a steel-framed building.

Figure H-2: MSF 1000 km range at 100 mV/m signal strength

Service provision and performance

The following table summarises the service provided by MSF.

Mast location	latitude 52° 22' N, longitude 1° 11' W
Carrier frequency	60 kHz
Power output	15 kW equivalent monopole radiated power (EMRP)
Range	100 microvolts/m at 1000 km range
Antenna	Twin 250 m masts with horizontal connecting stay
Time signal	Achieved with on-off carrier modulation (see Figure 2-1): Carrier is switched off for 500 ms to indicate start of UTC minute Carrier is switched off for 100 ms to indicate start of UTC second
Time message coding	On-off carrier modulation (see Figure 2-1): For seconds 1-59, for either the period 100-200 ms or 200-300 ms in the second, a '1' is indicated by the carrier being 'on', and a '0' is indicated by the carrier being off. This gives two bits per second (except the first second of the minute) which in each second are denoted bit A and bit B.
Encoding scheme within a minute	**Bit** **Indication** 1A-16A Set to 0 (may be used in future) 17A-24A Binary Coded Decimal (BCD) year 25A-29A BCD month 30A-35A BCD Day of month 36A-38A Day of week 39A-44A BCD hour 45A-51A BCD minute 52A-59A Combination set to '01111110' indicates minute mark to follow

	1B-16B Information on difference (DUT1) between atomic and industrial time 17B-52B Set to 0 (may be used in future) 53B Set to 1 in the last hour before the change to British Summer Time (BST) 54B-57B Parity bits 58B Indicates British Summer Time (BST) 59B Set to 0 (may be used in future)

The performance of the DCF service is given in the following table.

UK Coverage	Whole of UK geographical region
Frequency accuracy at user	2×10^{-12}
Timing accuracy at user	1 millisecond
Minute, hour, day information	Yes
Traceability/validation	Traceable to UTC (NPL, UK)
Service availability	Continuous apart from for up to 4 hours on the first Tuesday of every April, July, October and January between 1000 UTC and 1400 UTC, plus yearly maintenance periods of up to 2 weeks
Interference resistance	High, but nevertheless liable to interference from atmospheric, magnetic and electric sources
Transmission complexity	Low
Receiver complexity	Low
Receiver availability	High
Receiver cost	Low (less than £100)
Use indoors	Yes
Usability/applicability to different user groups	Includes for example: airports, railway stations, broadcast stations, drives BBC time pips, used by local radio/TV stations, national rivers authority, domestic clocks

H.4.1.4 Dependencies

The MSF signal is dependent on the generation at Rugby of a time signal using atomic clocks and time code equipment provided by NPL. The broadcast signal also has to be monitored and controlled relative to the national time standard at the NPL site in Teddington.

H.4.2 DCF77

H.4.2.1 Overview

DCF77 is a radio time and frequency reference similar to the UK MSF service, and is used as one of the means of broadcasting the German UTC time standard. The service is provided by the German Physikalisch-Technische Bundesanstalt (PTB). The time is broadcast mainly through the LF transmitter DCF77 which the PTB rents from the German Post Office (DBP).

The signal is provided by amplitude-modulating the carrier frequency with second marks. At the beginning of each second (with the exception of the 59th second of each minute), the carrier amplitude is reduced for the duration of either 0.1 or 0.2 seconds. The start of the carrier reduction marks the precise beginning of the second. The minute is marked by the absence of the previous second mark.

In order to increase the accuracy of the time signal, the carrier of DCF77 is modulated with a pseudo-random phase noise. Correlation algorithms then allow PZF receivers to determine the correct time with an accuracy of a few microseconds, which is better than the accuracy achieved by standard AM receivers.

H.4.2.2 Institutional

The PTB is responsible for the keeping and broadcasting of German time. The German UTC-derived time is generated in the PTB Atomic Clock Building in Braunschweig. The PTB has sole responsibility for the control of DCF77, while the DBP has responsibility for the transmitter and antennas.

H.4.2.3 Service Delivery

Signal coverage

The coverage area of the DCF77 signal is indicated (by the yellow circles) in Figure H-3 below.

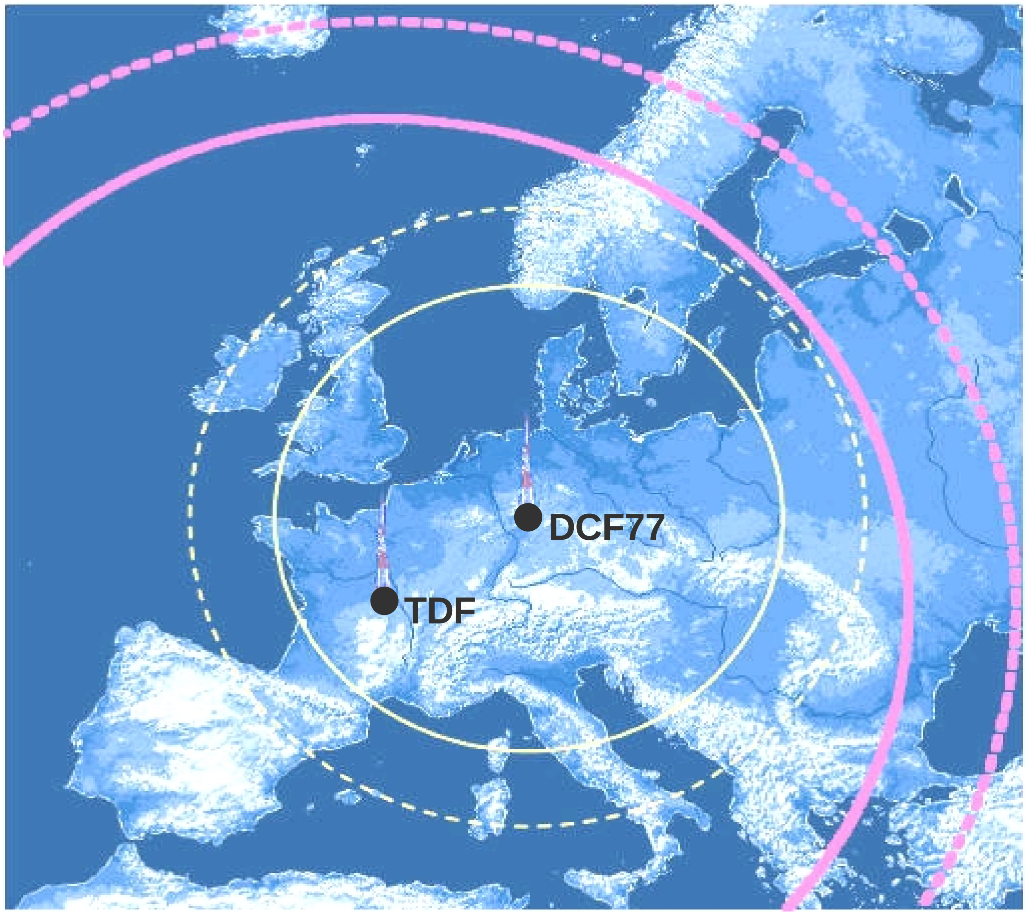

Figure H-3: German DCF77 range (range boundary in yellow) and French TDF range (range boundary in pink)

Service provision and performance

The following table summarises the service provided by DCF77.

Mast location	Mainflingen transmitter complex, (50° 01’ N, 09° 00’ E), about 25 km south-east of Frankfurt am Main.
Carrier frequency	Standard frequency 77.5 kHz.
Power output	Transmitter power 50 kW, estimated emitted power approximately 25 kW.

Range	1000 – 1500 km
Antenna	150 m high (backup antenna 200 m high) vertical omnidirectional antenna with top capacitance.
Transmission times	24-hour continuous service. Short interruptions (of a few minutes) are possible if the service must be switched to a backup transmitter or antenna. Thunderstorms can cause longer interruptions.
Time signal	The carrier is amplitude-modulated with second marks. At the beginning of each second (with the exception of the 59th second of each minute), the carrier amplitude is reduced for the duration of either 0.1 or 0.2 seconds. The start of the carrier reduction marks the precise beginning of the second. The minute is marked by the absence of the previous second mark.
Time code	Values for minute, hour, day, weekday, month and year are BCD-encoded through the pulse duration modulation of the second marks. A second mark with duration 0.1s encodes a binary 0 and a duration of 0.2s encodes 1.
Encoding scheme within a minute	**Second** **Indication** 0 Minute indicator (always 0) 1-14 Reserved 15 Signals use of backup antenna 16 Announcement of change in daylight saving 17,18 Time zone 19 Leap second announcement 20 Start bit for encoded time (always 1) 21-27 Minutes 28 (Parity bit) 29-34 Hours 35 (Parity bit) 36-41 Day in month 42-44 Day in week 45-49 Month number 50-57 Year 58 (Parity bit) 59 No mark transmitted

The performance of the DCF77 service is given in the following table.

UK Coverage	80%. Not complete over North and West UK (see Figure 3-3) – accuracy may be reduced at limits of coverage
Frequency accuracy at user	2×10^{-12}
Timing accuracy at user	5-25 milliseconds accuracy obtainable after normal receiver processing – improves with wideband receiver processing
Minute, Hour, Day Information	Yes
Traceability/Validation	Traceable to UTC (PTB, Germany)
Service Availability	99.7% guaranteed long-term average availability
Interference Resistance	High, but liable to interference from atmospheric, magnetic and electric sources
Transmission Complexity	Low
Receiver Complexity	Low
Receiver availability	High
Receiver cost	Low (less than £100) (e.g. makers are Meinberg, Leunig)
Use indoors	Yes

Usability/applicability to different user groups	Applicable to the same user groups as the UK MSF service

H.4.2.4 Dependencies

The transmitted DCF77 time signal is dependent on the PTB for the time signal generation.

H.4.3 French TDF service

H.4.3.1 Overview

The French TDF is a radio time and frequency reference similar to the UK MSF service, and is used as one of the means of broadcasting the French UTC time standard. The French TDF service is operated over a commercial radio transmitter onto which the time signal is modulated. The long range of the TDF system results from its gigantic transmission rating of 2 times 1 megawatt and its two 350 metre transmission masts.

If the transmitters are out of operation due to maintenance work or a fault, a reserve transmitter of 600 kW can be connected to one of the two antennae.

A relatively expensive process is needed to demodulate the signal.

H.4.3.2 Institutional

The time and frequency service is provided by the French Laboratoire Primaire du Temps et Frequences (LPTF). The radio transmitter is commercially owned and operated.

H.4.3.3 Service Delivery

Signal coverage

The coverage area of the TDF signal is indicated (by the pink circles) in Figure H-3 above.

Service provision and performance

The following table summarises the service provided by TDF.

Mast location	47° 10' N, 2° 12' E, Allouis, France
Carrier frequency	162 kHz
Power output	2000 kW
Range	2500 - 3500 km
Antenna	Two 350 m antennas
Transmission times	Continuous except every Tuesday from 01:00 to 05:00 UTC
Time signal	Amplitude modulated
Time code	Time signals are transmitted by phase modulation of the carrier by + and -1 radian in 0.1 s every second except the 59th second of each minute. This modulation is doubled to indicate binary 1.
Encoding scheme within a minute	**Second** **Indication** 13 Indicates day before public holiday 14 Indicates public holiday 17 Indicates daylight saving time 18 Indicates winter time 20 to 58 Same as for the German DCF77

The performance of the TDF service is given in the following table.

UK Coverage	Yes, Complete over UK (see Figure 3-4)
Frequency accuracy at user	2×10^{-12}
Timing accuracy at user	0.2 millisecond (1 sigma, over all France)
Minute, Hour, Day information	Yes
Traceability/validation	Traceable to UTC (LPTF, France)
Service Availability	Better than 99% when operational, but off every Tuesday from 01:00 to 05:00 UTC
Interference resistance	High, but liable to interference from atmospheric, magnetic and electric sources
Transmission complexity	Low
Receiver complexity	Low
Receiver availability	Low in UK (Quartzlock in UK produce a LF Tracking Receiver Frequency Standard, http://www.quartzlock.com/resources/DSQL2001.pdf) Alarm clocks are available in France which pick up the TDF signal (e.g. from BHL Electronique, Dyna Electronique, Telematique SA).
Receiver cost	Medium (less than £1000)
Use indoors	Yes
Usability/applicability to different user groups	Applicable to the same user groups as the existing UK MSF service

H.4.3.4 Dependencies

The transmitted TDF time signal is dependent on the LPTF for the time signal generation. However, more importantly, it is dependent on a commercial radio transmitter.

H.4.4 Rail on-board odometry sensors

H.4.4.1 Overview

To determine the position and speed of the train different on-board sensors are used, alone or combined, for instance:

- Tachometer: It measures distance and/or speed. The principle of the odometer measurement is to count and sum up the number of wheel rotations. As the value of the measured distance involves the radius of the wheel, the main error component results from a measuring inaccuracy of the wheel radius. Also a significant error due to wheel slip and slide has to be considered. The error of an odometer is naturally only along track and growing with travelled distance. The error has a strong deterministic character and is basically a constant percentage of travelled distance.

- Doppler Radar: It measures distance and/or speed. A Doppler Radar operates by transmitting a narrow beam of microwave energy to the ground and measuring the frequency shift that occurs in the reflected signal as a result of the relative motion between the sensor and the ground. Given knowledge of the wavelength of the transmission and the slant angle, an estimate of the velocity can be determined from the measured frequency shift. The noise type error in the measured velocity value transforms to a drift in the distance value.

- Accelerometer: Accelerometers measure translation motion. Double integration of the measured acceleration yields displacement, which can be transformed into position if the initial situation and the orientation during integration are known. Therefore, accelerometers in conjunction with gyroscopes are often used for navigation purposes. Depending on the construction technology of the accelerometers, they can be classified as mechanical or solid-state.

- Gyroscope: Gyroscopes measure angular orientation or rotation and are also typically used for guidance and navigation applications. Different types of gyroscopes exist, the most important ones being mechanical, optical and micro-electro-mechanical system (MEMS) gyroscopes. Besides those three main categories of gyros, other types are known, like e.g. piezoelectric gyroscopes or are currently under development, like e.g. atomic gyroscopes - that use wave property of matters interferometry or superfluid gyroscopes - using cryogenic liquid helium interferometry.

- Integrated Inertial systems: Inertial measurement units (IMU) measure the linear acceleration and angular rate of rotation of a vehicle. A typical IMU includes (integrates) three accelerometers and three gyroscopes. Accelerometers measure the linear acceleration of a vehicle, which is used to determine vehicle velocity and vehicle position. Gyroscopes measure the angular rate of rotation of a vehicle. From these measurements, a computer can calculate the vehicle's position and heading, which then constitutes an inertial navigation system (INS).

These on-board sensors are the most common way used nowadays in railways for determining the position of a train on the track. Regardless of their intrinsic technological principle, their use for rail operations is based on knowing how much distance the train has covered from a point of known co-ordinates. The distance is measured longitudinally along the track from a reference point. The reference point is established by another means, like track circuits and balises (explained below).

These on-board odometry sensors do not use radio navigation technology. In this sense it is not possible to speak about service delivery.

For conventional odometry (speed and position determination for driver information and conventional signalling) the technology commonly used is just tachometers. For high-performance odometry (high-speed trains and ATP signalling systems), a combination of the above systems through a hybridisation or sensor fusion process is used.

These sensors (mainly hybridised sensors) are used for safety applications (ATP systems). Integrity is achieved by means of a hybridisation process (mutual cross-check to detect errors), redundancy and other techniques.

H.4.4.2 Institutional

These sensors are usually part of another more complex systems, like ATP systems or other train equipment. They are private systems owned by the train operator. In this sense, there is neither a service nor a service provider.

There is not a European standard for these sensors, but instead for higher-level systems as ATP of which these sensors are a part. System providers can choose the location technology freely as long as they meet the performance requirements for the system and the application.

However, these sensors, as on-board equipment, need to comply with other kind of normative, RAMS specifications, EMC (ElectroMagnetic Compatibility), environmental, etc. pertinent for this type of systems. The institution responsible for developing these specifications in Europe is CENELEC (Comité Européen de Normalisation Électrotechnique), although they are enforced nationally by the different national railway administrations. Some of these specifications are listed below:

- CENELEC - EN 50126 Railway applications. The specification and demonstration of dependability, reliability, availability, maintainability and safety.

- CENELEC - EN 50125-3 Railway applications. Environmental conditions for equipment.
- CENELEC - EN 50128 Railway applications. Software for railway control and protection systems.
- CENELEC - EN 50129 Railway applications. Safety related electronic systems.
- CENELEC - EN 50155 Railway applications. Electronic equipment for rolling stock.
- CENELEC - EN 50121-1- Railway applications. Electromagnetic compatibility. General.
- CENELEC - EN 50121-3-1- Railway applications. Electromagnetic compatibility. Rolling stock requirements. Complete train.
- CENELEC - EN 50121-3-2- Railway applications. Electromagnetic compatibility. Rolling stock requirements. Equipment.

This set of European standards are then transposed to equivalent national normative, and together with other national regulations constitute an acceptance criteria for users.

H.4.4.3 Service Delivery

As it was said before, it is not possible strictly to speak about services in this case.

The on-board odometry sensors are used for safety and non-safety applications. All the applications using this sensors can be considered mission critical.

They are largely used for safety applications, and the required levels of safety are currently met by these systems. Redundancy and combination of several sensors are techniques used to mitigate failure modes. European EN 50126, EN 50128 and EN 50129 are applicable for these systems.

All these systems can be considered designed for professional applications. Moreover, odometry systems are custom-built for railways application by a few specialised companies.

The performance of the odometry on-board sensors considered is shown in the following table along with the purchase cost for each of them (average values, it varies depending on the provider):

On-board sensor	Information provided	Precision	Update frequency	Cost
Tachometer	Speed/distance	1 % and 10 % of travelled distance	1 Hz	TBD €
Doppler Radar	Speed/distance	0.1 % of travelled distance	1 Hz	TBD €
Accelerometer	Acceleration	0.1-1 mg	10 Hz	1.200 €
Gyroscope	Angle of rotation	0.05-10 º/hour	100 Hz	1.500 €
Inertial Systems	Position and Heading	< 0.1 CEP[114]/hour	1 Hz	4.000 €

114 CEP – Circular Error Probable

There are different providers for these sensors, amongst which are: Sécheron, Honeywell, Sab Wabco, Bombardier, iMAR, Schneider, Galaxy Scientific, Oxford Technical Solutions, etc.

H.4.4.4 Dependencies

The on-board odometry sensors directly provide distance and heading information for different functions on the train without the need of any other system. Normally this information constitutes a direct input to the on-board computers.

To achieve the complete odometry information required for the safe movement of a train, reference distance points, provided by other means as balises, are combined with the information coming from the on-board sensors.

H.4.5 Eurobalise

H.4.5.1 Overview

This technology is used as a communication and positioning subsystem in the ERTMS/ETCS system. ERTMS/ETCS is the current European standard for ATP (Automatic Train Protection) systems, for achieving interoperability across Europe.

The Eurobalise consists of electromagnetic transponders placed along the rail track that communicate with the train (via a short-range radio link based on an electromagnetic coupling) with an antenna placed under the train cabin. The balises are energised when the train passes over them and they transmit the information to the train by means of a FSK 4.29 MHz signal. Eurobalises transmit signalling information (track occupancy and route established) but they also serve as a complement to the on-board sensors to accurately calculate the position of the train, generating the odometry information needed by ERTMS/ETCS. Positioning in ERTMS/ETCS is done by measuring the relative distance travelled (using on-board sensors) from the last balise captured (it is a one-dimensional relative position on the track). In this sense, although radio signals are used, we believe Eurobalises cannot be considered a radio-navigation system.

The location information provided by balises is:

- Reference points for measuring relative distances (thus resetting odometry errors)
- Calibration of on-board sensors
- Determination of sense of movement
- Track determination

Eurobalises use a short range (less than 5 meters), point-to-point radio link to perform their function.

A 27 MHz continuous wave (or amplitude modulated) electromagnetic signal is used to power the balise (the “downlink” signal). The onboard antenna generates this telepowering signal and activates the balise when it passes over it.

The balise answers with a 4.29 MHz FSK modulated wave (the “uplink” signal) where the information is embedded in the form of telegrams. The data rate is 564 Kbit/s.

Within the telegram, apart from the signalling information, the balise sends its identity and its position relative to other balises in the group, which is used to determine the sense of movement. The relative distances between balises is well-known and it serves to calibrate on-board sensors.

The location of the balise is not provided by the telegram, but it is determined by the on-board subsystem taking into account the on-board sensors data. The accuracy of location of the balise is ± 1 m. That means that the on-board antenna can detect the balise centre with this accuracy due to the electromagnetic properties of the uplink signal.

The Eurobalise radio link is defined and standardised at all the levels. Protocol and language is defined in the ERTMS/ETCS standards. Safety is also ensured at all the levels by the application of established concepts, methods, tools and techniques throughout the lifecycle of the system. Data is protected against transmission errors by means of a coding strategy.

Vulnerability due to unintentional interferences is controlled by means of RAMS and EMC requirements for the Eurobalise. Probability of vulnerability due to intentional interferences is very low.

H.4.5.2 Institutional

The Eurobalises in the different European Railways Networks are owned, operated and controlled by the Infrastructure Managers of the lines, which use them for Automatic Train Protection and Train Control purposes within the ERTMS/ETCS provisions. We cannot consider therefore this system as an external service.

The Eurobalise subsystem and the data transmission are specified at all the levels (application, physical, etc.) and constitutes a component of the European ERTMS/ETCS standard. The ERTMS/ETCS standard is in turn, part of the European Technical Specifications for Interoperability (TSI). These specifications are mandatory in all Europe to ensure interoperability of trans-European corridors.

AEIF is the organisation in charge of drafting and maintaining the TSIs. The ERTMS/ETCS has become a standard in Europe since March 2000 and it is now being implemented in several countries.

The Eurobalise Specifications, as part of the ERTMS/ETCS standard, included in the Technical Annex of the TSI for the Control and Command Subsystem, are the following:

- UNISIG-SUBSET-036, FFFIS for Eurobalise, issue 2.2.1.
- UNISIG-SUBSET-081, Tests specifications for Eurobalise FFFIS, issue 2.1.2

Other CENELEC normative applicable for this system is:

- CENELEC - EN 50121-1- Railway applications. Electromagnetic compatibility. General.
- CENELEC - EN 50121-4- Railway applications. Electromagnetic compatibility. Signalling and communication systems.
- CENELEC - EN 50126 Railway applications. The specification and demonstration of dependability, reliability, availability, maintainability and safety.
- CENELEC - EN 50125-3 Railway applications. Environmental conditions for equipment.
- CENELEC - EN 50128 Railway applications. Software for railway control and protection systems.
- CENELEC - EN 50129 Railway applications. Safety related electronic systems.

H.4.5.3 Service Delivery

Eurobalises are short range devices located along the railway track. As it was said before, balises provide reference points for location, calibration of on-board sensors and sense of movement (forward or reverse along the track).

The intrinsic accuracy of the location reference points is ± 1 m as a consecuence of the electromagnetic field distribution of the balise. But the accuracy of the balise location is also determined by the errors in the on-board sensors. Besides, there is the error of positioning the balises in the track, due to the errors induced by the techniques to measures distances in the track which are about 5% of the relative distance of the balises.

Taking into account the whole chain of errors, the total estimated error is used to compute the confidence interval and the safety margins for the position of the train.

These are of course, very specific products for this kind of application, although there exists products based in the same technology for other type of markets. RFID technology is similar to Eurobalise technologies.

Price of a single balise is 1.200 € (installed and commissioned). It has to be noticed that for a normal installation a balise is installed approximately every 1.500 meters.

High level safety requirements and high level hazard for this subsystem have been identified and are recorded in the Eurobalise specifications.

H.4.5.4 Dependencies

Balise data related to location is pre-programmed inside the balise or up-dated dynamically through another component of the ETCS system.

Location of the balise is determined by the on-board equipment with the help of the on-board sensors.

Similar systems

Many of the different Automatic Protection Systems working nowadays in Europe use balise technology for transmission media and location aide (EBICAB, TVM[115], RSDD[116]). These systems have similar principles to those of ERTMS/ETCS, but they are not standardised, only proprietary systems.

The "balises" used in those systems have almost the same purpose and follow the same principles as described before for Eurobalises. These balises are used also as location reference.

The working principle is also a short range, point to point radio link to communicate with the on-board subsystems. Most of the points considered above for Eurobalises are also applicable to this kind of balises.

EBICAB balise system works with an amplitude modulated (50 KHz) telepowering signal of 27,115 MHz. Balise response (up-link signal) is a 4.5 MHZ FSK telegram at a 50 Kbits/s rate of data transmission.

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115 Transmission Voie-Machine

116 Ripetizione Segnali Discontinua Digitale

KVB[117] technical characteristics are almost the same.

In other similar systems like LZB[118] (working in Germany, Austria or Spain), the transmission media between trackside and on-board is via a trackside inductive cable loop and an on-board ferrite antennae. This is also a short range, point-to-point radio link. LZB cable loops are laid out between the rails.

For LZB, data transmission from track to train is a 36 KHz FSK telegram at a bit rate of 1200 bit/s. Transmission from train to track is a 56 KHz FSK telegram at a bit rate of 600 bit/s. LZB loop in the track is also used for location purposes with the same functionality of balises: reference points, determination of sense of movement and on-board odometry calibration. Reference points are achieved in the following way:

The maximum logical loop length is 12.7 Km. The conductors are transposed every 100 m for compensating electrical characteristics as well as for determining the physical positions of the train. The on-board equipment senses the phase change when passing a transposition. The number of transpositions passed is counted. The position of a train is transmitted to the control centre by indicating the number of 100 m sections traversed by the front end of the train. The count of coarse positions is dependent on the direction of travel of the train within the length of an inductive loop. A second, independent fine positioning procedure installed on the locomotive allows to transmit position of the train within each 100 m section with an accuracy of 12.5 m.

Again, this is a system owned and operated by railways administrations, which owns and operates also the LZB system. We cannot consider therefore this system as an external service.

ATP systems different from ERTMS are likely to disappear in a medium-term, as ERTMS/ETCS standard is mandatory for high speed corridors in Europe. For conventional or low traffic lines, the trend will be towards a lower-price standard based in ERTMS.

H.4.6 GSM-R

H.4.6.1 Overview

In these recent years, and in parallel with the development of the ETCS standards, a new standard for communication in railways has been adopted: the GSM-R[119] standard. GSM-R is the transport layer of the Euroradio system, which is the system used in ERTMS/ETCS (levels 2 and 3) to transmit signalling information from trackside subsystem (RBC) to on-board subsystem. It is based in conventional GSM system but with a dedicated frequency band, special requirements (able to work at high speed up to 500 km/h, high quality of service parameters) and special services created for railways communications.

GSM-R standard guarantees the performances required for this safety-related application in railways. Safety is preserved by means of an additional layer in the communication stack layer. This layer provides the required integrity data and data authentication, both for the messages and the entities communicating, by means of a key management system.

Through this system the train receives the information of Movement Authority and End of Movement Authority (actual route to be followed by the train and the stopping point). The train reports its position to the trackside subsystem through the Euroradio system (GSM-R).

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117 Côntrol de vitesse par balise

118 Linienförmige Zugbeeinflussung

119 GSM-R - Global System for Mobile communications - Rail

Currently, GSM-R subsystem is not used inside ETCS for location purposes, apart from transmitting train position from train to trackside system. However, GSM-R is likely to be extended to other applications in railways, both inside and outside ERTMS/ETCS. For example, It can be envisaged that in a near future GSM-R will be used also for aiding GNSS navigation in trains, for example transmitting local or regional augmentations to the on-board GNSS system, like assisted-GNSS.

Based on the ETSI GSM standard, the system architecture comprises the following elements:

- Base station sub-systems of base station controllers controlling base transceiver stations (BTSs).
- Network sub-systems interfacing the BSS[120]. It contains mobile services switching centres (MSCs).
- GPRS[121] infrastructure elements.
- Mobile equipment interfacing to the BSS via the air interface.
- Subscriber Identity Modules (SIMs).
- Operation and Maintenance Centre for managing the network.
- Billing Centre.

The frequency bands for GSM-R are the following:

- 876 – 880 MHz (mobile station transmit); paired with
- 921 – 925 MHz (base station transmit).

The data rate is up to 2.4 Kbit/s.

For network planing, the coverage level is defined as the field strength at the antenna on the roof of a train. The following minimum values shall apply:

- Coverage probability of 95 % based on a coverage level of 38.5 dBmV/m for voice and non-safety critical data.
- Coverage probability of 95 % based on a coverage level of 41.5 dBmV/m on lines with ETCS levels 2 and 3.

H.4.6.2 Institutional

GSM-R networks are private-owned networks. The owners are the Rail Infrastructure Managers, which are the institutions in charge of rail infrastructure in Europe. In principle, the operator of the system and the service provider are also the Infrastructure Managers, although this situation could change in the future. Services are provided in principle to Train Operators (owners of trains), for ETCS application. For future applications of GSM-R in railways, other service users can be envisaged.

Nowadays, services provision charges are included inside the fee that train operators will pay to infrastructure managers for using the railway infrastructure.

120 BSS - Base Station System

121 GPRS - General Packet Radio Service

As explained before, GSM-R is a European standard for mobile communications in railways. The set of documentation that conforms the standard is the following:

- EIRENE AA385D008/FRS: Functional Requirements Specification/FRS, version 2.1.
- EIRENE AA444D009: System Requirements Specification/SRS, version 14.
- MORANE A 04 T 6002 2: Subsystem Requirements Specification/SSRS, version 2.
- MORANE A 11 T 6001 3: Radio Transmission FFFIS for Euroradio, version 3.
- MORANE E 10 T 6001 2: FFFS for Functional Addressing, version 2.
- MORANE F 10 T 6001 2: FFFS for Location Dependent Addressing, version 2.
- MORANE F 10 T 6002 2: FFFS for Confirmation of High Priority Calls, version 2.
- MORANE F 10 T 6003 2: FFFS for Presentation of Functional Numbers to Called and Calling Parties, version 2.
- MORANE E 12 T 6001 2: FIS for Functional Addressing, version 2.
- MORANE F 12 T 6001 1: FIS for Location Dependent Addressing, version 1.
- MORANE F 12 T 6002 2: FIS for Confirmation of High Priority Calls, version 2.
- MORANE F 12 T 6003 2: FIS for Presentation of Functional Numbers to Called and Calling Parties, version 2.
- MORANE F 12 T 7003 2: FFFIS for Mobile Terminal interface of the Eirene Mobile Station, version 2.
- ERTMS (ETCS/EIRENE) MMI: The Man Machine Interface of the European Train Control System and the European Radio System for Railways (ISBN 90-804601-1-7).

ERTMS/ETCS normative concerning the Euroradio system:

- ERTMS-UNISIG SUBSET-039: FIS RBC/RBC Handover, version 2.0.0.
- ERTMS-UNISIG SUBSET-038: FIS Key management, version 2.0.0.
- ERTMS-UNISIG SUBSET-051: FIS Key management – second phase, version 2.0.0.
- ERTMS-UNISIG SUBSET-060: FIS Key management migration, version 1.1.1.
- ERTMS-UNISIG SUBSET-037: FIS for EURORADIO, version 2.0.0.
- ERTMS-UNISIG SUBSET-52: EURORADIO FFFIS Class 1 requirements, version 2.0.0.

Other standards applicable for these subsystems are:

- CENELEC - EN 50126 Railway applications. The specification and demonstration of dependability, reliability, availability, maintainability and safety.
- CENELEC - EN 50128 Railway applications. Software for railway control and protection systems.
- CENELEC - EN 50129 Railway applications. Safety related electronic systems

H.4.6.3 Service Delivery

GSM-R system is based on the ETSI GSM standard, supplemented by:

- The following GSM services:
  - o Voice broadcast service;
  - o General Packet Radio Service;
  - o Voice group call service;
  - o Enhanced multilevel precedence and pre-emption,
- Railway specific application:
  - o Exchange of number and location information between train and ground to support functional and location dependent addressing;
  - o Emergency calls;
  - o Shunting mode;
  - o Multiple driver communications;
- Driver mode facility for set-to-set operations;

Other specific Railway features and services are:

- Voice broadcast and group call facilities;
- Functional numbering;
- Location-dependent addressing;
- Direct mode communication;

As explained before, the GSM-R standard has been designed for ERTMS/ETCS application in railways, which is a safety application. However, the standard is suitable also for non-safety applications in rails and it is likely to be extended to many of them.

Euroradio subsystem meets the safety requirements for ETCS subsystem. High-level safety requirements and high-level hazard for this subsystem have been identified and are recorded in the Euroradio specifications. As explained before, safety is preserved by means of an additional layer in the communication stack layer of the Euroradio Subsystem.

Therefore, GSM-R does not ensure safety by itself. It is the non-trusted part of the Euroradio system.

GSM-R equipment is used by professionals of the railway sectors. Indicative prices in Euros for network elements are:

Base station sub-systems (BTS)	44.284,92
Base station controllers (BSC)	238.117,91
Mobile services switching centres (MSC)	1.059.804,52
BSS operating system	62.307,33

Operating system NSS[122] / Switch Commander (SC)	177.706,31

H.4.6.4 Dependencies

Data is generated by the ETCS system and goes through application layer and safety layer of Euroradio subsystem before being transmitted by GSM-R

H.4.7 RFID

H.4.7.1 Overview

Radio Frequency Identification technology (sometimes called Dedicated Short-Range Communications, DSRC) is based on the capability of storing formation and reading it by means of a magnetic inductive coupling of two antennas up to a range of tenths of meters. It is therefore a short-range communication link.

Usually the system is formed by a transponder (antenna + an electronic circuit) attached to the vehicle to be identified and located, and reader antennas located all along the route to be surveyed. When the vehicle passes by one of these readers, the identity and exact position of the vehicle is sent to the control centre. The system is used therefore, to identify and locate vehicles in its route, complementing other technologies, as GNSS or on-board sensors, to guarantee robust and reliable location services (such as positioning in tunnels, very precise transiting across sensitive and warning areas). The system allows for the interchange of other kind of information between the vehicle and the infrastructure.

RFID technology is very similar to balise technology (working principles are the same). The difference we make here is that balises (transponders) are placed in the track and readers are place on-board the trains, while in RFID systems, transponders (RFID tags) are placed on-board the trains (or wagons) and reader antennas are placed along the track in places where train position have to be monitored. In fact, they can be considered two applications of the same technology because purpose of the system and performances required are different.

RFID systems are usually formed by the following elements:

- A RFID low-cost tag (passive or active), installed under the wagon (or vehicle) or in a side of the vehicle.
- A reader antenna, installed in the track in between rails or along the wayside
- A reader equipment, formed by a radio-frequency module and a decoder module.
- A Management Centre computer, receiving the information of the tracked vehicles through radio or fix communications.

The tags used in this system are usually passive tags, that is, the tag is activated by a telepowering electromagnetic signal coming from the reader antenna. Therefore, they are low-cost tags, robust, reliable and requiring a minimum of maintenance.

Depending on the application, tags can be only readable or also programmable.

122 NSS - Nodal Switching Subsystem

Passive tags have a link range between 1.5 and 3 meters. For application requiring longer reading distances active tags should be used (up to 11 meters). Active tags are usually powered by lithium batteries.

Operating frequency band for these tags depends on the producer and can be divided in low frequency tags (125 KHz) or high frequency tags (915 MHz y 2450 MHz). Dual frequency tags also exist.

The tag consist on a small micro-chip, plus an antenna, encapsulated in a protecting material, sealed and water-resistant. It contains a unique code, factory pre-programmed or re-programmable. Memory is about 4096 bits capacity and a typical transmission rate is 250 kbps. They are prepared to work in a rough railway environment, with high electromagnetic noise, mechanical vibrations, etc.

The reader antenna is connected to the reader equipment and it transmits the telepowering energy to the tag and receives the information contained in it through two different frequency bands.

The reader equipment consist on a RF module plus a decoder. The RF module generates the telepowering signal and sends it to the antenna. On the other hand it receives the signal reflected by the tag and captured by the reader antenna, pre-amplifies and conditions the signal before sending it to the decoder.

The decoder module extracts the code, validates it and transmits it (plus time, date, decoder identity, etc.) to the Management Centre computer. It performs a data authentication before transmitting data to avoid interference with other decoders in the vicinity.

This application cannot be considered as a location application, but an automatic identification and tracking of vehicles, because trains are tracked when passing through pre-determined places.

These systems have been developed to support a wide range of public-safety and private operations in roadside-to-vehicle and vehicle-to-vehicle environments for the transportation industry both in USA and Europe. It enables a new class of communications applications that can support future transportation systems and needs.

These systems are currently in use in rail applications (in USA) mainly for fleet management (tracking of wagons and trains), and scheduling and users information. The use of RFID technology in rail freight transport will result in better interoperability in intermodal road/rail freight transport, increasing efficiency and enhancing work of relevant users when shifting goods from road to rail.

H.4.7.2 Institutional

An RFID system can be owned and operated by Railways Administrations (infrastructure managers) or alternatively, it can be operated by other institution that offer services to the Railways (rail operators or infrastructure managers).

In the United States, the Association of American Railroads (AAR) has adopted as a standard the use of RFID technology for the identification of vehicles and fleet management. More than 99% of the vehicles are equipped with RFID tags, allowing the remote localization of vehicles across the country.

In Europe there are standards for other applications, like Electronic Toll Collection in road traffic, but there is not any standard for railways, although a pilot project to standardise this technology in Europe was launched some years ago (without success). The implementation of this technology for vehicle identification and tracking in railways is not widespread although some railway administrations (as SBB, Swiss Federal Railways) already use it.

H.4.7.3 Service Delivery

Services to be provided can be external or internal, as explained before.

The information provided is not purely location information but:

- Time, date and identity (co-ordinates) of the receiver when the vehicle passes through.

Speed and sense of movement can be also determined by means of the appropriate configuration of the elements. Besides, depending on the tag capabilities, other information, like status of the vehicle for maintenance purposes can also be provided.

Location is not continuous, but achieved only when passing through the control points. Therefore, a large number of reader equipment may be needed if the application requires high performance.

Service volume can be estimated from the number of vehicles to be tracked and the update frequency of the information. Indicative numbers are: 12.000 vehicles to be tracked and 15 minutes update rate for each one.

Although RFID tags are used for a large variety of applications outside railways (surveillance systems, for example), RFID products for railways are very specific as they required very special working conditions.

Indicative prices for these elements are (final price depends on the quantity to be commanded):

Passive RFID tag	70,00 € per tag
Reader Antenna	1943,00 € per antenna
Reader equipment (for four antennae)	5130,00 € per reader

H.4.7.4 Dependencies

Data generation relies on the system itself. Data delivery depends also on communications between reader equipment and Management Centre. Mobile communications (GSM, GPRS) can be used as well as fixed communication infrastructure.

I Market Requirements

I.1 Aviation

I.1.1 Market Specific

I.1.1.1 Institutional Environment

The aviation market sector is characterised by a variety of different types of airspace users. The diagram below summarises the main categories of airspace users.

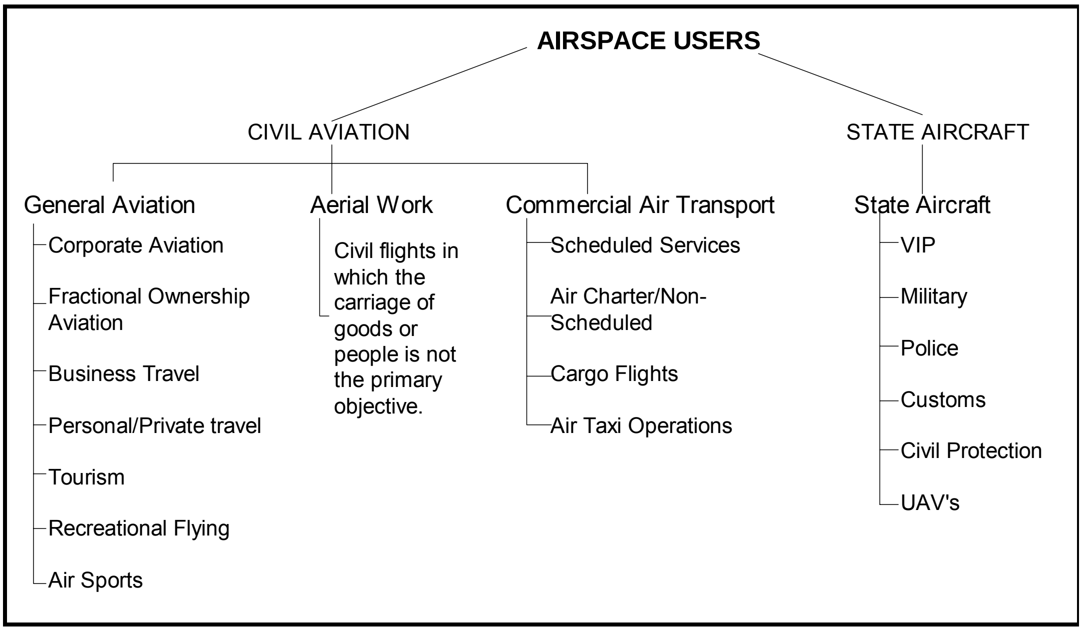


Figure H-1: Categorisation of airspace users

The following aviation market segments are defined based on aircraft type:

- Air Transport (AT) – The operation of an aircraft, used in trade, involving the carriage of passengers or cargo.
- General Aviation (GA) – This is all other commercial or leisure aircraft, including the following: leisure, business aviation, police, air ambulance, flying training, aerial photography and survey, crop spraying/agriculture, pipeline and electricity cable.
- Military/State Aircraft – This is aircraft that are owned and/or operated by the military or state or public service organisations.
- Individual units – These would be used by, eg, skydivers.

In this annex we will concentrate on applications pertaining to the first three of the above market segments, as they represent the majority of the market so far as applications related to radionavigation systems are concerned.

I.1.1.2 Application Summary

The aviation applications which will be described are summarised in the table below. The table also indicates, for each application, whether the application currently exists, whether radionavigation systems are currently used, and whether it is safety or mission critical.

Application	Current Status	Critical

	Existing	Radionav	Safety	Mission
Oceanic and remote airspace	Yes	Yes	Yes	
En-route airspace	Yes	Yes	Yes	
Terminal airspace	Yes	Yes	Yes	
NPA and APV	Yes	Yes	Yes	
Precision approach and landing	Yes	Yes	Yes	
Surface Movement	R & D	No	Yes	
Automatic Dependent Surveillance	R & D	No	Yes	
Ground Proximity Warning	Yes	Yes	Yes	
Data communications	R & D	No	Yes	

Table 11 – Aviation application summary

I.1.2 Oceanic and remote airspace

I.1.2.1 Overview

In oceanic and remote airspace there are no terrestrial navigation aids such as DMEs, VORs and NDBs. In such airspace, aircraft have to rely for navigation either on inertial systems or on GNSS, currently GPS.

GPS is currently used for 'sole means' navigation in oceanic airspace under FAA Notice 8110.60. Where GPS is used for sole means navigation in such airspace, the following must also be in place:

- Predictive RAIM (Receiver Autonomous Integrity Monitoring);
- Access to NANU (Notice Advisory to Navstar Users) information;
- Fault Detection and Exclusion (FDE).

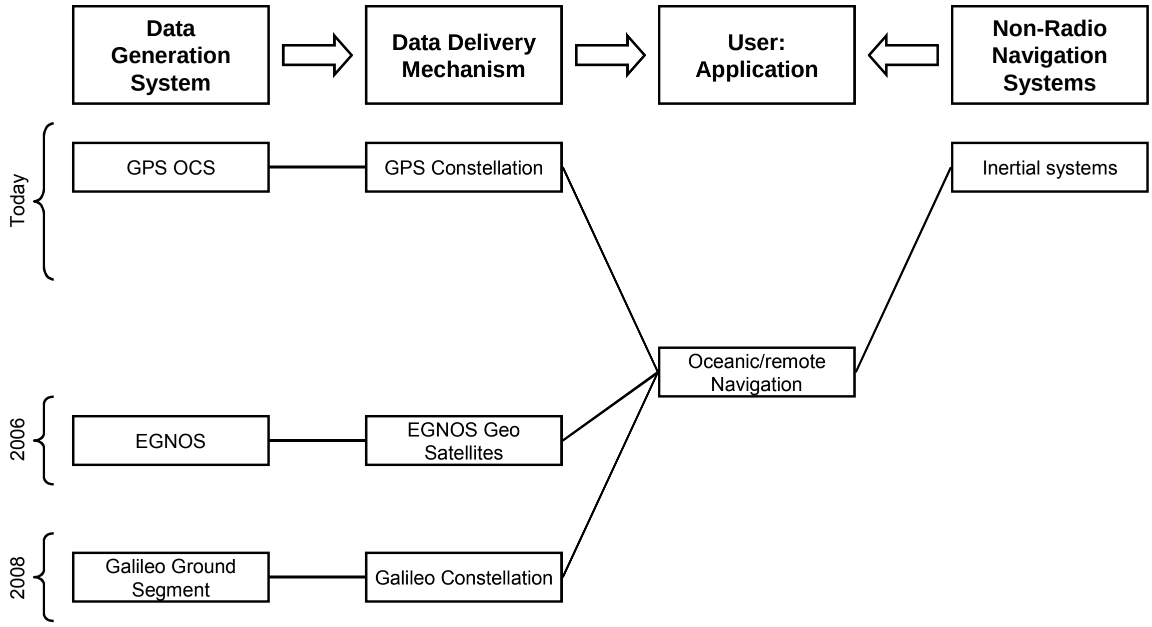
In Australia, a number of GPS en-route operational approvals are in place. The UK also allows GPS sole means on the North Sea Main Helicopter Routes. No other 'sole means' applications are known of in Europe, although there may be some small special case operations similar to the North Sea helicopter application.

EGNOS is likely to be used in oceanic/remote airspace in the near future (2006 timeframe), and Galileo beyond that (2008 timeframe).

I.1.2.2 Service Delivery

Service delivery flow diagram

The mechanism for service delivery is as shown in the diagram below.



Performance requirements

The performance requirements are as shown in the tables below.

Operation	Accuracy (95%)		Integrity	Alert Limit	
	Horizontal	Vertical		Horizontal	Vertical
Oceanic	12.4 nm	-	$1\text{-}10^{-7}$ per hour	12.4 nm	-

Operation	RNP Value	Time to alert	Continuity	Availability
Oceanic	< 20	2 min	$1\text{-}10^{-5}$ per hour	0.99 to 0.99999

I.1.2.3 Application environment

Air traffic management in oceanic airspace

Currently aircraft in North Atlantic airspace are under procedural control. Aircraft fly on parallel tracks with the following minimum separations:

- 60 NM lateral;
- minutes longitudinal;
- 1000 ft vertical (reduced from 2000 ft to 1000 ft under RVSM).

The use of the organised track structure (OTS) enables a large volume of traffic in a region outside radar coverage. The disadvantage is that aircraft operators can be limited in the choice of track.

In order to ensure that aircraft are suitably equipped to fly on the OTS, a Minimum Navigation Performance Specification (MNPS) has been established. Only aircraft that meet the MNPS are allowed to operate on the OTS.

Navigation equipment requirements

For unrestricted operations in MNPS airspace, aircraft are currently required to be fitted with two fully serviceable Long Range Navigation Systems (LRNS). An LRNS may be one of the following:

- Inertial Navigation System (INS);
- GPS. If both LRNSs are GPS, they must be approved in accordance with FAA Notice 8110.60 (GPS as Primary Means of Navigation for Oceanic/Remote Operations) or equivalent national documentation. If GPS serves as only one LRNS, then it must be approved in accordance with TSO-129 as Class A1, A2, B1, B2, C1 or C2;
- One navigation system using the inputs from one or more IRS or any other system complying with the MNPS requirement.

Radionavigation coverage requirements

Radionavigation system coverage needs to extend over the routes that aircraft tend to fly. As there are many different routes that aircraft may take to reach different destinations across one ocean, in practice this means that global coverage is required.

Communications usage

Currently the majority of communications is via HF voice. This suffers from capacity limitations and is subject to interference. It is possible to use satcom voice in emergencies, or when there is service disruption, such as sunspot activity, that may prevent the use of HF voice.

HF voice messages are relayed using a land-based radio station. The majority of messages are associated with position reported. Pilots report their position verbally via HF at intervals of between 30 and 50 minutes. ADS is currently being trialled as an alternative to voice position reports and is expected to eventually replace them. The remaining messages are clearance requests, clearance readback, miscellaneous, or leaving/reaching reports.

It is anticipated that controller pilot data link communications (CPDLC) will become the primary means of communications between pilots and controllers.

I.1.2.4 Service Availability

The following table assesses the potential for service disruption for GPS and assesses the risk, consequence and mitigation difficulty/cost.

Threat	Risk	Consequences	Mitigation difficulty/cost
System failure	L	H	M
Power supply failure	L	H	M
Receiver/antenna failure	L	H	M
Onboard Interference	L	H	M
External Interference	L	H	M
Ionospheric	M	M	M

Jamming	M	H	M
Spoofing	M	H	M

H = High. High risk means likely to be encountered more than once a year. High consequence means complete loss of use of the system. High mitigation difficulty/cost means that it is unlikely to be achieved.

M = Medium. Medium risk means likely to be encountered less than once a year. Medium consequence means system still usable but degraded. Medium mitigation difficulty/cost means achievable at significant cost.

L = Low. Low risk means unlikely to be encountered. Low consequence means that the system is still usable. Low mitigation difficulty/cost means achievable.

Impact of service disruption

Most aircraft using oceanic airspace will have inertial systems plus GPS systems. An aircraft will typically carry two of each type of system to mitigate failure of any one system. Disruption of the GPS signal-in-space either globally or in the region of the aircraft will have a serious impact on the accuracy of the aircraft's navigation. However, most aircraft would still be able to report their position using the on-board inertial system. The response to failure of the GPS signal-in-space would be for ATC to increase the nominal separations between aircraft.

Responsibility for current radionavigation services

The GPS service is the responsibility of the US Government.

I.1.2.5 Service Charges

GPS is operated and controlled by the US Military and is currently provided free of charge.

I.1.3 En-route airspace

I.1.3.1 Overview

In Europe, aircraft in upper airspace must meet B-RNAV requirements. GPS with RAIM is approved as a navigation source for B-RNAV. However, an alternative terrestrial navigation source is always required. For example, within Europe, the ECAC Navigation strategy includes the long-term use of DME/DME as a back-up to GPS.

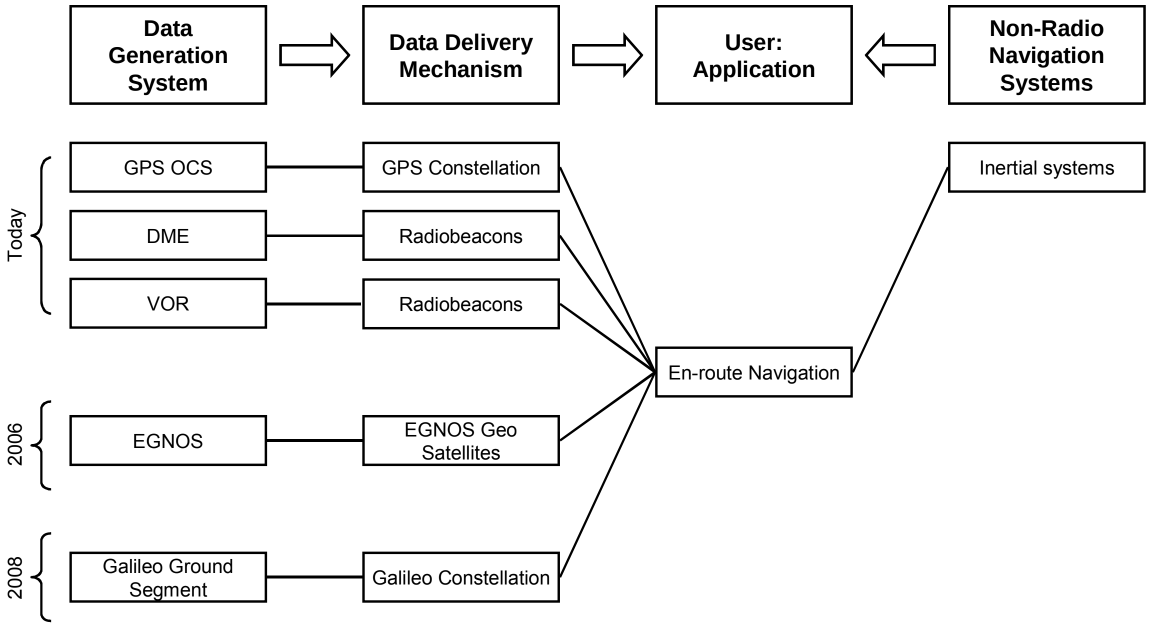
Most navigation systems take multiple navigation sources, usually GPS, DME/DME and/or inertial reference systems (IRS). Some B-RNAV systems rely totally on GPS, with the pilot reverting to manual VOR/DME flight in the case of loss of GPS.

EGNOS may be used in en-route airspace in the near future (2006 timeframe), and Galileo beyond that (2008 timeframe).

I.1.3.2 Service Delivery

Service delivery flow diagram

The mechanism for service delivery is as shown in the diagram below.



Performance requirements

The performance requirements are as shown in the tables below.

Operation	Accuracy (95%)		Integrity	Alert Limit	
	Horizontal	Vertical		Horizontal	Vertical
En-route	2.0 nm	-	$1\text{-}10^{-7}$ per hour	2.0 nm	-

Operation	RNP Value	Time to alert	Continuity	Availability
En-route	4	1 min	$1\text{-}10^{-5}$ per hour	0.99 to 0.99999

I.1.3.3 Service Availability

The table assessing the potential for service disruption for GPS was given in Section H.1.2.3.

The following table assesses the potential for service disruption for DME and assesses the risk, consequence and mitigation difficulty/cost.

Threat	Risk	Consequences	Mitigation difficulty/cost
System failure	L	H	M
Power supply failure	L	H	M
Receiver/antenna failure	L	H	M
Onboard Interference	L	H	M
External Interference	L	H	M
Ionospheric	n/a	n/a	n/a
Jamming	L	H	M

Spoofing	L	H	M

H = High. High risk means likely to be encountered more than once a year. High consequence means complete loss of use of the system. High mitigation difficulty/cost means that it is unlikely to be achieved.

M = Medium. Medium risk means likely to be encountered less than once a year. Medium consequence means system still usable but degraded. Medium mitigation difficulty/cost means achievable at significant cost.

L = Low. Low risk means unlikely to be encountered. Low consequence means that the system is still usable. Low mitigation difficulty/cost means achievable.

The following table assesses the potential for service disruption for VOR and assesses the risk, consequence and mitigation difficulty/cost.

Threat	Risk	Consequences	Mitigation difficulty/cost
System failure	L	H	M
Power supply failure	L	H	M
Receiver/antenna failure	L	H	M
Onboard Interference	L	H	M
External Interference	L	H	M
Ionospheric	n/a	n/a	n/a
Jamming	L	H	M
Spoofing	L	H	M

H = High. High risk means likely to be encountered more than once a year. High consequence means complete loss of use of the system. High mitigation difficulty/cost means that it is unlikely to be achieved.

M = Medium. Medium risk means likely to be encountered less than once a year. Medium consequence means system still usable but degraded. Medium mitigation difficulty/cost means achievable at significant cost.

L = Low. Low risk means unlikely to be encountered. Low consequence means that the system is still usable. Low mitigation difficulty/cost means achievable.

Impact of service disruption

Most aircraft using en-route airspace will have inertial systems, GPS systems, plus VOR/DME systems. An aircraft will typically carry two of each type of system to mitigate failure of any particular system.

Disruption of the GPS signal-in-space either generally or in the region of the aircraft will impact on the ability of the aircraft to navigate. However, aircraft would still be able to navigate successfully using the on-board inertial system plus VOR/DME systems.

If one DME station, or one VOR station, or one combined VOR/DME station becomes disabled, there are normally other nearby stations that an aircraft can locate, and an aircraft can still continue to navigate using GPS and inertial systems.

Responsibility for current radionavigation services

The GPS service is the responsibility of the US Government. DME and VOR services are operated via ground-based stations and are the responsibility of the Air Traffic Service Provider (ATSP) in the state in which the equipment is located.

I.1.3.4 Service Charges

Service charges for GPS were discussed in H.1.2.4. In the case of en-route traffic, the DME and VOR services are charged for via the overflight charges applicable to the state concerned.

I.1.4 Terminal airspace

I.1.4.1 Overview

P-RNAV has been developed for terminal airspace and increasingly European States are introducing terminal procedures (Standard Instrument Departures, SIDs, and Standard Terminal Arrival Routes, STARs) that rely on it.

GPS with RAIM is a suitable navigation source for P-RNAV, but DME/DME must also be available.

In the next few years, many more P-RNAV procedures will be introduced in Europe. In the longer-term, these will be replaced with RNP RNAV procedures. Again, GPS with RAIM is a suitable navigation source for RNP RNAV, but DME/DME must also be available.

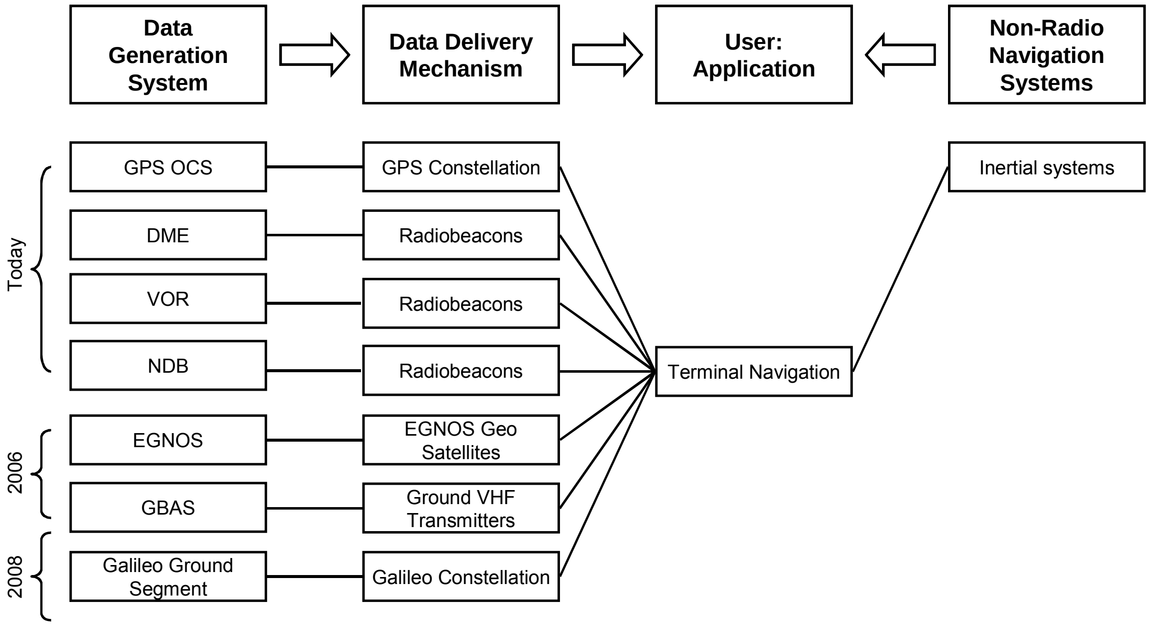
Aircraft may also use Non-Directional Beacons (NDBs) in terminal airspace. NDBs may be used, for example, to find the initial approach point of an instrument landing system near an airport.

GBAS and/or EGNOS may be used in terminal airspace in the near future (2006 timeframe), and Galileo beyond that (2008 timeframe).

I.1.4.2 Service Delivery

Service delivery flow diagram

The mechanism for service delivery is as shown in the diagram below.



Performance requirements

The performance requirements are as shown in the tables below.

Operation	Accuracy (95%)		Integrity	Alert Limit	
	Horizontal	Vertical		Horizontal	Vertical
Terminal	0.4 nm	-	$1\text{-}10^{-7}$ per hour	1.0 nm	-

Operation	RNP Value	Time to alert	Continuity	Availability
Terminal	1	30 sec	$1\text{-}10^{-5}$ per hour	0.99 to 0.99999

I.1.4.3 Service Availability

The table assessing the potential for service disruption for GPS was given in Section H.1.2.3.

The tables assessing the potential for service disruption for DME and for VOR were given in Section H.1.3.3.

The following table assesses the potential for service disruption for NDBs and assesses the risk, consequence and mitigation difficulty/cost.

Threat	Risk	Consequences	Mitigation difficulty/cost
System failure	L	H	M
Power supply failure	L	H	M
Receiver/antenna failure	L	H	M
Onboard Interference	L	H	M
External Interference	M	H	M
Ionospheric	n/a	n/a	n/a
Jamming	L	H	M
Spoofing	L	H	M

H = High. High risk means likely to be encountered more than once a year. High consequence means complete loss of use of the system. High mitigation difficulty/cost means that it is unlikely to be achieved.

M = Medium. Medium risk means likely to be encountered less than once a year. Medium consequence means system still usable but degraded. Medium mitigation difficulty/cost means achievable at significant cost.

L = Low. Low risk means unlikely to be encountered. Low consequence means that the system is still usable. Low mitigation difficulty/cost means achievable.

Impact of service disruption

Most aircraft using terminal airspace will have inertial systems, GPS systems, plus VOR/DME and NDB systems. An aircraft will typically carry two of each type of system to mitigate failure of any particular system.

Disruption of the GPS signal-in-space either generally or in the region of the aircraft will impact on the ability of the aircraft to navigate. However, aircraft would still be able to navigate successfully using the on-board inertial system plus VOR/DME and NDB systems.

If one NDB station, or one DME station, or one VOR station, or one combined VOR/DME station becomes disabled, there are normally other nearby stations that an aircraft can locate, and an aircraft can still continue to navigate using GPS and inertial systems.

Responsibility for current radionavigation services

The GPS service is the responsibility of the US Government. DME, VOR, and NDB services are operated via ground-based stations and are the responsibility of the Air Traffic Service Provider (ATSP) in the state in which the equipment is located.

I.1.4.4 Service Charges

Service charges for GPS were discussed in H.1.2.4. In the case of terminal airspace traffic, the DME, VOR, and NDB services are charged for via a combination of overflight charges and airport landing charges applicable to the state concerned.

I.1.5 NPA and APV

I.1.5.1 Overview

Non-precision approaches (NPA) based on GPS are becoming increasingly popular because they are easier and potentially safer to fly than conventional approaches.

A new sort of approach has recently been defined by ICAO; Approach with vertical guidance (APV). This is designed to be supported by GPS augmented with Space Based Augmentation System (SBAS).

Two types of APV have been defined:

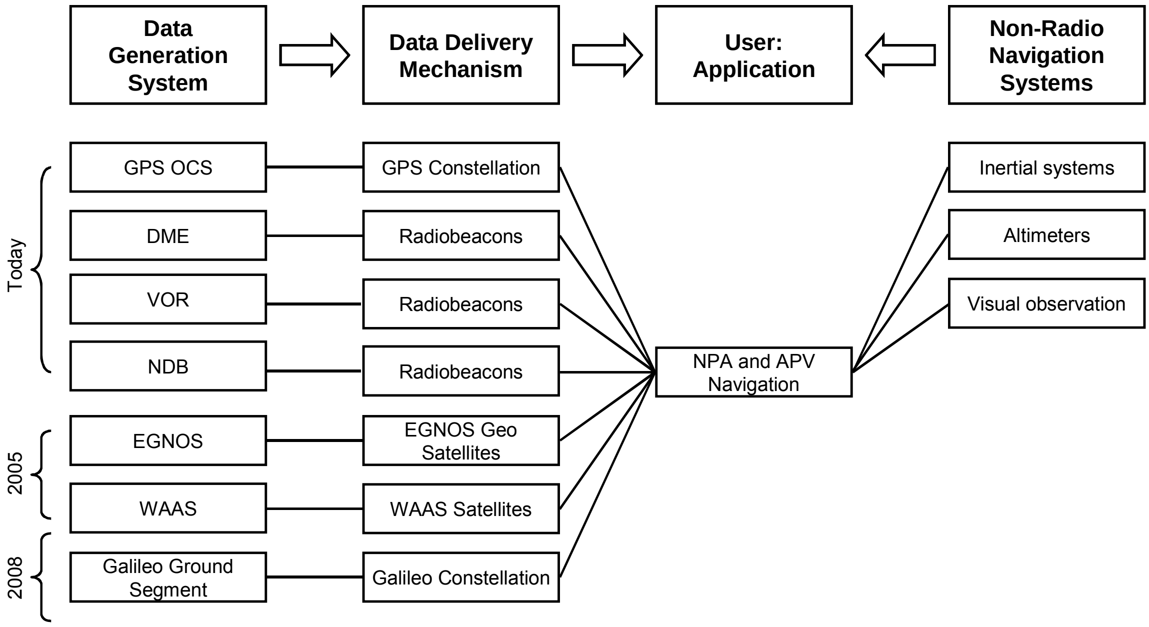
- APV I approaches are where the RNAV system provides lateral and vertical guidance. APV I criteria are 0.3 Nm Horizontal Alert Limit (HAL) and 50m Vertical Alert Limit (VAL) with a 10 second time to alert. APV I is designed to be supported using SBAS or Baro-VNAV.
- APV II approaches are where the RNAV system provides lateral and vertical guidance. APV II criteria are 40m HAL and 20m VAL with a 6 second time to alert. APV II is designed to be supported using SBAS.

For SBAS, the US Wide Area Augmentation System (WAAS) is planned to have APV I capability in 2003 and CAT 1 in 2010 to 2012. EGNOS, the European SBAS system is expected to support APV I and II by 2005.

I.1.5.2 Service Delivery

Service delivery flow diagram

The mechanism for service delivery is as shown in the diagram below.



Performance requirements

The performance requirements are as shown in the tables below.

Operation	Accuracy (95%)		Integrity	Alert Limit	
	Horizontal	Vertical		Horizontal	Vertical
NPA	220 m	-	$1\text{-}10^{-7}$ per hour	555 m	-
APV I	220 m	20 m	$1\text{-}2\times10^{-7}$ per approach	556 m	50 m
APV II	16 m	8 m	$1\text{-}2\times10^{-7}$ per approach	40 m	20 m

Operation	RNP Value	Time to alert	Continuity	Availability
NPA	0.3	10 sec	$1\text{-}10^{-5}$ per hour	0.99 to 0.99999
APV I	0.3/125	10 sec	$1\text{-}8\times10^{-6}$ per 15 s	0.99 to 0.99999
APV II	0.03/50	6 sec	$1\text{-}8\times10^{-6}$ per 15 s	0.99 to 0.99999

I.1.5.3 Service Availability

The impact of service disruption to either GPS, NDB, DME, and VOR was discussed in Section H.1.4.3.

The following table assesses the potential for service disruption for EGNOS, assuming this will be used in the near future, and assesses the risk, consequence and mitigation difficulty/cost.

Threat	Risk	Consequences	Mitigation difficulty/cost
System failure	L	H	M
Power supply failure	L	H	M
Receiver/antenna failure	L	H	M
Onboard Interference	L	H	M
External Interference	M	H	M
Ionospheric	M	H	M
Jamming	L	H	M
Spoofing	L	H	M

Impact of service disruption

Service disruption to EGNOS, when used for a non-precision approach, will mean that an aircraft will have to rely on other on-board systems to conduct its approach. The aircraft would have to have accurate on-board altimeters that could be used to provide the vertical guidance in the absence of the SBAS system.

Responsibility for current radionavigation services

EGNOS is currently the responsibility of the European Space Agency (ESA). However a new structure for responsibility may emerge once EGNOS becomes operational.

I.1.5.4 Service Charges

Service charges for EGNOS are likely to be collected, in the case of aviation, via the Airspace Navigation Service Providers (ANSPs).

I.1.6 Precision approach and landing

I.1.6.1 Overview

The Instrument Landing System (ILS) has been used for precision approach and landing for over 50 years and offers a CAT I, II and III landing capability. Almost all large commercial aircraft are equipped with ILS at manufacture.

Two factors are encouraging a transition away from ILS: the limited number of ILS channels available in the VHF frequency band, and multipath problems.

Multipath occurs when an aircraft receives a direct signal from the ILS and a reflected signal from, for example, a building. These signals combine in such a way as to produce a bend in the projected glide path. This ‘bending’ can significantly degrade the capability of ILS, eg from CAT II/III to CAT I. Because of these reflections, “sensitive and critical areas” are defined close to the ILS equipment on the ground. During low visibility procedures (LVPs), landing aircraft must clear these areas before the following aircraft can land. This is a significant factor reducing the capacity of airports in these conditions.

The alternatives for ILS are the GNSS landing system (GLS) and the microwave landing system (MLS). Both of them could largely overcome the limitations described above.

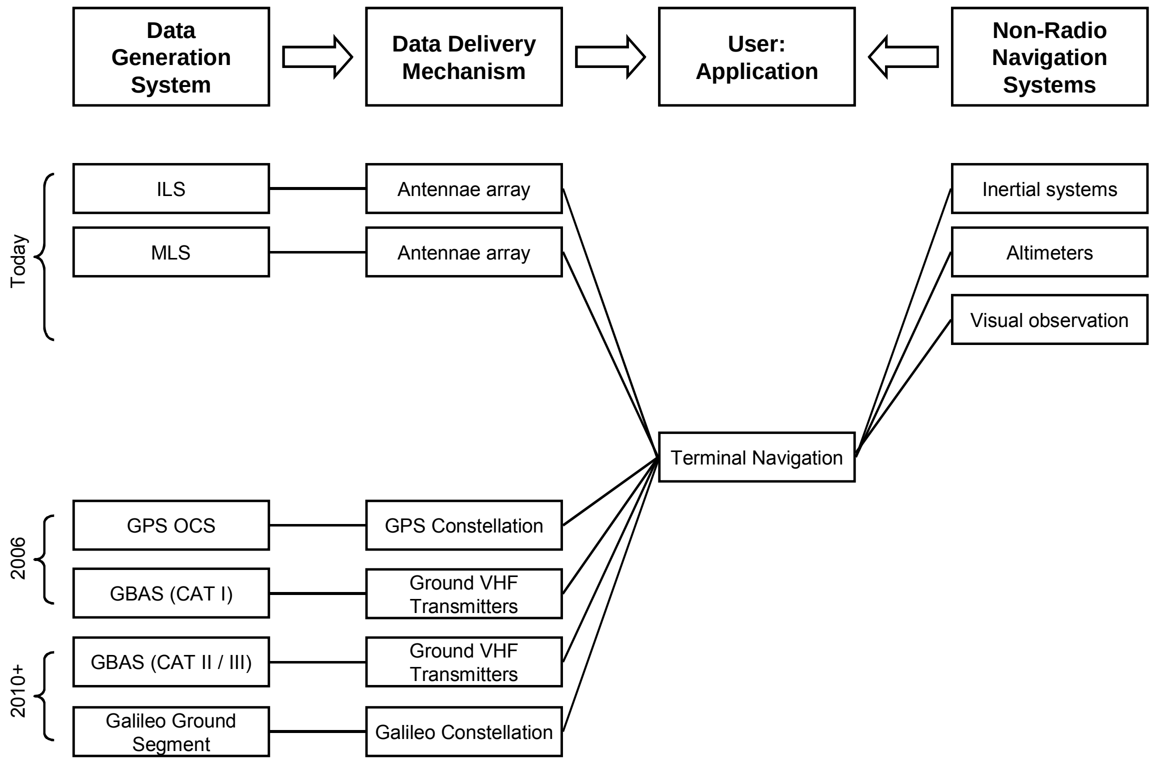
Standards for MLS have been available for a number of years and it should be able to support CAT I, II and III. An MLS system has already been deployed at Heathrow, and BA is equipping some A320s with it. Tests are also ongoing at a number of other major European airports.

Precision approach based on GLS is less mature. GLS CAT I is expected to be available from around 2005/6 based on the ground based GNSS augmentation system (GBAS). GLS CAT II/III is unlikely to be available before at least 2010. The architecture required for CAT II/III is unclear, including the satellite elements (dual frequency, Galileo, etc).

I.1.6.2 Service Delivery

Service delivery flow diagram

The mechanism for service delivery is as shown in the diagram below.



Performance requirements

The performance requirements are as shown in the tables below.

Operation	Accuracy (95%)		Integrity	Alert Limit	
	Horizontal	Vertical		Horizontal	Vertical
CAT I	16 m	4 to 6 m	$1\text{-}2 \times 10^{-7}$ per approach	40 m	10 to 15 m
CAT II	6.9 m	2.0 m	$1\text{-}10^{-9}$ per 15 sec	17.3 m	5.3 m
CAT III	6.2 m	2.0 m	$1\text{-}10^{-9}$ per 15 sec	15.5 m	5.3 m

Operation	RNP Value	Time to alert	Continuity	Availability
CAT I	0.02/40	6 sec	1-8x10^{-6} per 15 s	0.99 to 0.99999
CAT II	0.01/15	1 sec	1-4x10^{-6} in any 15 s	0.99 to 0.99999
CAT III	0.003/z	1 sec	1-4x10^{-6} in any 15 s (lateral) 1-4x10^{-6} in any 15 s (vertical)	0.99 to 0.99999

I.1.6.3 Service Availability

The following table assesses the potential for service disruption to ILS/MLS, assuming this will be used in the near future, and assesses the risk, consequence and mitigation difficulty/cost.

Threat	Risk	Consequences	Mitigation difficulty/cost
System failure	L	H	M
Power supply failure	L	H	M
Receiver/antenna failure	L	H	M
Onboard Interference	L	H	M
External Interference	M	H	M
Ionospheric	n/a	n/a	n/a
Jamming	L	H	M
Spoofing	L	H	M

Impact of service disruption

Aircraft with MLS

Service disruption to ILS only, will mean that an aircraft will have to rely on MLS to conduct its approach. Similarly, service disruption to MLS only, will mean that an aircraft will have to rely on ILS to conduct its approach.

Service disruption to ILS and MLS, may mean that, in the case of bad weather at an airport, an aircraft will have to divert to an airport where the visibility is better. The aircraft will have to have accurate on-board altimeters and inertial systems that aid visual observation during approach and landing in the absence of the ILS or MLS landing systems.

Aircraft without MLS

Service disruption to ILS may mean that, in the case of bad weather at an airport, an aircraft will have to divert to an airport where the visibility is better. The aircraft will have to have accurate on-board altimeters and inertial systems that aid visual observation during approach and landing in the absence of the ILS landing system.

Responsibility for current radionavigation services

ILS and MLS services are operated via ground-based stations and are the responsibility of the Air Traffic Service Provider (ATSP) in the state in which the equipment is located.

I.1.6.4 Service Charges

ILS and MLS services are charged for via airport landing charges applicable to the airport concerned.

I.1.7 Surface Movement

I.1.7.1 Overview

Advanced surface movement guidance and control (A-SMGCS) is a system providing routing, guidance, surveillance and control to aircraft and affected vehicles in order to maintain movement rate under all local weather conditions within the Aerodrome Visibility Operational Level (AVOL). A-SMGCS is seen as part of CNS/ATM and part of the "gate to gate" operations concept.

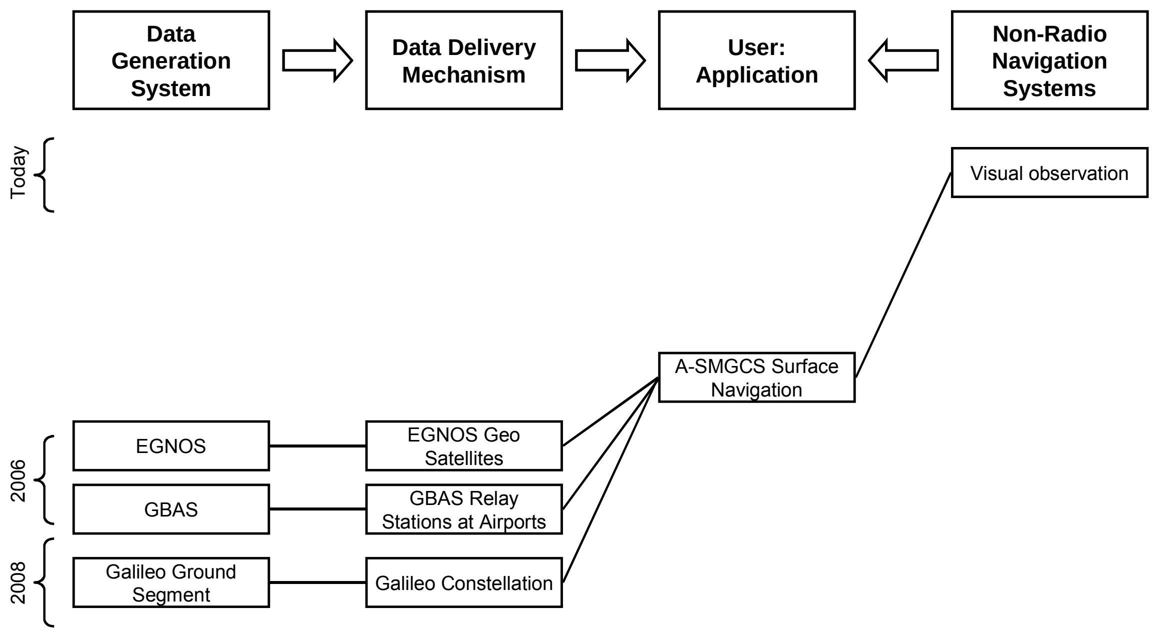
The ICAO A-SMGCS manual [*ICAO European Manual on Advanced Surface Movement Guidance and Control Systems (A-SMGCS) Final Draft (version 10), 22 November 2001*] states that: “The surveillance function of an A-SMGCS should have a capacity to provide accurate positional information on all movements within the movement area; the actual position of an aircraft, vehicle or obstacle on the surface should be determined within a horizontal radius of 7.5 m.”

GNSS will probably have a major role to support A-SMGCS, but it will be some years before that role is clear and it can be deployed, as A-SMGCS is currently in the development phase.

I.1.7.2 Service Delivery

Service delivery flow diagram

The mechanism for service delivery is as shown in the diagram below.



Performance requirements

The following table defines the navigation sensor requirements for airport surface applications [*The role of GNSS in supporting Airport Surface Operations, RTCA/DO-247*] presently being defined by RTCA.

Requirement	Visibility Conditions		
	1 and 2	**3**	**4**
Accuracy	10 m	2.2 m	1.5 m
Integrity	$1\text{-}10^{-5}$ per hour	$1\text{-}10^{-6}$ per hour	$1\text{-}10^{-7}$ per hour
Continuity	$1\text{-}10^{-3}$ per hour	$1\text{-}4\text{x}10^{-4}$ per hour	$1\text{-}3\text{x}10^{-3}$ per hour
Alert Limit	8 m	6m	TBD
Time to Alert	10 sec	2 sec	2 sec
Availability	0.95	0.999	0.999

I.1.7.3 Service Availability

The impact of service disruption to EGNOS was discussed in Section H.1.5.3.

The following table assesses the potential for service disruption to GBAS, assuming this will be used in the near future, and assesses the risk, consequence and mitigation difficulty/cost.

Threat	Risk	Consequences	Mitigation difficulty/cost
System failure	L	H	M
Power supply failure	L	H	M
Receiver/antenna failure	L	H	M
Onboard Interference	L	H	M
External Interference	M	H	M
Ionospheric	n/a	n/a	n/a
Jamming	L	H	M
Spoofing	L	H	M

Impact of service disruption

EGNOS only is available

Service disruption to GBAS, when used for surface movement, will mean that an aircraft will have to rely on visual observation to move around the airport.

GBAS only is available

Service disruption to GBAS, when used for surface movement, will mean that an aircraft will have to rely on visual observation to move around the airport.

EGNOS and GBAS are both available

Service disruption to either GBAS or EGNOS, when used for surface movement, will mean that an aircraft will have to rely on the other on-board system (EGOS or GBAS respectively) to move around the airport.

I.1.7.4 Service Charges

Service charges for EGNOS were discussed in Section H.1.5.4. Service charges for GBAS may be collected through the local Air Navigation Service Provider (ANSP).

I.1.8 Automatic Dependent Surveillance

I.1.8.1 Overview

GNSS is a potential source of navigation data for Automatic Dependant Surveillance (ADS). ADS is a surveillance concept in which an aircraft transmits its own estimate of position, velocity and intent to interested parties. Two forms have been standardised:

- ADS-Contract (ADS-C) in which information is transferred on a point-to-point addressed communications link (usually a satellite) to a ground system.
- ADS-Broadcast (ADS-B) in which information is broadcast to all interested parties, including ground systems and other aircraft.

ADS-C is currently used for surveillance in oceanic and remote areas. An implementation known as FANS-1/A is widely deployed on long-haul aircraft. GNSS is not a required system for operation of FANS-1/A, although it is usually present on the aircraft.

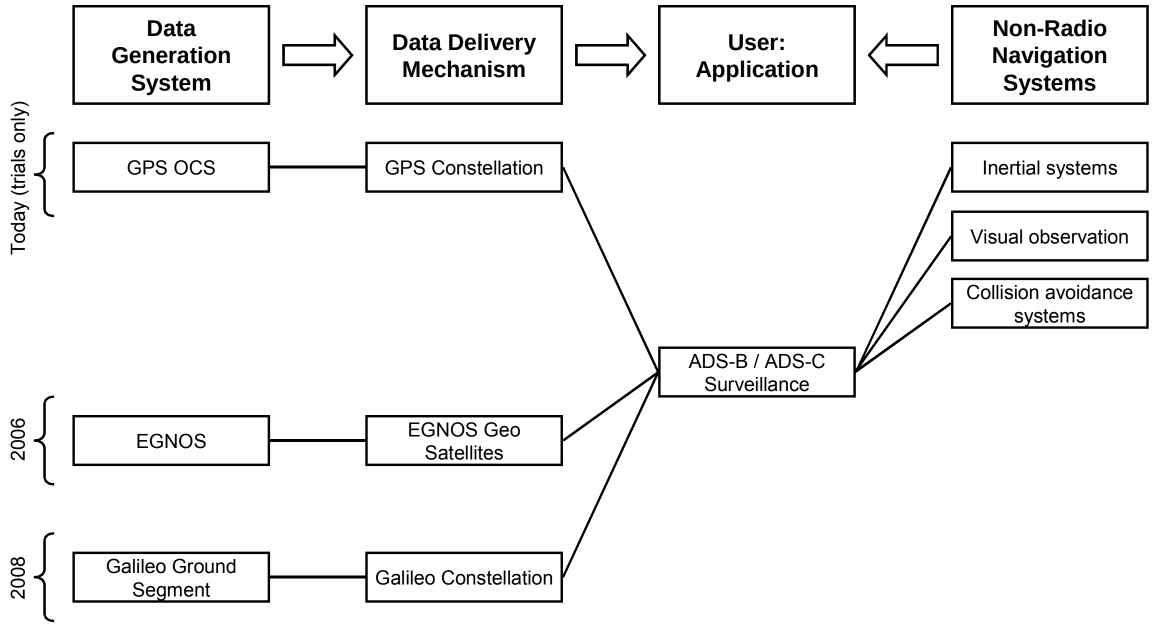
ADS-B supports both airborne and ground surveillance and is the key enabler of Airborne Separation Assistance System (ASAS) applications. At present, ADS-B is only deployed in a couple of “special interest” projects, e.g. for general aviation aircraft in Alaska, and is currently in the development phase. All current or planned implementations of ADS-B assume that GNSS is available as a positioning source (although availability of GNSS should not be a requirement, in practice it appears to be).

A key consideration for ADS-B is the requirements placed on the navigation sensors. This will depend on the other surveillance systems available, e.g. radar, and the type of operation performed. Some of the long-term applications proposed for ADS-B will place very high integrity and availability requirements on the GNSS position.

I.1.8.2 Service Delivery

Service delivery flow diagram

The mechanism for service delivery is as shown in the diagram below.



Performance requirements

The following table defines the requirements for ADS-B reports defined by RTCA ADS-B MASPS (DO-242A).

Operation	Position accuracy (95%)		Velocity accuracy (95%)		Integrity	Continuity	Availability
	Horizontal	Vertical	Horizontal	Vertical			
Terminal, En-route, Oceanic/Remote	50 m to 200 m	9.75 m	0.75 m/s to 5 m/s	0.3 m/s	10^{-6} per report	$2x10^{-4}$ per hour of flight	0.999
Approach	20 m	9.75 m	0.3 m/s	0.3 m/s	10^{-6} per report	$2x10^{-4}$ per hour of flight	0.999
Surface	2.5 m	n/a	0.3 m/s	n/a	10^{-6} per report	$2x10^{-4}$ per hour of flight	0.999

I.1.8.3 Service Availability

The table assessing the potential for service disruption for GPS was given in Section H.1.2.3.

Impact of service disruption

ADS-B systems will use GPS as the default positioning source. If GPS becomes unavailable either in a region around an aircraft or globally, an ADS-B system will have to revert to other sources of position information such as inertial systems. The immediate consequence will be a degrading of the aircraft's position accuracy.

Some ADS-B systems such as UAT and VDL Mode 4 also rely on GPS to provide an accurate source of UTC time. Each of these systems has a backup mode so that the ADS-B system can continue to operate without time provided by GPS. However the integrity of the ADS-B system will be degraded if GPS time (and position) is lost, and the aircraft will have to rely more heavily on other surveillance means such as visual observation and (at short range) collision avoidance systems.

I.1.8.4 Service Charges

Service charges for GPS were discussed in H.1.2.4.

I.1.9 Data communications

I.1.9.1 Overview

GNSS can provide time synchronisation to communications systems for two reasons:

- To support Time Division Multiple Access (TDMA) schemes used in the mobile communications Mode 3 and 4. Both of these systems are emerging at the moment and may be deployed over the next few years.
- To allow timestamping of data messages.

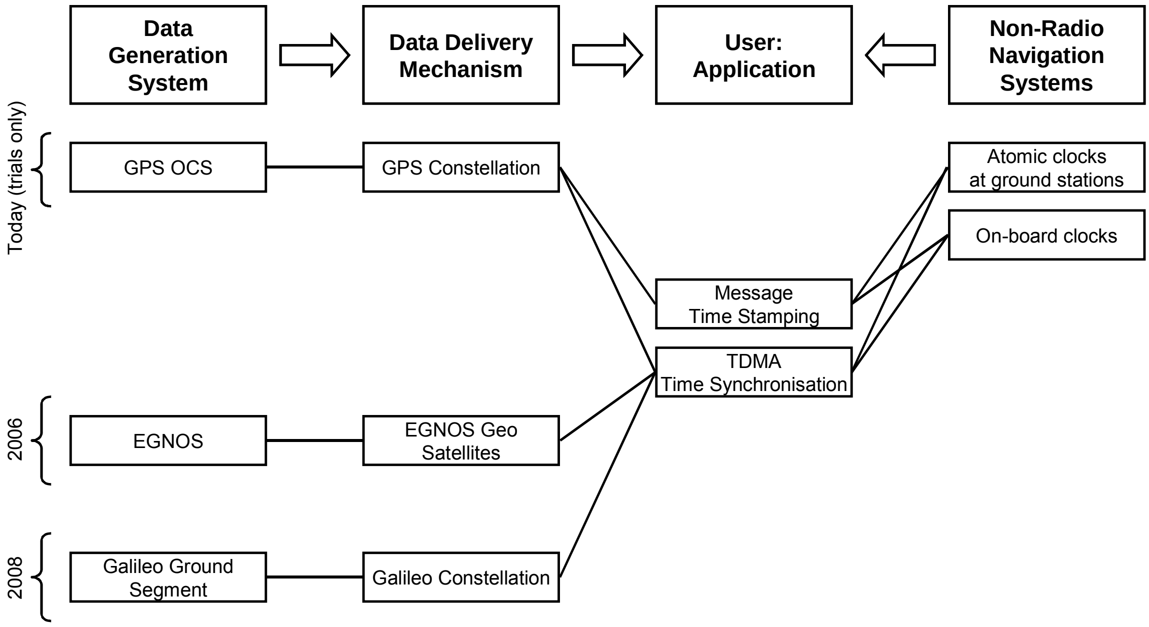
Air-to-ground datalink applications currently being deployed in Europe and the US (known as controller-pilot datalink communications, CPDLC) require timestamping to GPS time. The European project implementing CPDLC is called Link2000+ and co-ordinated by Eurocontrol. CPDLC is likely to be widely implemented in core Europe over the next 10 years.

There are currently no specific international standards relating to the time synchronisation of ATC facilities. Eurocontrol has developed Functional and Technical Specifications for Time Reference Systems (TRS) [*AS Generic Document (EGD) Part 5: Communication and Navigation Specifications, Chapter 11: Time Reference System (TRS), STS-EGD.COM.TRS, Edition 2.0, March 2001*], which include synchronisation to GPS time. The specification is not mandatory.

I.1.9.2 Service Delivery

Service delivery flow diagram

The mechanism for service delivery is as shown in the diagram below.



Performance requirements

The performance requirements are estimated in the table below.

Application	UTC Time Accuracy	Availability
Message Time Stamping	< 10 ms	0.99
TDMA Time synchronisation	< 400 ns	0.999

I.1.9.3 Service Availability

The table assessing the potential for service disruption for GPS was given in Section H.1.2.3.

Impact of service disruption

A number of TDMA communications systems will use GPS as the default source of UTC time. Each of these systems will have a backup mode so that the ADS-B system can continue to operate without time provided by GPS. However the integrity of the communications system will be degraded if GPS time is lost, and the aircraft may have to rely more heavily on other communications means such as VHF voice.

I.1.9.4 Service Charges

Service charges for GPS were discussed in H.1.2.4.

I.1.10 Ground Proximity Warning

I.1.10.1 Overview

The Ground Proximity Warning System (GPWS) provides an automatic warning to the flight crew when the aeroplane is in potentially hazardous proximity to the ground terrain. GPWS is only able to provide terrain alerts a short time ahead. It was developed mainly to reduce incidence of controlled flight into terrain (CFIT).

With technological advances in terrain and airport mapping techniques, and integration of GPS, the Enhanced Ground Proximity Warning System (EGPWS) has been developed. This is more sophisticated than GPWS and provides a look-ahead moving map display of the surrounding terrain to the pilot as well as earlier terrain warnings.

EGPWS is referred to by the FAA as Terrain Awareness Warning System (TAWS).

In the USA, all new turbine aircraft (private and commercial) with six or more seats were required to be fitted with TAWS by the end of March 2002. All in-service aircraft are to be equipped by the end of March 2005.

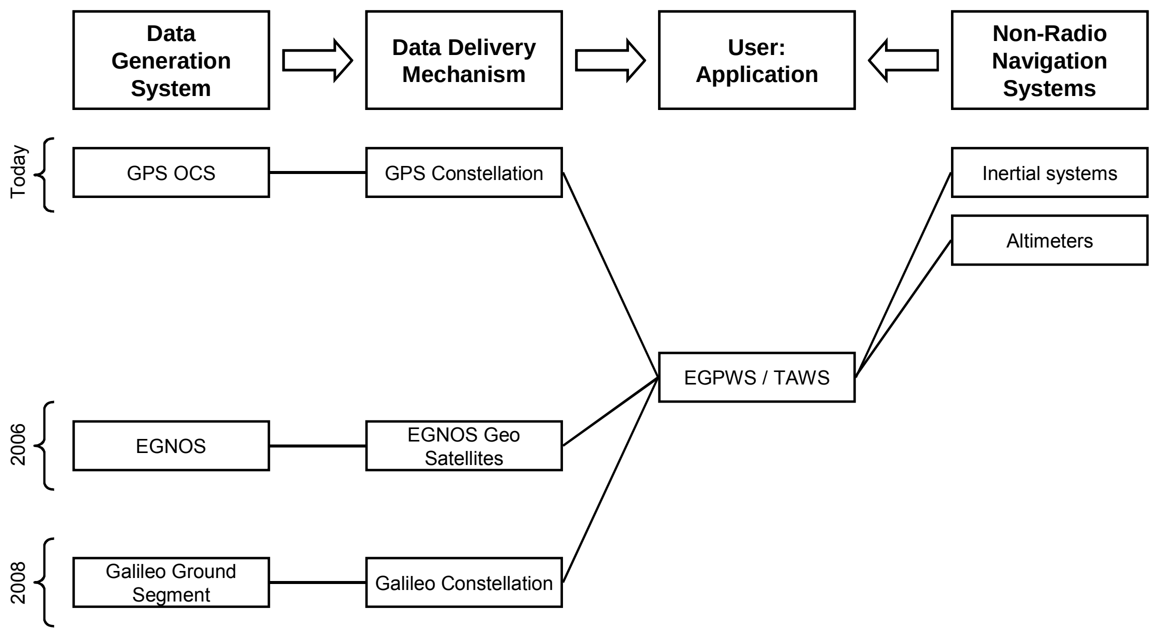
In Europe, all new aircraft in commercial operation with a maximum take-off weight of between 5,700 kg and 15,000 kg, or between 9 and 30 passengers, must be fitted with a EGPWS by January 2003. All in-service aircraft weighing more than 15,000 kg or with more than 30 passengers must be equipped by January 2005 [*www.EGPWS.com web site*].

Most EGPWS/TAWS installations use GPS (although alternative navigation sources are possible) and therefore most aircraft equipping with EGPWS/TAWS mandate are expected to install GPS.

I.1.10.2 Service Delivery

Service delivery flow diagram

The mechanism for service delivery is as shown in the diagram below.



Performance requirements

Performance requirements are not currently available.

I.1.10.3 Service Availability

The table assessing the potential for service disruption for GPS was given in Section H.1.2.3.

Impact of service disruption

Loss of GPS either in a region around an aircraft or globally will result in degradation of the integrity of the ground proximity warning system. The warning system will have to rely on other methods of position determination such as inertial sensors and altimeters.

I.1.10.4 Service Charges

Service charges for GPS were discussed in H.1.2.4.

I.2 Maritime

I.2.1 H.2.1 Market Specific

I.2.1.1 H.2.1.1 Institutional Environment

Institutional framework

The current institutional framework governing radionavigation in the maritime sector is illustrated in the following figure.

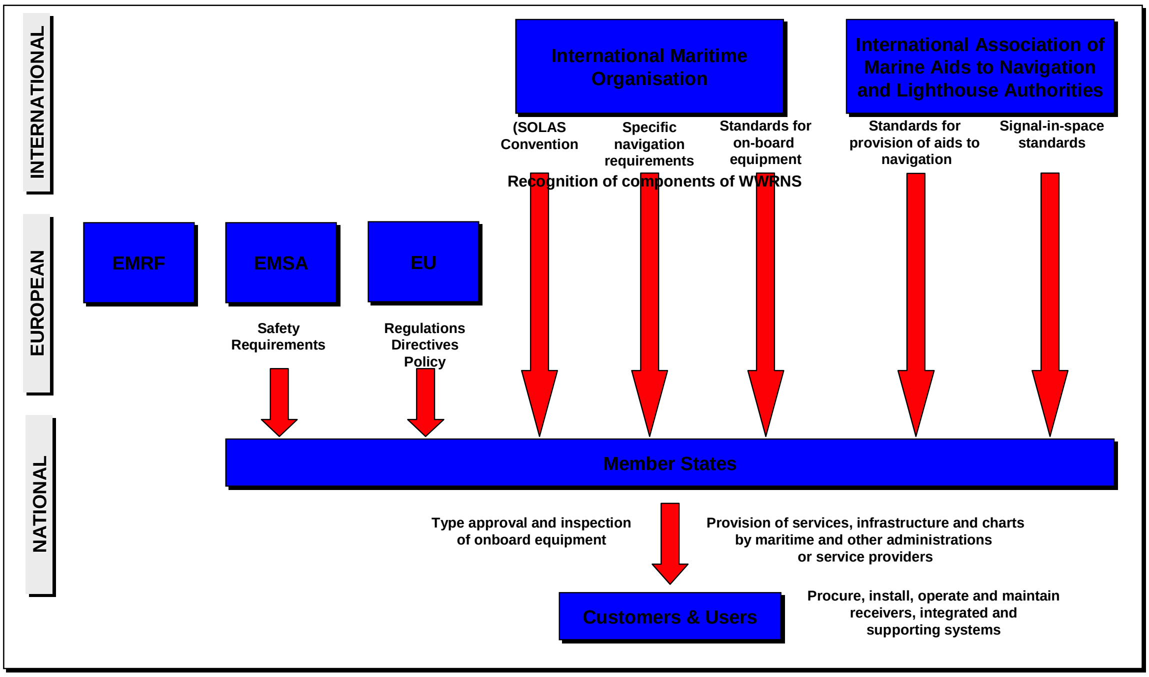


Figure 46 - Institutional framework for radionavigation in the maritime sector

The actors identified in Figure 46 are at three levels: international, European and national.

The actors at the **international** level are:

- the International Maritime Organisation (IMO) (see Section D.1.1), responsible for:
    - defining national obligations for the safety of navigation, principally through the Convention on the Safety of Life at Sea (SOLAS)
    - defining specific navigation requirements
    - defining standards for onboard equipment, often in conjunction with the International Electrotechnical Commission

- the International Association of Aids to Navigation Providers and Lighthouse Authorities (IALA) (see Section D.1.1), responsible for:
    - o setting the standards for the provision of marine radionavigation services
    - o initiating the definition of signal-in-space standards, principally through the International Telecommunications Union (ITU) and the Radio Technical Commission Maritime (RTCM).

The actors at the **European** level are:

- the European Union (see Section D.1.2), which through its executive the European Commission, is responsible for setting policy and formulating and implementing legislation through Regulations, Directives and other instruments
- the European Maritime Safety Agency (EMSA) (see Section D.1.2), established, following the Erika disaster, to enhance maritime safety in the European Union. Although radionavigation is not specifically mentioned in the remit of EMSA, closely associated systems, such as vessel traffic monitoring and information services are identified. It is clear that EMSA will have a role to play in European maritime radionavigation matters
- the European Maritime Radionavigation Forum (EMRF) (see Section D.3.2) is an informal grouping open to all European maritime stakeholders with an interest in radionavigation and is the primary focal point for discussion of maritime radionavigation development in Europe.

At the **national** level the actors are:

- the Member States (of IMO, IALA and the EU) that are responsible for implementing IMO conventions and resolutions, IALA recommendations, as well as European Union regulations and directives (for EU and associated States).Through the SOLAS Convention, the Member States are obligated to provide aids to navigation, which may include radionavigation systems. However, the precise arrangements for the provision of these aids to navigation varies from State-to-State – some services are provided through government departments whereas others are provided through quasi-government bodies (see Section D.2.2). In each case the mechanism is defined in national legislation
- customers and users of radionavigation services that are responsible for the procurement, installation, operation, maintenance and integration of radionavigation systems on their vessels.

System recognition

In order for a (future[123]) radionavigation system to accepted by the maritime community, it must be recognised as part of the World Wide Radionavigation System (WWRNS) by IMO and then subject to a formal standardisation process. A simplified and generic overview of the recognition and standardisation process is given in Figure 47.

Recognition of a system as part of the WWRNS by IMO indicates that the organisation accepts the system is capable of meeting requirements (as promulgated by IMO) in its coverage area and that carriage of the appropriately certified receiving equipment would meet

123 Systems deployed and operational prior to the publication of Resolution A.815(19) are not subject to this requirement

the relevant requirements of the SOLAS Convention. There are several criteria associated with this recognition[124]:

- the system must be stated as operational and available for use by merchant shipping by the organisation providing and operating it
- its coverage area must be stated
- continued provision must be assured
- the system must meet positioning requirements within its declared coverage area
- its characteristics, parameters and status and associated amendments must be published
- once recognised, any changes in performance, characteristics or parameters must be notified to IMO in a timely manner and adequate arrangements must be made to protect the safety of navigation in the light of these changes.

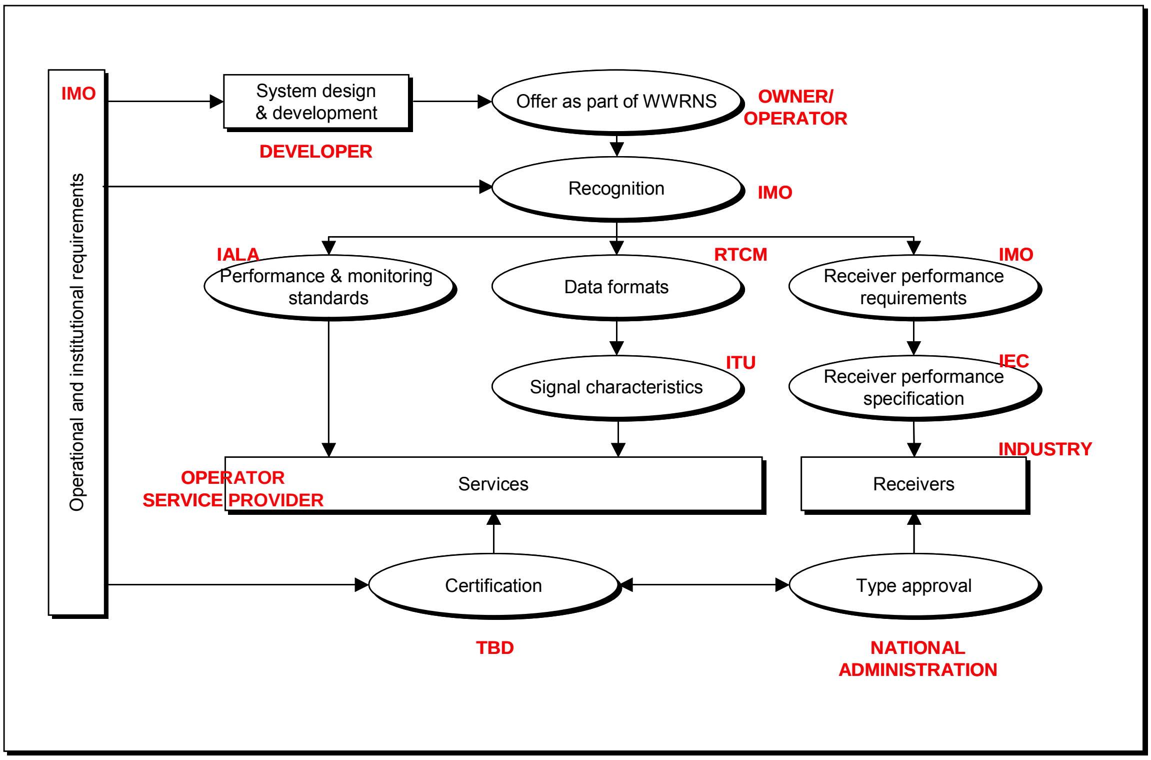


Figure 47 – Illustration of the recognition process

Following recognition of the system by IMO, standardisation of receiving equipment and the signal-in-space takes place. Any receiving equipment and services must be subject to this standardisation process, which is delegated by IMO to the competent international bodies.

Service providers are not responsible for the performance of shipborne receivers - these should meet the relevant performance standards. Shipborne equipment must also comply with the general requirements[125] of Resolution A.694(17).

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124 "*World-wide radionavigation system*", IMO Assembly Resolution A.815(19), 1995

125 "General requirements for shipborne radio equipment forming part of the global maritime distress and safety system (GMDSS) and for electronic navigational aids", Resolution A.694(17), 6 November 1991

The radionavigation standardisation process typically takes place in two stages:

- development of performance standards by IMO
- translation of the performance standards into equipment standards by the International Electrotechnical Commission (IEC).

Subsequently, equipment manufacturers self-certify or type-approve their equipment against these standards.

As well as specification radionavigation standards, all shipborne equipment must comply with a large number of general standardisation requirements[126,127,] etc.

A further requirement for all shipborne radionavigation equipment is that it must support the appropriate data interfaces to enable its integration with other electronic equipment on the bridge and elsewhere onboard[128],[129].

Standardisation of the signal-in-space is also required, especially for regional and local (augmentation) systems to ensure a seamless, global service and to ensure that the provision of the service is coordinated in the most efficient way. The maritime DGPS service is an example that can be used to illustrate the interaction of various organisations in the standardisation of a maritime system:

- IALA is responsible for development of operational standards and has assisted in coordinating frequency plans to optimise the performance of the overall DGPS system. IALA also maintains the list of operational stations and defines performance standards[130]
- RTCM has developed (and continues to develop) data message formats (RTCM-SC104)
- ITU-R has developed and published the characteristics of the correction signals, incorporating the above message format – ITU-R M.823 (which also defines some receiver characteristics).

To date the only successful examples of the recognition and standardisation process are those of GPS and GLONASS. Both of these systems were recognised as part of the WWRNS at the 66th Session of the IMO Maritime Safety Committee (MSC) in 1996.

Service provision requirements

The provision of aids to navigation by a State are governed by its obligations under the SOLAS Convention, Chapter V Regulation 13. This Regulation states:

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126 "General requirements for electromagnetic compatibility (EMC) for all electrical and electronic ship's equipment", IMO Resolution A813(19) , 23 November 1995

127 The Marine Equipment Directive (Council Directive 96/98/EC of 20 December 1996 on marine equipment and its amendment - Commission Directive 2002/75/EC of 2 September 2002)

128 IEC 61162-1 Ed. 2 on Maritime navigation and radiocommunication equipment and systems – Digital interfaces –Part 1:Single talker and multiple listeners, 2000

129 IEC 61162-2 on Maritime navigation and radiocommunication equipment and systems - Digital interfaces - Part 2: Single talker and multiple listeners, high-speed transmission, 1998

130 "IALA guidelines for the performance and monitoring of a DGNSS service in the band 283.5 – 325 kHz", March 1999

Each Contracting Government undertakes to provide, as it deems practical and necessary either individually or in co-operation with other Contracting Governments, such aids to navigation as the volume of traffic justifies and the degree of risk requires.

In order to obtain the greatest possible uniformity in aids to navigation, Contracting Governments undertake to take into account the international recommendations and guidelines when establishing such aids.

Contracting Governments undertake to arrange for information relating to aids to navigation to be made available to all concerned. Changes in the transmissions of position-fixing systems which could adversely affect the performance of receivers fitted in ships shall be avoided as far as possible and only be effected after timely and adequate notice has been promulgated

There is no specific requirement to provide any radio-based aid to navigation although when these are provided they must comply with international standards.

There are also obligations to provide systems related to radionavigation, such as vessel traffic services (VTS) (SOLAS V Regulation 12) and ship reporting systems such as automatic identification systems (AIS) (SOLAS V Regulation 11 and Directive 2002/59). such systems are, effectively, totally reliant on GPS at present.

Carriage requirements

IMO currently mandates the carriage of several systems through Chapter V of the SOLAS Convention:

- concerning radionavigation, Regulation 19 states

  " All ships irrespective of size shall have….

  …a receiver for a global navigation satellite system or a terrestrial radionavigation system, or other means suitable for use at all times throughout the intended voyage to establish and update its position by automatic means"

- concerning AIS, Regulation 19 also states:

  "AIS shall…

  …provide automatically to appropriately equipped shore stations, other ships and aircraft information, including the ship's identity, type, position, course, speed, navigational status and other safety-related information"

- concerning voyage data recorders (VDR), Regulation 20 states

  "…to assist in casualty investigations, ships, when engaged on international voyages, … shall be fitted with a voyage data recorder (VDR)".

These regulations effectively mandate the carriage and use of GPS as there is currently no alternative system available.

According to the SOLAS Convention (Chapter V, Regulation 18) all satellite and terrestrial radionavigation carried must comply with IMO performance requirements.

I.2.1.2 Application Summary

Current and potential maritime applications that do or could use radionavigation systems are summarised in the following table, according to IMO classifications. It must be stressed that the marine navigation environment is characterised by a mix of aids to navigation, including radionavigation, lights, buoys and fog signals – this mix of systems is likely to persist for the foreseeable future. It should also be noted that the only radionavigation system currently used by mariners in Europe is GPS, alone, augmented by the IALA DGNSS system or augmented by bespoke systems for special applications.

Application	Current Status		Critical	
	Existing	Radionav	Safety	Mission
General navigation (commercial and leisure users) as follows:				
Ocean phase	Yes	Yes	Yes	Yes
Coastal phase	Yes	Yes	Yes	Yes
Port approach, ports, restricted waters	Yes	Yes	Yes	Yes
Transition from sea to river navigation	Yes	Yes	Yes	Yes
Inland waterways	Yes	Yes	Yes	Yes
Operations, including the following				
Tugs and pushers	Yes	No	Yes	Yes
Icebreakers	Yes	No	Yes	Yes
Track control	Yes	Yes	Yes	Yes
Automatic collision avoidance	No	TBD	Yes	No
Automatic docking	No	TBD	Yes	Yes
Traffic management, including:				
Ship-to-ship coordination	Yes	Yes	Yes	No
Ship-to-shore coordination	Yes	Yes	Yes	No
Shore-to-ship traffic management	Yes	Yes	Yes	No
Search and rescue, comprising				
Local emergency response	Yes	No	Yes	Yes
GMDSS coordination	Yes	Yes	Yes	Yes
Hydrography	Yes	Yes	Yes	Yes
Oceanography	Yes	Yes	No	Yes
Marine engineering, construction and management, including:				
Dredging	Yes	Yes	Yes	Yes

Application	Current Status		Critical	
	Existing	Radionav	Safety	Mission
Cable and pipe laying	Yes	Yes	No	Yes
Construction works	Yes	Yes	No	Yes
Aids to navigation management	Yes	Yes	Yes	Yes
Port operations including:				
Local vessel traffic services	Yes	Yes	Yes	Yes
Container/cargo tracking & asset management	Yes	Yes	No	No
Law enforcement	Yes	No	No	No
Cargo handling	Yes	No	No	No
Casualty analysis	Yes	Yes	No	No
Offshore exploration and exploitation:				
Exploration	Yes	Yes	No	Yes
Appraisal drilling	Yes	Yes	No	Yes
Field development	Yes	Yes	No	Yes
Support to production	Yes	Yes	No	Yes
Post production	Yes	Yes	No	Yes
Fisheries, including				
Location of fishing grounds	Yes	Yes	No	Yes
Positioning during fishing	Yes	Yes	Yes	Yes
Recording of fish tracks & yield analysis	Yes	Yes	No	Yes
Fisheries monitoring	Yes	Yes	No	Yes
Marginal ships	Limited	Limited	Yes	Yes
Marine cadastre	Limited	No	No	Yes
Operation of coastal structures	Y	Y	Y	N

Table 12 – Maritime application summary

I.2.2 General navigation

I.2.2.1 Overview

The phases of general navigation, which is generally both safety and mission critical, are usually classified as:

- **Ocean:** where the distance from the nearest fixed obstacle is greater than 50 nautical miles or beyond the continental shelf where the water depth is greater than approximately 200m. The principal use of navigation systems in this phase of the voyage is for the execution of safe and efficient routes, accounting for weather conditions, therefore this application is both safety and mission critical. GPS is the principal radionavigation system used for ocean navigation due its global availability. Traditional methods, such as celestial navigation may also be used

- **Coastal:** where the distance from the coast is 50 nautical miles or less or at the limit of the continental shelf, (where the depth is approximately 200m), whichever is greater. The typical width of safe paths is 2 nautical miles one-way or 4 nautical miles two-way. The probability of encounters with other vessels and grounding is higher than for the ocean phase but lower than that for ports, port approaches and restricted water phase. The principal uses of navigation systems in this phase of the voyage are associated with maintaining safety. At present, coastal navigation only requires two-dimensional position-fixing but this may be increased to three-dimensional in the future, depending on the depth of channels being navigated. GPS is the principal radionavigation system used for coastal navigation, often augmented by the IALA DGNSS system. RACONS may also be used. However, a large network of traditional aids to navigation is essential for maintaining the safety of navigation. These aids include lights, buoys, markers and fog signals

- **Ports, port approaches and restricted waters**: where the freedom to manoeuvre is limited and it is often necessary to keep to specific channels or separate traffic routeing measures; accounting for channel width, under keel clearance and local conditions. Typically channel widths may be 200 to 600 metres wide at the seaward end and as narrow as 45m at the harbour end. The need for frequent manoeuvring, close proximity to other vessels and grounding mean that navigation requirements are more stringent than for the coastal phase and may require three-dimensional position fixing, depending on local circumstances, e.g. whether channels are shallow compared to the draught of the vessel. Again GPS, augmented by the IALA DGNSS system is used for this phase of navigation. As with coastal navigation, RACONS and traditional aids to navigation are essential for maintaining the safety of navigation. Onboard systems, such as depth sounders may also be used

- **Transition from sea to river navigation:** Some sea-going vessels also navigate in rivers and other inland waterways. An example of this is the navigation of North Sea coasters from the North Sea into the Rhine. For the purposes of this analysis, this type of navigation is not considered separately and is assessed to have the same requirements as navigation in ports, port approaches and restricted waters, introduced above. Navigation in this area may be further complicated by the mix of maritime and non-maritime vessels, having different carriage requirements and navigational capabilities.

- **Inland waterways:** Historically, inland waterways applications have not been considered explicitly. These requirements, and associated services, are generally governed by local or regional authorities (e.g. Central Commission for Navigation on the Rhine, the Danube Commission), which may or may not adopt IMO recommendations. In the absence of alternative material, it has been assumed that the IMO requirements are representative. Augmented GPS systems are used to support inland navigation, which is safety critical, along with visual aids.

I.2.2.2 Service Delivery

The service delivery chains for the various elements of general navigation are shown in the following figure.

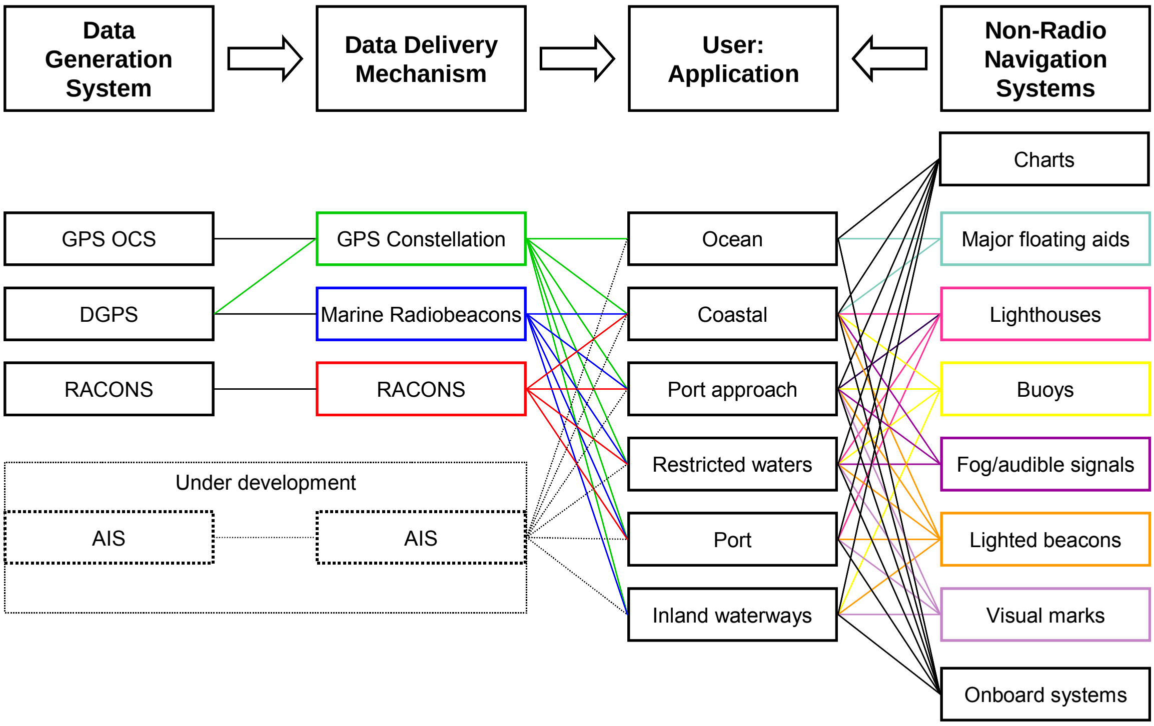

Figure 48 – Current service delivery chain for maritime general navigation

Figure 48 shows that the majority of general navigation applications are supported by GPS, augmented by DGPS using the IALA medium frequency DGNSS system where coverage permits as well as RACONS where their coverage permits. However, it is also clear from Figure 48 that maritime general navigation also relies heavily on the input from a wide range of non-radionavigation systems, both those provided externally and those onboard (these variously include magnetic compass, ECDIS, ARPA, depth sounders, etc. depending on the type, size and equipage of the vessel[131]).

Finally, the automatic identification system (AIS) is shown in Figure 48 as an aid to navigation. Currently IALA policy is that AIS will be used as an (radio) aid to navigation. As well as its primary reporting function, AIS can be used as a radionavigation system to generate both virtual and synthetic aids to navigation.

Charts are a key element of general navigation not shown in Figure 48. The future requirements for general navigation (See Section H.2.2.2.2) refer to *predictable* rather than *absolute* accuracy. From the user perspective, the use of predictable accuracy couples the requirement to the availability of suitable charts – it is well-known that in certain regions these charts are not currently available, either electronically or in paper form.

The requirements for radionavigation systems to support general navigation have been agreed globally within the IMO forum and may be split into two groups:

1. requirements that are currently applicable
2. future requirements

131 Carriage of the following equipment is mandated for SOLAS vessels (depending on size): magnetic compass, nautical charts fit for purpose, an echo sounder, 9GHz radar, a radar plotting device, a heading device, a gyro compass, AIS, a 3GHz radar or a second 9GHz radar, an ARPA, a track control device, a rate of turn indicator and a speed and distance measuring device. See SOLAS V Regulation 19 for precise details

Current requirements

Current requirements for general navigation are specified in IMO Resolution A.815(19) on the World-Wide Radio Navigation System (WWRNS)[132] and in IMO Resolution A.529(13) on accuracy standards for navigation[133]. These requirements are applicable to current systems and are considerably less stringent than those specified for future GNSS (see Section H.2.2.2.2 below). The current requirements are specified in two parts:

- Resolution A815(19) specifies the operational requirements for navigation in harbour entrances, approaches and other restricted waters (i.e. discrete, local coverage is required) as follows:
    - accuracy should be better than 10m to 95% probability
    - signal availability should be 99.8% over a 30-day period
    - the update rate should be better than once every 10 seconds (every 2 seconds if the position data is used to control the vessel directly)
    - the service reliability (undefined) should be better than 99.97% per year
    - the time-to-alarm should be better than 10 seconds.
- Resolution A529(13) specifies accuracy standards for other phases of the voyage (i.e. uniform global coverage is required) as:
    - 4% of the distance from danger (with a maximum of 4.0 nautical miles)
    - update rate governed by the accuracy of the navigation system and the distance from danger (typically between 10 minutes and 5 hours).

Future requirements

Future requirements for maritime radionavigation[134] are specified in IMO Resolution A.915(22). This resolution also contains all of the definitions of the terms used to define performance requirements – this is very important as the definitions used in the maritime sector can be subtly different to those used in other sectors.

The requirements for general navigation are abstracted into Table 13

132 "*Worldwide radionavigation system*", IMO Resolution A.815(19), 23 November 1995

133 "*Accuracy standards for navigation*", IMO Resolution A.529(13), 17 November 1983

134 "*Revised maritime policy and requirements for a future global navigation satellite system (GNSS)*", IMO Resolution A.915(22), 22 January 2002

	Absolute Accuracy	Integrity			Availability % per 30 days	Continuity % over 3 hours	Coverage[2]	Fix interval[3] (seconds)
	Horizontal (metres)	Alert limit (metres)	Time to alarm[2] (Seconds)	Integrity risk (per 3 hours)				
Ocean	10	25	10	10^{-5}	99.8	N/A[1]	Global	1
Coastal	10	25	10	10^{-5}	99.8	N/A[1]	Regional link	1
Port approach and restricted waters	10	25	10	10^{-5}	99.8	99.97	Discrete local over a region	1
Port	1	2.5	10	10^{-5}	99.8	99.97	Discrete local	1
Inland waterways	10	25	10	10^{-5}	99.8	99.97	Regional link	1

Notes: *1: Continuity is not relevant to ocean and coastal navigation*

2: Coverage requirements have been adapted for consistency of definition with other (non-maritime) applications considered within the ERNP

3: More stringent requirements may be necessary for ships operating above 30 knots

Table 13 – Future requirements for general navigation

I.2.3 Operations

I.2.3.1 Overview

Requirements for applications grouped under the heading "*operations*" were not officially specified prior to the adoption of IMO Resolution A.915(22). The requirements for this group of applications is, therefore, only specified for and applicable to future systems. This group of applications comprises:

- **tugs and pushers:** where a relative positioning is required between the tug and the other vessel. This application is currently performed visually but has been identified as having potential for contribution by radionavigation systems
- **icebreakers:** where a relative positioning is also required between the icebreaker and the ice floe. As with tugs, icebreaking is normally carried out visually, although the path of the icebreaker, and hence the cleared channel, can be controlled using GPS
- **track control:** whereby the ship is kept automatically on a pre-planned track over the ground using position, heading and speed information from the ship's navigation system. The latency of the navigation data will be an important parameter for this application. Performance standards[135] require that the primary position fixing system for track control be an electronic positioning system approved by IMO with the position being monitored by a second independent position fixing system. In this case absolute accuracy is required
- **automatic collision avoidance**: is an application identified by EMRF but omitted from the IMO requirements. EMRF envisages that this application would use auto-tracking[136] where the navigation information of the vessel is combined with that of other vessels, obtained via datalink (probably AIS) as well as radar to provide continuous, accurate and timely situation evaluation. This is an application, the feasibility of which remains to be demonstrated., Current decision support systems are limited to the ship's radar and automatic radar plotting aid (ARPA), which can be used[137] to monitor the traffic situation, track targets (vessels, obstructions and aids to navigation (AtoNs) equipped with radar reflectors or radar beacons (RACONS)) and provide alerts when the system predicts a pre-defined minimum range of closest approach (guard ring) will be breached. Rules for actions to be taken when potential conflicts between vessels are identified are promulgated in the collision regulations (COLREGs). The full requirements for automatic collision avoidance are not yet fully specified or agreed
- **automatic docking:** which has been identified as a possible future application, which will require position-fixing to be performed in both the horizontal and vertical planes. Some basic systems based on real time kinematic (RTK) carrier phase DGPS have limited use in some ports. A key aspect of automatic docking is the control of residual speed, which must be kept very low in order to avoid extensive damage to both vessel and dock. In addition, in connection with the use of satellite navigation systems for

135 "Recommendation on performance standards for track control systems", Annex 2 to MSC 74(69) adopted on 12 May 1998

136 "Preliminary draft revised performance standards for automatic pilots", Annex 1 to IMO NAV 41/6, 9 January 1995

137 Note: radar and ARPA are only fitted to certain classes of vessels

berthing manoeuvres, on-board systems would need additional input, such as rate of turn, speed and heading. Propulsion and rudder controls would also need to be integrated into the ship's controls. Given the need to control the position and speed of the vessel relative to the dock, it appears unlikely that satellite-based navigation positioning systems alone offer the best solution to meet the requirements of this application. Furthermore, in order to establish the requirements for automatic berthing, further work must be performed, including analysis of the integration and interface requirements for on-board systems.

H.2.3.2 Service delivery

The service delivery chains for the various elements of operations are shown in the following figure (Figure 49).

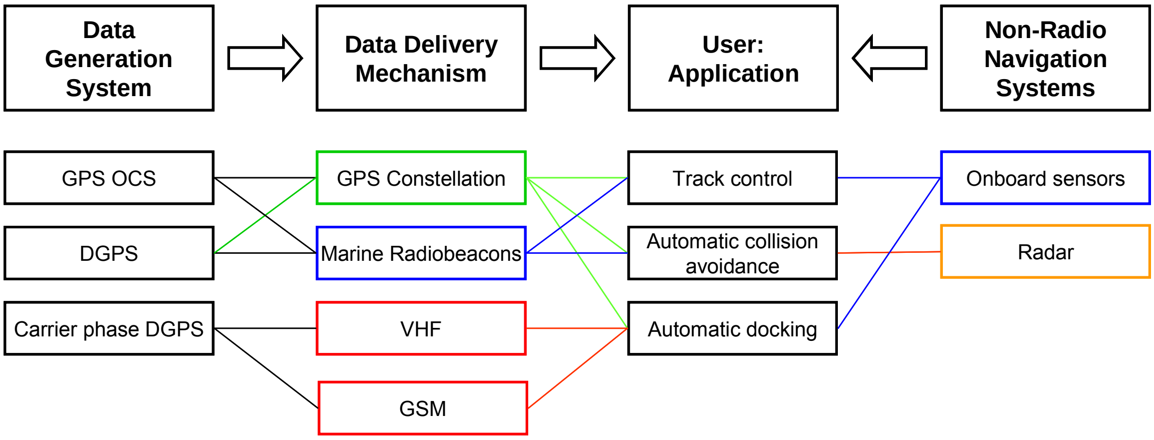

Figure 49 – Service delivery chain for maritime operations

Figure 49 shows that the operations applications are completely dependent on augmented GPS. Table 14 shows the requirements for future GNSS specified for these applications.

	Accuracy		Integrity			Availability % per 30 days	Continuity % over 3 hours	Coverage[3]	Fix interval[2] (seconds)
	Horizontal (metres)	Vertical[1] (metres)	Alert limit (metres)	Time to alarm[2] (Seconds)	Integrity risk (per 3 hours)				
	Relative accuracy								
Tugs and pushers	1	-	2.5	10	10^{-5}	99.8	99.97	Local discrete	1
Icebreakers	1	-	2.5	10	10^{-5}	99.8	99.97	Local discrete	1
Automatic collision avoidance	10	-	25	10	10^{-5}	99.8	99.97	Uniform global	1
	Absolute accuracy								
Track control	10	N/A	25	10	10^{-5}	99.8	99.97	Uniform global	1
Automatic docking	0.1	0.1	0.25	10	10^{-5}	99.8	99.97	Local discrete	1

Notes: *1: There may be a requirement for accuracy in the vertical plane for some port and restricted water operations*

2: More stringent requirements may be necessary for ships operating above 30 knots

3: Coverage requirements have been adapted for consistency of definition with other (non-maritime) applications considered within the ERNP

Table 14 – Future requirements for operations

I.2.4 Traffic management

I.2.4.1 Overview

The automatic identification system (AIS) can support ship-to-ship and ship-to-shore identification and therefore can be used to assist vessel traffic services (VTS) and to monitor aids to navigation. AIS is now mandated for carriage and performance standards are specified in Annex 3 to IMO Resolution MSC 74(69) adopted on 12 May 1998 but do not specify the accuracy requirement for input data. It is expected that there will be an operational requirement for position information to be provided to vessel reporting systems and VTS[138] with an accuracy consistent with the vessel's operations and environment. This application is principally associated with enhancing safe and efficient VTS and port operations.

The dynamic information is derived from the vessel's navigation equipment and must be provided with accuracy, data rates, etc. consistent with the navigation requirements of the particular phase of the voyage and local traffic management requirements, as applicable. Three different basic regimes can be envisaged:

- ship-to-ship coordination
- ship-to-shore coordination
- shore-to-ship traffic management.

At present the sole position input is derived from GPS or DGPS. Furthermore, the timing input to the self-organising time division multiple access (SoTDMA) is also derived from GPS, although backup modes are defined should GPS time become unavailable.

I.2.4.2 Service delivery

The service delivery chain for traffic management is show in Figure 50.

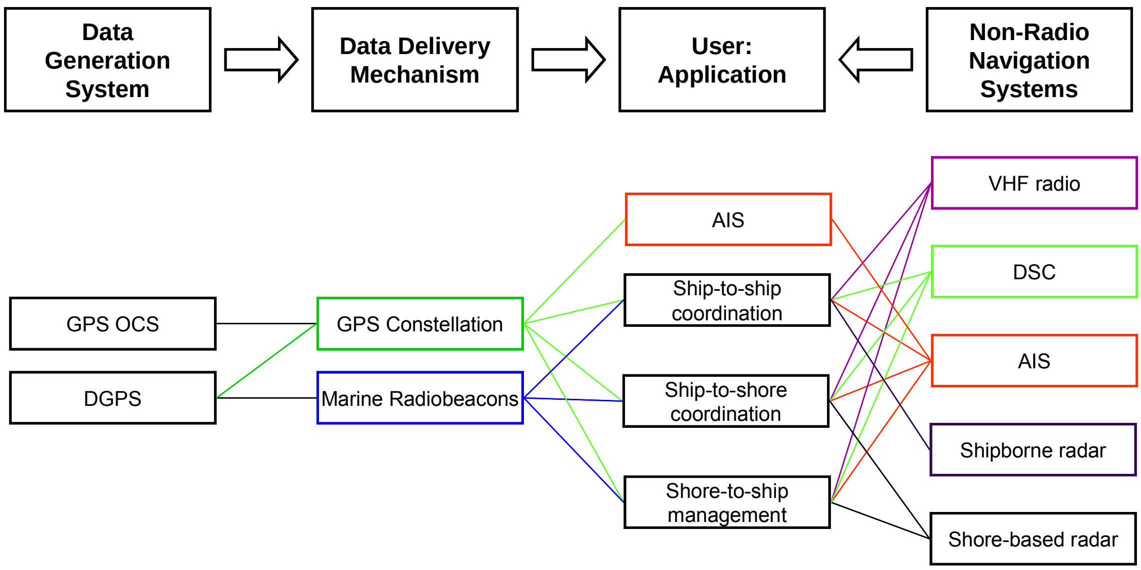

Figure 50 – Delivery chain for traffic management

The future requirements to traffic management applications, as promulgated by IMO, are shown in Table 15.

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138 "*Marine Navigation Plan. Period to 2015*", General Lighthouse Authorities. The United Kingdom and the Republic Of Ireland, Issue 1, July 1997

	Accuracy		Integrity			Availability % per 30 days	Continuity % over 3 hours	Coverage[4]	Fix interval[2] (seconds)
	Horizontal (metres)	Vertical[1] (metres)	Alert limit (metres)	Time to alarm[2] (Seconds)	Integrity risk (per 3 hours)				
Traffic management[3]	**Absolute accuracy**								
• ship-to-ship coordination	10	-	25	10	10^{-5}	99.8	99.97	Uniform global	1
• ship-to-shore coordination	10	-	25	10	10^{-5}	99.8	99.97	Link regional	1
• shore-to-ship traffic management	10	-	25	10	10^{-5}	99.8	99.97	Link regional	1

Notes: *1: There may be a requirement for accuracy in the vertical plane for some port and restricted water operations*

2: More stringent requirements may be necessary for ships operating above 30 knots

3: Traffic management applications in some areas may require higher accuracy

4: Coverage requirements have been adapted for consistency of definition with other (non-maritime) applications considered within the ERNP

Table 15 – Future requirements for traffic management

I.2.5 Search and rescue

I.2.5.1 Overview

The main tasks of search and rescue (SAR) cover two different scales:

- local emergency response, e.g. homing and man-overboard
- coordination within the world-wide global maritime distress and safety system (GMDSS).

SAR is a combination of two major tasks. The first, alerting, is a positioning function, whereas the second, tracking and search, is a navigation function (this is not considered further here). SAR effectiveness depends on knowledge of accurate positions of incidents and also supporting SAR assets (e.g. assisting vessels, lifeboats, aircraft).

Local emergency response is most often dealt with using search and rescue transponders (SARTs) on survival craft or distressed vessels. These transponders reply to the S-band radar and are limited to short range use.

GMDSS alerting systems include emergency position indicating radiobeacons (EPIRBs), emergency locating transmitters (ELT) and personal locator beacons (PLB).

EPIRBS operating at 121.5/243MHz transmit signals that can be detected by overflying aircraft or by COSPAS/SARSAT satellites. Due to frequency congestion, very high false alarm rates and ambiguity problems, two passes of a satellite are needed to confirm the EPIRB signal, making these beacons inefficient and delaying rescue by four to six hours. This type of EPIRB is expected top be phased out by around 2008-2009.

The more modern EPIRBS used by the COSPAS/SARSAT system transmit distress signals at 406MHz. The majority of these signals now include a location derived from GPS on the beacon. These signals are relayed using both polar orbiting COSPAS/SARSAT and geostationary GEOSAR satellites. Some older EPIRBS may not have GPS fitted – the location of these beacons is derived using Doppler techniques which is limited to the polar orbiting satellites. 406MHz EPIRBS also include a 121.5MHz homing signal to aid rescue vessels to locate the target.

IMO also introduced digital selective calling (DSC) on VHF, MF and HF maritime radios as part of the GMDSS system. DSC distress alerts, which consist of a preformatted distress message, are used initiate emergency communications with ships and rescue coordination centres. IMO and ITU both require that the DSC-equipped VHF and MF/HF radios be externally connected to a satellite navigation receiver. That connection is required to ensure accurate location information is sent to a rescue coordination centre when a distress alert is transmitted

GMDSS services are also provided by Inmarsat using Inmarsat A, B, C, E (for use with EPIRBS, which must use GPS-derived position information) and Fleet (F) 77. All of these methods require positioning input from GPS. The architecture of the Inmarsat system is illustrated in Figure 51 (courtesy of Inmarsat).

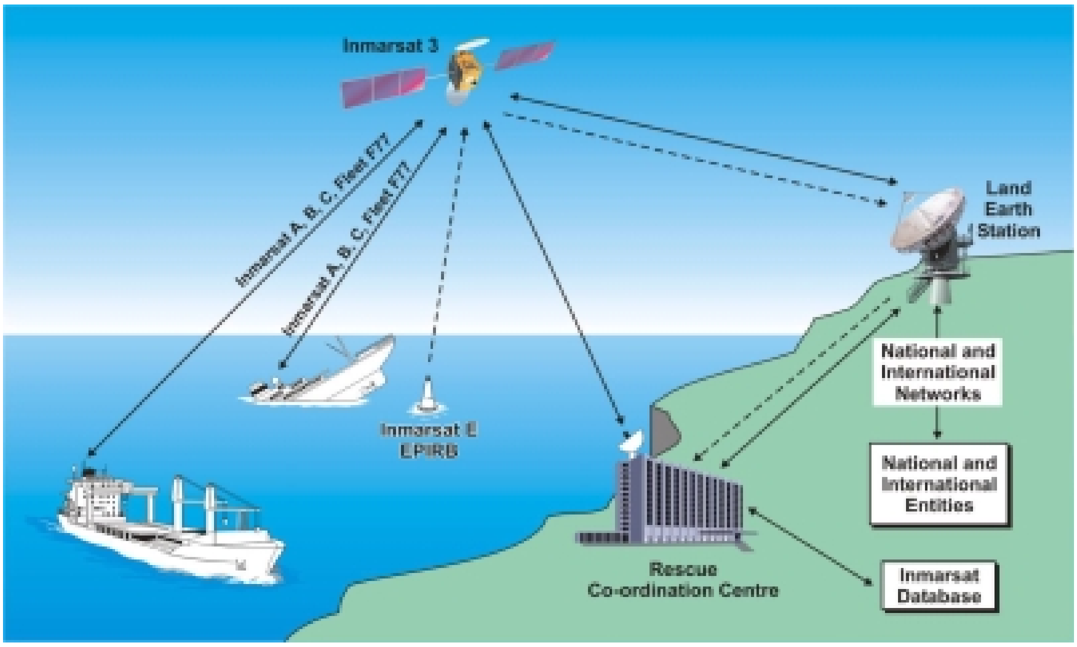


Figure 51 - Illustration of Inmarsat GMDSS architecture

I.2.5.2 Service delivery

The service delivery chains for the alerting function of SAR are shown in Figure 52.

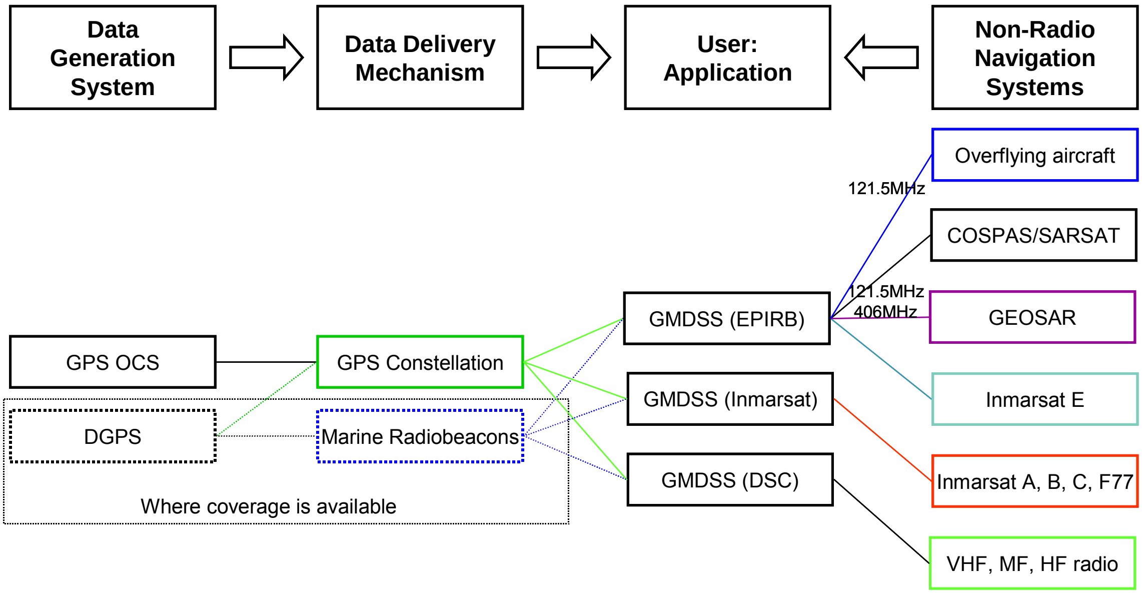


Figure 52 - Service delivery chain for GMDSS

Future radionavigation requirements for SAR are outlined in Table 16.

	Accuracy		Integrity			Availability % per 30 days	Continuity % over 3 hours	Coverage[3]	Fix interval (seconds)
	Horizontal (metres)	Vertical (metres)	Alert limit (metres)	Time to alarm (Seconds)	Integrity risk (per 3 hours)				
	Absolute accuracy[1]								
Search and rescue	10	-	25	10	10^{-5}	99.8	-	Uniform global	1
Hydrography	1 - 2	0.1	2.5 - 5	10	10^{-5}	99.8	-	Link regional	1
OCEANOGRAPHY	10	10	25	10	10^{-5}	99.8	-	Uniform global	1
Marine engineering, construction, maintenance and management									
• dredging	0.1	0.1	0.25	10	10^{-5}	99.8	-	Discrete local	1
• cable & pipe laying	1	-	2.5	10	10^{-5}	99.8	-	Link regional	1
• construction works	0.1	0.1	0.25	10	10^{-5}	99.8	-	Discrete local	1
Aids to navigation management	1	1	2.5	10	10^{-5}	99.8	-	Link regional	1

Notes: *1: The IMO requirement does not state which type of accuracy is required for these application – absolute accuracy is assumed*

2: The IMO requirement does not identify a vertical element for AtoN management but this could be beneficial, e.g. for tide monitoring

3: Coverage requirements have been adapted for consistency of definition with other (non-maritime) applications considered within the ERNP

Table 16 – Future requirements for search and rescue, hydrography, marine engineering and aids to navigation management

I.2.6 Hydrography

I.2.6.1 Overview

Hydrographic surveys provide data for charting seas and inland waterways and adjacent topography. Provision of hydrographic information adequate to support the safety of navigation is a national obligation under the SOLAS Convention (Chapter V Regulation 9).

Survey requirements are specified in International Hydrographic Organisation Special Publication IHO S-44. The determination of position coupled with depth sounding information must be undertaken to compile charts with sufficient absolute accuracy to ensure that safety of navigation is not compromised when using available navigation systems (currently limited to GPS). Post-processing of data can be used to improve accuracy when necessary.

A variety of GPS-based systems and services are used for hydrographic survey, including:

- the IALA DGPS system
- commercial services such as Thales Skyfix and Fugro Seastar
- post-processed dual frequency carrier phase solutions calibrated using reference networks when these are available
- on-the-fly kinematic techniques to correct for squat and other survey vessel motion.

I.2.6.2 Service delivery

The service delivery chains for hydrography are shown in Figure 53.

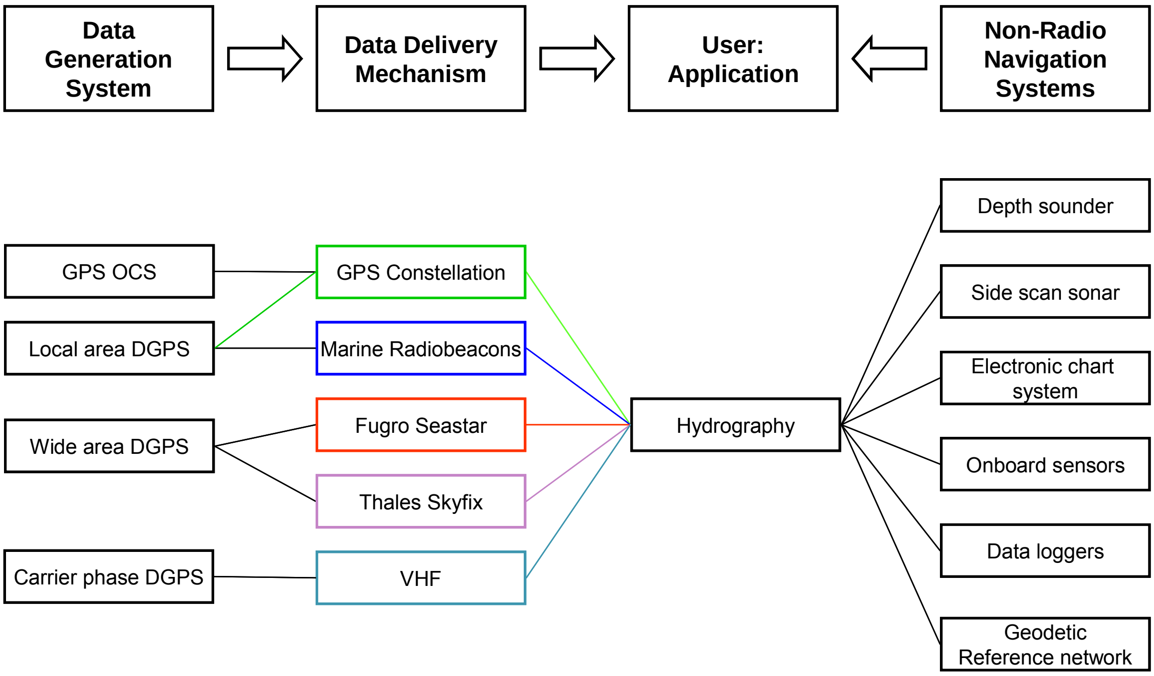


Figure 53 - Service delivery chain for hydrography

The radionavigation requirements for hydrography are listed in Table 16.

I.2.7 Oceanography

I.2.7.1 Overview

Oceanography is a scientific application concerned with identifying and understanding the behaviour of the oceans and ocean features, including mapping their boundaries (extent and depth), their geology, the physics and chemistry of their waters, marine micro-biology, and both the conservation and exploitation of their resources. Both horizontal and vertical accuracy will be needed in absolute geodetic coordinates together with global coverage.

GPS and various DGPS services are used together with other sensors, including earth observation satellites, and a vast array of airborne and shipborne sensors including magnetometers, radar, sonar, infrared, salinity, etc. As some oceanographic activities are undertaken by the military, the GPS PPS can be used

I.2.7.2 Service delivery

The service delivery chains for oceanography are shown in Figure 54.

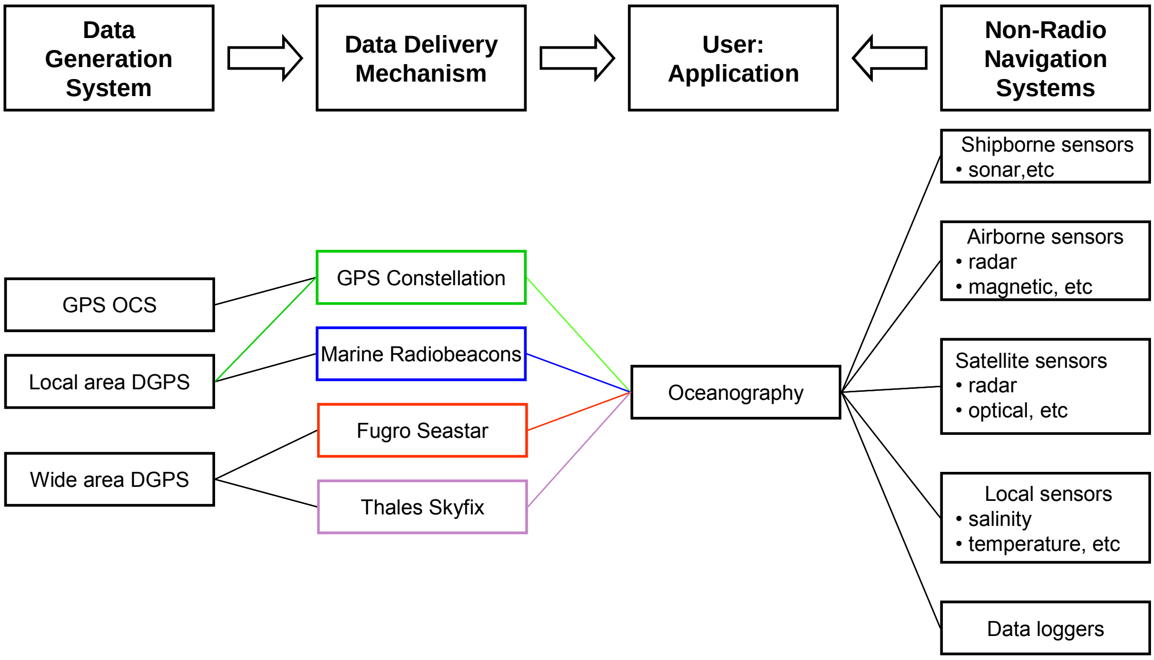


Figure 54 - Service delivery chain for oceanography

The radionavigation requirements for oceanography are listed in Table 16.

I.2.8 Marine engineering, construction and management

I.2.8.1 Overview

This set of applications includes:

- dredging for the maintenance of fairways, channels and port areas with very stringent horizontal and vertical absolute accuracy requirements but with coverage confined to the specific areas of interest. Dredgers currently use GPS, IALA DGPS and carrier phase solutions to support the positioning and control of the dredger. Real-time solutions are needed
- cable and pipe laying, where coverage may be required over large areas. GPS and wide-area differential services, such as those provided by Fugro and Thales may be used. As with dredging, positioning is needed in real-time.

- construction works, where high accuracy may be required but with limited coverage volumes. This application is identical to other land-based construction applications and uses similar solutions.

I.2.8.2 Service delivery

The service delivery chains for marine engineering, construction and management are shown in Figure 55.

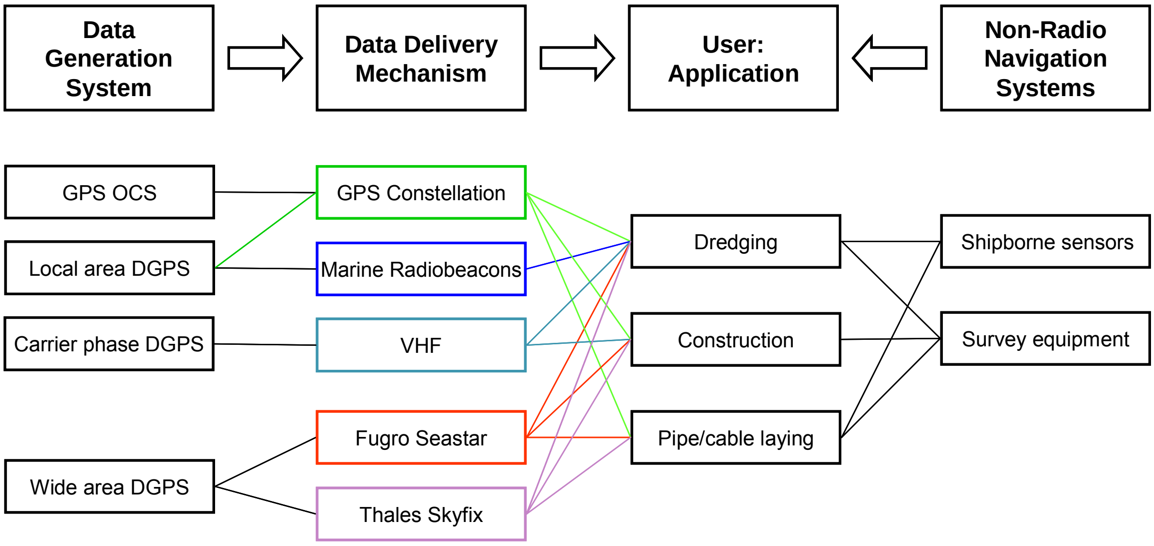


Figure 55 - Service delivery chain for marine engineering, construction and management

The radionavigation requirements for marine engineering, construction and management are listed in Table 16.

I.2.9 Aids to navigation management

I.2.9.1 Overview

GNSS can be used as a survey-tool to initially position floating aids to navigation and subsequently to monitor their position providing alerts when the drift off-station is beyond an acceptable limit. The need for an accurate position for such floating aids depends on the purpose of the particular aid to navigation, its location and specific circumstances (e.g. guard ring, depth of water, etc.). Coverage must be adequate for the areas where floating aids are deployed. Either GPS or IALA DGPS is used for this application. The position of the floating aid is usually relayed to a remote control and monitoring station using an appropriate communications bearer. AIS is also being used for this function.

I.2.9.2 Service delivery

The service delivery chain for marine aids to navigation management is shown in Figure 56.

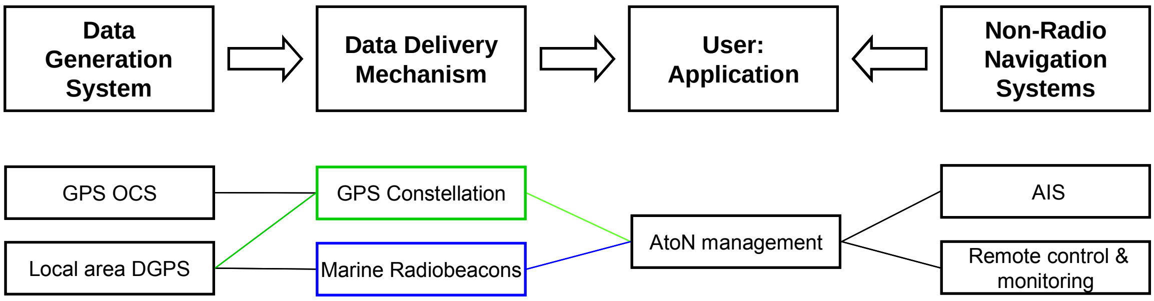


Figure 56 - Service delivery chain for aids to navigation management

The radionavigation requirements for aids to navigation management are listed in Table 16.

I.2.10 Port operations

I.2.10.1 Overview

In this context, port operations are restricted to activities associated directly with the vessels themselves, e.g. loading and unloading. Other activities, such as intermodal freight management are excluded. Port operations include a variety of activities, including:

- local traffic management (VTS), with similar applications to those introduced above for traffic management but with requirements (accuracy and coverage) adjusted to meet the specific port environment
- container and cargo tracking and asset management, where both horizontal and vertical positioning will be required with coverage over the extent of the port and to an accuracy level sufficient to distinguish between containers
- law enforcement activities, such as customs and immigration, where similar performance to that needed for container and cargo tracking is likely to be required
- cargo handling, which will require accuracies of around 0.1m, a fix rate of around 1s and a time to alert of around 1s

The requirements for these applications are, therefore, in the range 0.1-10m. It is important to note that for some of these applications, a vertical dimension is required.

I.2.10.2 Service delivery

The service delivery chain for port operations is shown in Figure 57.

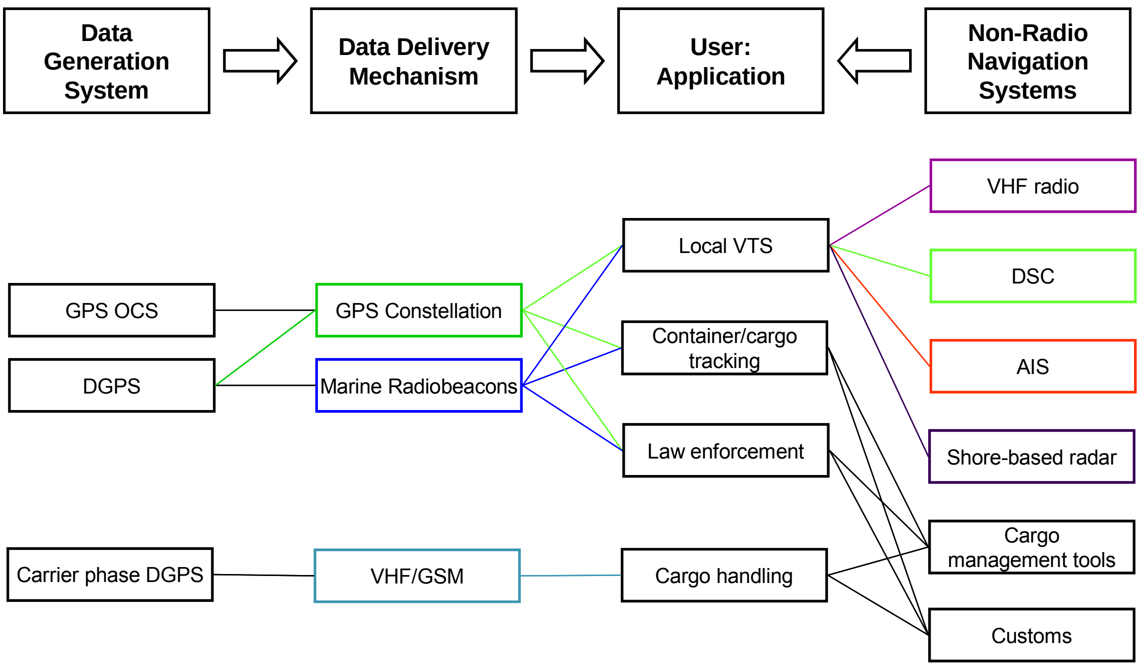


Figure 57 - Service delivery chain for port operations

The radionavigation requirements for port operations are listed in Table 17.

I.2.11 Casualty analysis

I.2.11.1 Overview

IMO requires ships engaged on international voyages to carry voyage data recorders (VDRs) to aid in the analysis and reconstruction of accidents and incidents, as follows:

- passenger ships constructed on or after 1 July 2002
- roll-on, roll-off (ro-ro) passenger ships constructed before 1 July 2002 not later than the first annual survey after 1 July 2002
- passenger ships, other than ro-ro passenger ships, constructed before 1 July 2002 not later than 1 January 2004
- all ships other than passenger ships of 3,000 gross tonnage and upwards constructed on or after 1 July 2002.

The ship's navigation systems will provide the position-fixing input to the VDR, along with input from the ship's other navigation sensors. It is likely that the required input to the VDR will be consistent with that for navigation in the relevant phase of the voyage.

I.2.11.2 Service delivery

The service delivery chain for casualty analysis is shown in Figure 58.

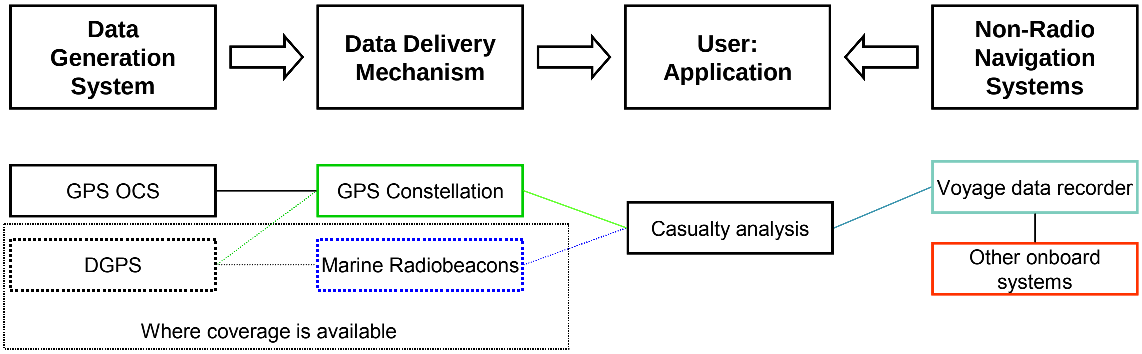


Figure 58 - Service delivery chain for casualty analysis

The radionavigation requirements for casualty analysis are listed in Table 17.

I.2.12 Offshore exploration and exploitation

I.2.12.1 Overview

Offshore oil, gas and mineral discovery and extraction are of major economic importance. Some operations associated with the offshore industry are also hazardous and have safety-of-life implications. The various applications can be classified as follows:

- **exploration:** mainly performed using seismic survey. This requires an absolute accuracy of around 1m and is currently carried out using differencing techniques superimposed on a geodetic framework. Post-processing techniques can be used
- **appraisal drilling:** examination of the extent of a potential site is performed by drilling subsidiary wells, accounting for previous drilling and extractions. An absolute accuracy of around 1m is required

- **field development:** involves the location of drilling wells, delineation of boundaries, identification of hazards, laying of pipelines and field control. This requires an absolute accuracy of approximately 1m
- **support to production:** involves provision of access to all parts of the field for maintenance and repair, supply and delivery in all weathers. Support to production involves the operation of support vessels and helicopters. The accuracy requirements are likely to be of the order 1m
- **post-production:** involves the removal of all structures, pipelines and debris. Positioning accuracies of around 1m are needed to the efficient location of all material.

In addition to the well-known oil and gas sectors, the offshore industry also includes the mining other resources such as sand and gravel. Furthermore, increasingly offshore facilities are being developed to take advantage of renewable sources of energy. These activities include wind, wave and tidal farms.

The offshore industry has been one of the major drivers in the development of commercial differential GPS services, for example provided by Thales and Fugro.

I.2.12.2 Service delivery

The service delivery chain for offshore exploration and exploitation is shown in Figure 59.

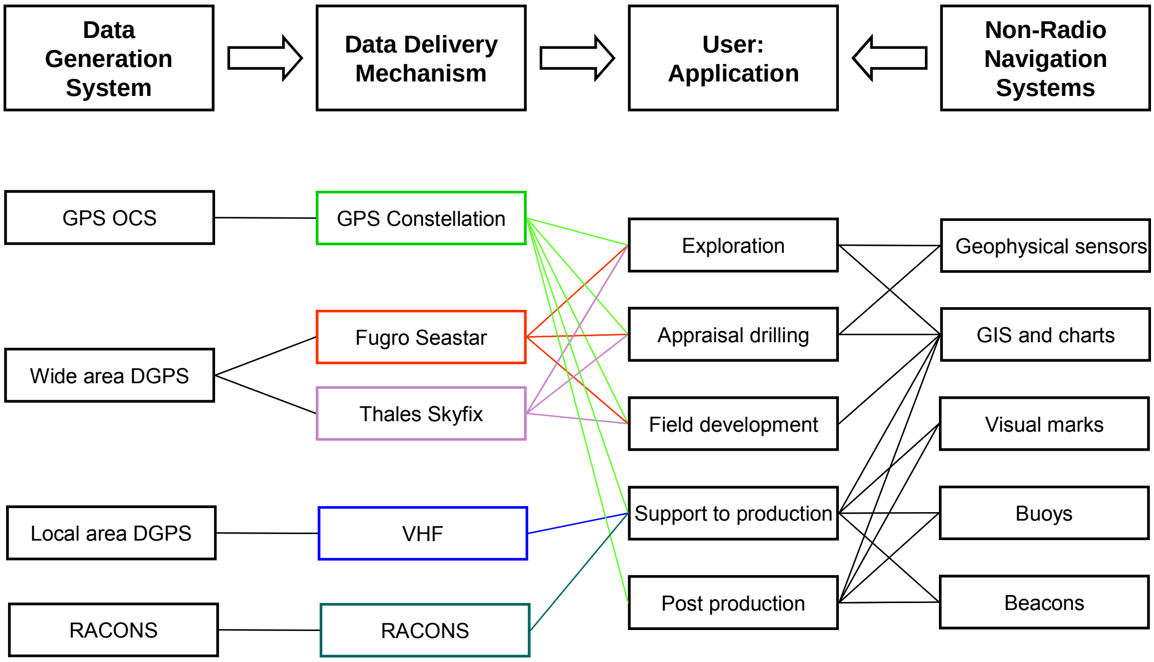


Figure 59 - Service delivery chain for offshore exploration and exploitation

One of the clear messages from Figure 59 is the need for non-radionavigation aids to support production and to mark structures post-production. There are well-defined rules for the marking of offshore structures during construction, as well as and after the period of their operation, particularly to mitigate the risk of collision between maritime traffic and the structures.

The radionavigation requirements for offshore exploration and exploitation are listed in Table 17.

	Accuracy		Integrity			Availability % per 30 days	Continuity % over 3 hours	Coverage	Fix interval[1] (seconds)
	Horizontal (metres)	Vertical (metres)	Alert limit (metres)	Time to alarm[1] (Seconds)	Integrity risk (per 3 hours)				
Port operations	**Absolute accuracy**								
▪ local VTS	1	-	2.5	10	10^{-5}	99.8	99.97	Discrete local	1
▪ container/cargo management	1	1	2.5	10	10^{-5}	99.8	-	Discrete local	1
▪ law enforcement	1	1	2.5	10	10^{-5}	99.8	-	Discrete local	1
▪ cargo handling	0.1	0.1	0.25	1	10^{-5}	99.8	-	Discrete local	1
Casualty analysis	**Predictable accuracy**							-	
▪ ocean	10	-	25	10	10^{-5}	99.8	-	Uniform global	1
▪ coastal	10	-	25	10	10^{-5}	99.8	-	Uniform global	1
▪ port approach and restricted waters	1	-	2.5	10	10^{-5}	99.8	-	Link regional	1
Offshore exploration and exploitation	**Absolute accuracy**								
▪ exploration	**1**	-	2.5	10	10^{-5}	99.8	-	Regional	1

▪ appraisal drilling	1	-	2.5	10	10^{-5}	99.8	-	Regional	1
▪ field development	1	-	2.5	10	10^{-5}	99.8	-	Regional	1
▪ support to production	1	0.1[2]	2.5	10	10^{-5}	99.8	-	Regional	1
▪ post-production	1	0.1[2]	2.5	10	10^{-5}	99.8	-	Regional	1

Notes: *1: More stringent requirements may be necessary for ships operating above 30 knots.*

2: A vertical accuracy of a few cm (less than 10) is necessary to monitor platform subsidence

3: Coverage requirements have been adapted for consistency of definition with other (non-maritime) applications considered within the ERNP

Table 17 – Future requirements for port operations, casualty analysis and offshore activities

I.2.13 Fisheries

I.2.13.1 Overview

There are three principal applications for radionavigation in the fisheries context:

- **general navigation:** as described previously
- **location of fishing grounds:** a high repeatable accuracy is required to enable fishing vessels to relocate and return to rich fishing grounds. It is expected that a repeatable accuracy of 100m is required to ensure the vessel returns to rich fishing grounds.
- **positioning during fishing itself:** requires control of the position of the vessel during fishing. An absolute accuracy of 3-5m may be required to control the vessel and nets during fishing itself, especially if the activity is taking place near to underwater obstructions
- **recording of fishing tracks and yield analysis:** will require an accuracy of better than 10m
- **fisheries monitoring:** under a European Community directive Member States are required to monitor the activities of their fishing vessels to ensure that quotas are not exceeded. This is achieved, partly, by the vessel reporting its position back to a national fisheries control and monitoring centre. Currently most systems are based on GPS position reported through an Inmarsat-C satellite datalink. The requirement for this application is approximately 100m, however, assurance of the integrity of the position is required for the position reports to be of use in any subsequent court or legal action.

I.2.13.2 Service delivery

The service delivery chain for fisheries applications is shown in Figure 60.

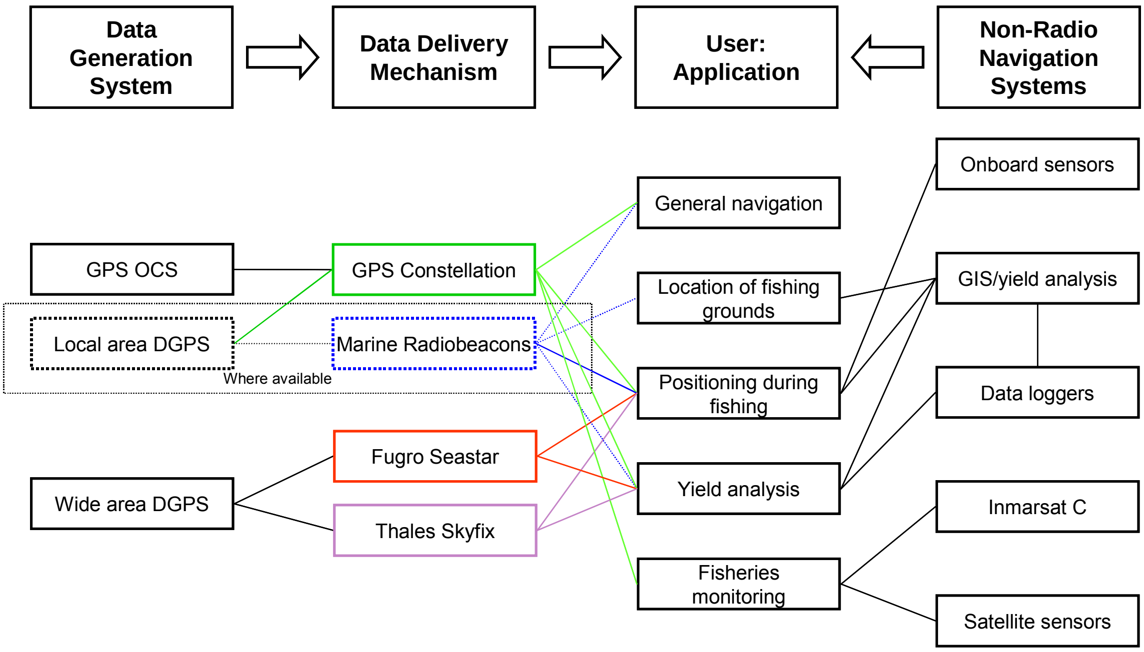


Figure 60 - Service delivery chain for fisheries applications

I.2.14 AIS as an aid to navigation

I.2.14.1 Overview

As mentioned in Section H.2.14.2, AIS is expected to be used as an aid to navigation (AtoN) in the future. This function will provide a number of applications:

- a reliable means of identifying an AtoN on AIS and ships' radar displays
- complementing existing signals from AtoNs, including RACONS
- transmitting accurate positions of floating aids (possibly corrected by DGNSS)
- indicating if a floating AtoN is off station, monitoring its status and tracking it if it is drifting
- providing reference points for a ship's radar
- providing virtual AtoNs
- marking or delineating Tracks, Routes, Areas, and Limits (for example Areas To Be Avoided and Traffic Separation Schemes)
- marking offshore structures (for example wind turbines, oil and gas platforms)
- providing weather, tidal, and sea state data.

The application of AIS to AtoNs is likely to be a significant use of the AIS, and ITU has defined AIS Message 21 for exclusive use with AtoNs. Other messages may be used with AtoNs and may be referenced in ITU-R M.1371-1.

Three implementation methods are envisaged:

- AtoN AIS, where the aid is equipped with an AIS Station designed to generate the appropriate AIS messages using local data from the aid
- Synthetic AIS, where the AIS message for the AtoN is transmitted from another location and the AtoN is physically located at the position given in the AIS message
- Virtual AtoN AIS, where the AIS message is an AtoN message but no real aid exists at the location indicated in the AIS message.

The use of AIS as an AtoN is under development and, as yet, no formal delivery chain exists.

I.2.15 Other applications

I.2.15.1 Overview

There are a number of other maritime applications foreseen for the near future that will utilise both radionavigation and non-radionavigation inputs. Although the formal requirements and delivery chains for these applications do not yet exist they must be included in future plans. These applications include, but are unlikely to be limited to:

- **operation of marginal ships:** marginal ships include vessels that are large relative to the dimensions, including depth, of the waterway in which they are operating as well as high speed and fast manoeuvrable craft. This type of operations is increasing
- **marine cadastre:** concerned with the legal definition of boundaries in the sea. There may be vertical as well as horizontal boundaries. Furthermore these boundaries may be critical, for example in defining mineral rights and environmental protection areas

- **operation of coastal structures:** increasingly offshore and coastal facilities are being developed to take advantage of renewable sources of energy. These activities include wind, wave and tidal farms. These structures are often near to or in navigation channels and must be marked in order not to cause hazards to the traffic using those channels.

I.2.15.2 Service Availability

The main radionavigation components of the services provided to support maritime applications are:

- GPS
- the IALA MF DGPS radiobeacon service
- RACONS
- AIS
- bespoke carrier phase DGPS systems
- commercial DGPS systems such as those provided by Thales and Fugro.

GPS vulnerability

Considerable work has been undertaken in the maritime sector to understand the vulnerabilities of GPS and the consequences of these vulnerabilities on service availability[139]. The results are repeated in the following table.

Threat	Risk	Consequences	Mitigation difficulty/cost
System failure	L	H	H
Power supply failure	H	H	L
Receiver/antenna failure	M	H	L
Onboard interference	M	M	L
External interference	L	H	M
Ionospheric	L	M	M
Jamming	L	H	M
Spoofing	L	H	H

H = High. High risk means likely to be encountered more than once a year. High consequence means complete loss of use of the system. High difficulty or cost of mitigation means it is unlikely to be achieved.

M = Medium. Medium risk means likely to be encountered less than once a year. Medium consequence means system still usable, but degraded. Medium difficulty or cost means achievable at significant cost.

L = Low. Low risk means unlikely to be encountered. Low difficulty or cost means mitigation should be achieved.

Table 18 – Maritime assessment of the vulnerability of GPS

The impact of loss of GPS depends on a number of factors, including the geographical area covered and the length of time of the outage:

139 "*GNSS Vulnerability*", European Maritime Radionavigation Forum Report, EMRF 12/7/1, 25 February 2003

- long outages over wide areas would be very severe from the safety, security, environmental and mostly economic perspectives because of the almost total reliance on GPS (unaugmented or augmented) for positioning, navigation and for the functioning of dependent systems, such as AIS. Although contingency systems, such as buoys and visual aids, are in widespread use, these systems are unlikely to be capable of supporting the volumes of traffic and types of operations (e.g. high speed ferries) that are now in place
- short outages over large areas would be severe but there would still be a large negative impact on safety, security, the environment and economics, due to increased risks of collision, grounding and the lack of availability of dependent systems
- long outages over small areas would have a large negative impact for that particular area. Specifically, traffic would be likely to avoid that area if possible
- short outages over confined areas, such as specific ships, can still have large negative impacts, as exemplified by the grounding of the Panamanian registered vessel Royal Majesty off the Massachusetts coast in 1995.

Although there is total reliance on GPS in the maritime sector, there is no formal assurance concerning the performance and continuity of the system other that the offer made by the US Administration to IMO and the subsequent recognition by IMO of GPS as an element of the WWRNS.

DGPS vulnerability

As an augmentation of GPS, the IALA DGPS system will suffer from the same intrinsic vulnerabilities affecting the core service. It will also suffer from additional vulnerabilities impacting on the augmentations alone. There has been little work done on these vulnerabilities but an initial, preliminary assessment is provided in Table 19.

Threat	Risk	Consequences	Mitigation difficulty/cost
DGPS System failure	M	L	M
Power supply failure	H	M	L
Receiver/antenna failure	M	M	L
Onboard interference	M	M	L
External interference	L	M	M
Jamming	L	M	M
Spoofing	L	H	H

H = High. High risk means likely to be encountered more than once a year. High consequence means complete loss of use of the system. High difficulty or cost of mitigation means it is unlikely to be achieved.

M = Medium. Medium risk means likely to be encountered less than once a year. Medium consequence means system still usable, but degraded. Medium difficulty or cost means achievable at significant cost.

L = Low. Low risk means unlikely to be encountered. Low difficulty or cost means mitigation should be achieved.

Table 19 – Maritime assessment of the vulnerability of DGPS

The major differences between a GPS outage and an outage of the augmentation system are:

- the latter only results in a loss of augmentation signals and the overall system could continue to function but with degraded performance

- the outage of the DGPS system would affect only a restricted area within the range of the beacon
- dual beacon coverage is available in most service areas, further mitigating the loss of a single beacon
- jamming would require much higher powers than for GPS because of the relatively high power received at the vessel and may only be effective for vessels at long ranges from the beacon being jammed.

However, spoofing could have a major consequence, albeit only affecting the vessels within the coverage area of the spoofed beacon.

The operational performance of the marine DGPS system is specified in IALA Recommendation R-121[140]. Frequency allocation of the stations is also coordinated by IALA[141] to ensure minimum inter-station interference. Although these are voluntary (minimum performance) standards, there is widespread adherence by the Member States of IALA and IMO. In addition, where States provide higher levels of service, these may be promulgated in individual navigation plans.

RACON vulnerability

RACONS are local, relatively high power systems and are, therefore, not subject to the same external interference risks as GPS. They would also not be subject to the same risks from spoofing, although it is possible that false RACONS could be deployed to lure vessels into dangerous areas in the same way that false lights have been used to draw ships onto rocks in the past. A preliminary estimate of the factors affecting the availability of RACONS is provided in the following table.

Threat	Risk	Consequences	Mitigation difficulty/cost
Transponder failure	M	L	M
Onboard radar failure	L	H	M
Onboard interference	L	L	M
External interference	L	L	M
Jamming	L	L	H
Spoofing	L	H	H
Clutter/multipath	M	L	M
Precipitation	H	L	H

H = High. High risk means likely to be encountered more than once a year. High consequence means complete loss of use of the system. High difficulty or cost of mitigation means it is unlikely to be achieved.

M = Medium. Medium risk means likely to be encountered less than once a year. Medium consequence means system still usable, but degraded. Medium difficulty or cost means achievable at significant cost.

L = Low. Low risk means unlikely to be encountered. Low difficulty or cost means mitigation should be achieved.

140 "Recommendation on the performance and monitoring of DGNSS services in the frequency band 283.5KHz – 325KHz", IALA Recommendation R-121, June 2001

141 "Information and guidance on allocation of identification numbers for Differential Global Navigation Satellite system (DGNSS) reference and transmitting stations in the maritime radionavigation (radiobeacon) band", IMO Circular SN/Circ.223, 6 November 2002

Table 20 – Preliminary assessment of the vulnerability of RACONS

RACONS currently operate at S-band (3GHz) and X-band (GHz) although there is debate about the future of the S-band capability. Although the probability of failure of an onboard radar is low, the availability of dual systems provides extra redundancy and robustness. The availability of the two frequencies can also be used to mitigate the negative impact of precipitation (rain, snow) on the performance of the X-band system alone.

One limitation on the performance of RACONS can be caused by sea clutter and/or multipath – where the radar performance is limited due to reflections from the sea surface. This depends on the relative geometry of the shipborne radar, the RACON and the sea conditions, particularly sea state. These effects can be and are mitigated through standard radar techniques such as side-lobe suppression.

The impact of the loss of a RACON, although not negligible, is likely to be relatively small as the RACON is most often mounted on another aid to navigation and only provides a service over a restricted area. However, the performance of the overall aids to navigation system will be degraded and the risk of groundings may be increased local to the particular RACON.

RACON operation is defined in IALA Recommendation R-101[142] and associated publications[143,144]. As with DGPS, these standards are voluntary but have been adopted very widely.

AIS vulnerability

AIS is much more broad than a radionavigation system and a full analysis of its vulnerabilities are far beyond the scope of the ERNP. However, it is important to note several points:

- AIS is totally dependent on GPS for position information and is, therefore, extremely vulnerable to GPS failures, be they intentional or unintentional
- AIS is largely dependent on GPS for the timing function within the self-organising time division multiple access (SoTDMA) system
- AIS communications are open and therefore vulnerable to introduction of false targets and extraction of information on all reporting vessels
- as a cooperative system in the security context, AIS suffers from the vulnerability of its owner being able to switch-off the transponder rendering the target invisible unless some autonomous system, such as primary radar, is used in conjunction.

Carrier phase DGPS

Currently carrier-phase DGPS is used to support some specialist maritime applications, including hydrography and special pilotage operations. Outages of this type of DGPS are commonplace, especially when the system is operated in real-time and resolution of position ambiguities is difficult. The robustness of the technique must be improved before it could be relied on totally to support critical applications.

Commercial services

Commercial services are not generally used for real-time safety critical applications. The performance provided is usually subject to a commercial agreement between the user and

142 "*Recommendation on marine radar beacons*", IALA Recommendation R-101, December 2000

143 "*Technical parameters for radar beacons*", ITU-R M.824-2

144 "*Radar beacons and transponders*", IMO Resolution A.615(15)

service provider. This performance is not regulated and the vulnerabilities of the systems are not known, other than they rely on GPS as the core system.

I.2.15.3 Service Charges

Services provided under the SOLAS Convention

The majority of the services described above are provided under States SOLAS Convention and other obligations, such as the VTMIS Directive. These services include the IALA DGPS service, RACONS and AIS. It is important to note that where costs are recovered, these are based on the bundled aids to navigation service (both radionavigation and traditional aids to navigation) – charges are not generally levied for services on an individual basis.

Cost recovery for the provision of these services is currently not wide spread. In the EU, only five States (Great Britain, Ireland, Sweden, Greece and Finland) currently undertake cost recovery on a significant level for their services. Two other States, Denmark and Germany, recover a small percentage of their costs through pilotage fees.

Charges are limited to commercial vessels, fishing vessels, pleasure craft and international shipping which uses the State port facilities. These charges are currently paid by vessels making a stop at a port within the State and therefore making use of port and harbour services. Usually, user charges are made for each port visit up to a certain limit per year. In certain circumstances (for example fishing vessels) annual charges are raised by invoice. Depending on the State, certain vessels are eligible for exemption, these include cruise vessels, State or military vessels and vessels under a certain specified tonnage

Article 26 of the United Nations Convention on the Law of the Sea (UNCLOS) is one of the major impediments to the implementation of a general cost recovery system for marine aids to navigation. This article makes it impossible for authorities to charge international shipping in transit. The history of this clause dates back to the Treaty of Denmark in 1857, which is still in force. This Treaty was imposed upon Denmark to prevent the hindering the passage of shipping by stretching a chain across the entrance to the Baltic, until a toll had been paid. The agreement gave ships un-hindered passage (‘*right of free passage*’) to and from the Baltic. Denmark is still prevented from recovering costs for its aids to navigation.

This principle of ‘ right of free passage’ was developed further with International shipping over the early decades of the 20th Century by developing the concept of ‘general’ and ‘specific’ services:

A ship’s master seeks ‘*specific services*' and having voluntarily made contact with the service provider, can be charged without an additional imposed disruption to the passage. Using the available '*general services*' creates no direct opportunity for charging, so the providers wishing to be paid would have to intercept the ship. General services, under this heading were considered as light fees and bouyage, whereas specific services would be, for example, pilotage. However this approach, which eventually became Article 26 of UNCLOS in the 1960s, was developed before the advent of radar or the more complex communication and navigation systems of today (such as Vessel Traffic Services(VTS)). There is now some level of confusion as to what could be considered general and specific services.

Cost recovery mechanisms: The ship’s master, or shipping agent in the port, is responsible for payment of the fees, which are usually collected by the harbour master or the customs official in the port concerned. The fee collected gives the ship the right of entry to all ports in the country of question during a specified period (usually one month) or for a specified number of port calls. The ships master is therefore required to carry a certificate of payment throughout that period and produce it to the harbour masters of any subsequent ports he may enter.

This system of fee collection by port dues was instituted because of the difficulty of collecting from the ship owner by means of invoicing. Many international ships are flagged-out and have complex chains of ownership. This makes the likelihood of retrospective cost recovery small, and offers the Ports Authority no way to recover the costs through normal legal processes.

Rate of Recovery: The rate of recovery of costs for provision of navigational services varies greatly amongst the different States. The following chart illustrates the degree of variance:

State	Approximate level of recovery	Comments
Finland	70%	
Denmark	4%	Charges for port approaches only
Greece	60%	
Ireland	75%	
UK	92%	
Sweden	84%	
Germany	3%	Small percentage of charges recovered as pilot dues

Table 21 – Examples of marine navigation cost recovery in EU States

Emergency services

Emergency services, such as those provided in support of GMDSS by COSPAS/SARSAT and Inmarsat, are provided free of charge to the user. The operation of these services is funded through national contributions to the organisations concerned. The contents of international treaty prohibit direct charges to the user for provision of these services.

Commercial services

Commercial services, such as those provided by Thales and Fugro, are charged on a commercial basis defined by contracts between the customer and the service provider.

I.3 Rail

I.3.1 Market Specific

I.3.1.1 Institutional Environment

Currently, the legal framework of the railway market in Europe is very well defined.

In order to revitalise the railway sector in Europe, the European Union has undertaken a variety of measures that have led to the current legislation of the Railway Market in Europe. This set of directives establishes the basic rules of railway systems in Europe and look for the creation of an integrated European railway area. These directives have to be transposed into national laws by all the member states, giving rise to national legislation in this matter.

First Railway Package and Rail Infrastructure Package

The first set of measures was called “first railway package” and it was presented in December 2000. This package led to three new directives which entered into force on 15 March 2001. The European Union Countries must have implemented this package by 15 March 2003.

These directives clarify the roles of all parties concerned, within a neutral, transparent framework:

- The railway undertakings are responsible for carriage,
- The independent infrastructure managers ensure equitable rights to access to the infrastructure,
- Regulatory bodies arbitrate to settle potential disputes,

These three directives were further improved in a new package called the “Rail Infrastructure Package” published in the Official Journal L75 on 15 March 2001. Member States must have implemented the provisions of these Directives in national legislation by 15 March 2003 at the latest.

Directive 2001/12/EC of the European Parliament and of the Council of 26 February 2001 amending Council Directive 91/440/EEC on the development of the Community's railways

The first piece of major legislation goes back to 1991 and the adoption of a directive by the Council of Ministers (91/440/EEC). It introduced a degree of liberalisation into certain areas of rail transport, above all prompting the railways to concentrate more on competitiveness.

The directive required Member States:

- to manage railway undertakings in such a way that they understand the need for competitiveness and sound financial management. Member States must thus, jointly with existing public railway operators, take steps to reduce the indebtedness of railway undertakings.
- to make railway undertakings independent by giving them a budget and an accounting system separate from those of the State.
- on specific terms, to guarantee rights of access for rail transport operators in other Member States to international combined transport services. The aim here was to open up the Community markets in these sectors. It also created the possibility to open the market for international freight and passenger services under certain conditions.
- to have separate accounting for railway infrastructure (track and related equipment) and the operation of transport services as such. The aim here was greater transparency in the use of public funds, but also the ability to better measure the actual performance of these two branches. It is with this requirement in mind that a number of Member States have in recent years set up bodies which manage the railway infrastructure but are separate from the railway companies, which continue to manage the carriage of passengers and freight.

Directive 2001/12 modified Directive 91/440 (consolidated version) on the development of the Community’s railways. It requested the Member States to adapt their national legislation to enable the extension of access rights for international freight transport services to the national sections of the Trans European Rail Freight Network (TERFN), which has a length of approximately 50.000 km. About 70-80% of the rail freight traffic is carried over the TERFN. As of 15 March 2008, the entire European Rail Network will be open to international freight services.

The Directive also provided that different organizational entities must be set up for transport operations and infrastructure management. Essential functions, such as rail capacity allocation, infrastructure charging and licensing will be separated from transport operations to enable new rail operators fair access to the rail market. This Directive also foresees that Railway Undertakings set up different account for passenger transport services and freight transport services.

Directive 2001/13/EC of the European Parliament and of the Council of 26 February 2001 amending Council Directive 95/18/EC on the licensing of railway undertakings

In 1995 the Council of Ministers adopted another directive (95/18/EC) which set common criteria for the licensing of railway undertakings established in the European Union. To obtain an operating licence the railway undertaking must meet a number of specific conditions (requirements in respect of good repute, financial standing and professional competence plus civil liability).

Directive 2001/13 amended directive 95/18 (consolidated version) on licensing of railway undertakings by defining the conditions under which companies could obtain a licence to run rail freight services over the TERFN. The Directive set the framework for the financial, economic and safety conditions to which railway undertakings must comply to obtain a licence. The licensing authority would issue licenses that would be notified to the Commission and that would be valid throughout the territory of the Community. The Commission would publish the licenses in the Official Journal. An operator does not only need a licence, but it would also require the attribution of capacity, so-called train paths, to effectively run trains on the network.

Directive 2001/14/EC of the European Parliament and of the Council of 26 February 2001 on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification. (In replacement of Council Directive 95/19/EC of 19 June 1995 on the allocation of railway infrastructure capacity and the charging of infrastructure fees)

The following rules were also laid down in 1995 on the allocation of railway infrastructure capacity (Directive 95/19/EC), which was replaced in 2001 by Directive 2001/14/EC. In essence, the Member States, meeting within the Council of Ministers, agreed a text stipulating who, and under what conditions, could use the rail network to move a train between two destinations at a given time. The professionals refer to this procedure as "path allocation".

This directive required Member States to create an organisation (Infrastructure manager) to allocate railway infrastructure capacity in a fair and non-discriminatory way. The infrastructure could only be used by railway undertakings which held an operating licence under Directive 95/18. This organisation could allow priority of passage to public services (mainly unprofitable passenger services), which continued to operate under the public service obligation.

The directive also laid down a number of guiding principles for the charging of fees for infrastructure use. Thus the body responsible for managing railway infrastructure must maintain a balance between income from fees and State contributions on one hand, and infrastructure spending on the other. Member States must also ensure that the prices charged are market prices, and must not charge fees which are unfair or discriminatory.

However, the directive does not cover railway undertakings whose activity is confined to urban, suburban and regional transport or the road vehicle shuttle service through the Channel Tunnel.

Interoperability Directives

In parallel to that and under the EC Treaty (Articles 154 and 155), the Community had the task of contributing to the establishment and development of trans-European networks in the area of transport. In order to achieve these objectives, the Community had to take the necessary measures to ensure the interoperability of the networks, particularly in the field of technical standardisation.

The Council took an initial measure in the rail sector on 23 July 1996 when it adopted Directive 96/48/EC on the interoperability of the trans-European high-speed rail system.

Council Directive 96/48/EC of 23 July 1996 on the interoperability of the trans-European high-speed rail system

In order to achieve the objectives of that directive, technical specifications for interoperability (TSIs) are drawn up by the European Association for Railway Interoperability (AEIF), which acts as the joint representative body defined in the directive, bringing together representatives of the infrastructure managers, railway companies and industry.

A number of tools and methodologies had to be developed in order to prepare the TSIs. Pending the adoption of TSIs, and in order to guide the technical choices made in the projects in progress in several Member States, the Commission adopted two instruments:

- 2001/260/EC: Commission Decision of 21 March 2001 on the basic parameters of the command-control and signalling subsystem of the trans-European high-speed rail system referred to as "ERTMS characteristics" in Annex II(3) to Directive 96/48/EC (Text with EEA relevance).
- Commission Recommendation of 21 March 2001 on the basic parameters of the trans-European high-speed rail system referred to in Article 5(3)(b) of Directive 96/48/EC (Text with EEA relevance) (notified under document number C(2001) 745).

A programme to develop the corresponding European standards was launched in 1998 and it is regularly updated to reflect the work on TSIs.

The vast majority of Member States have prepared national measures transposing the directive into national law, as well as the independent bodies responsible for assessing the conformity and/or suitability for use of the interoperability constituents and for EC verification of subsystems.

The Commission made considerable efforts to adopt a decision on the TSIs at the beginning of 2002 in order to ensure that, from 2002 onwards, new high-speed lines and upgraded lines could be built to the new interoperable standard.

The texts of the TSIs (Technical Specifications for Interoperability) were published in the Official Journal L245 of 12 September 2002. The TSIs adopted for the 6 subsystems considered are:

- 2002/730/EC, Commission Decision of 30 May 2002 concerning the technical specification for interoperability relating to the maintenance subsystem of the trans-European high-speed rail system referred to in Article 6(1) of Directive 96/48/EC (Notified under document number C (2002) 1946).
- 2002/731/EC, Commission Decision of 30 May 2002 concerning the technical specification for interoperability relating to the control-command and signaling subsystem of the trans-European high-speed rail system referred to in Article 6(1) of Council Directive 96/48/EC (notified under document number C(2002) 1947).
- 2002/732/EC, Commission Decision of 30 May 2002 concerning the technical specification for interoperability relating to the infrastructure subsystem of the trans-European high-speed rail system referred to in Article 6(1) of Council Directive 96/48/EC (notified under document number C(2002) 1948).

- 2002/733/EC, Commission Decision of 30 May 2002 concerning the technical specification for interoperability relating to the energy subsystem of the trans-European high-speed rail system referred to in Article 6(1) of Directive 96/48/EC (notified under document number C(2002) 1949).
- 2002/734/EC, Commission Decision of 30 May 2002 concerning the technical specification for interoperability relating to the operation subsystem of the trans-European high-speed rail system referred to in Article 6(1) of Council Directive 96/48/EC (notified under document number C(2002) 1951).
- 2002/735/EC, Commission Decision of 30 May 2002 concerning the technical specification for interoperability relating to the rolling stock subsystem of the trans-European high-speed rail system referred to in Article 6(1) of Directive 96/48/EC (notified under document number C (2002) 1952).

Directive 2001/16/EC of the European Parliament and of the Council of 19 March 2001 on the interoperability of the trans-European conventional rail system

Directive 2001/16/EC on the interoperability of the conventional rail system adopted on 19 March 2001, similarly to the high-speed directive, introduced Community procedures for the preparation and adoption of TSIs and common rules for assessing conformity to these specifications.

The directive required a first group of priority TSIs to be adopted within three years, i.e. in 2004, in the following areas: control/command and signalling; telematic applications for freight services; traffic operation and management (including staff qualifications for cross-border services); freight wagons; and noise problems deriving from rolling stock and infrastructure.

Directive 2001/16/EC had to be implemented in the Member States by 20 April 2003 at the latest. Until now, the Commission has only received notifications from Denmark and Finland. The Commission has started infringement procedures for non-communication of the implementation measures against 13 out of the 15 Member States

The Second Rail Package

Based on the White Paper on transport, on 23 January 2002 the European Commission proposed a new package (“second package”) of measures to revitalise the railways, entitled “Towards an integrated European Railway area”. These measures are designed to stop the railways losing market share and aim at greater safety, interoperability and opening of the rail freight market. To give strong impetus to this process, the Commission also proposed establishing a European Railway Agency to steer the technical work on safety and interoperability.

The “second package” proposes five actions for legislation to make rapid progress towards an integrated European Railway Area. These five actions are now in the proposal phase and they are expected to become new European Directives:

- Proposal for a Directive of the European Parliament and of the Council on safety on the Community's railways and amending Council Directive 95/18/EC on the licensing of railway undertakings and Directive 2001/14/EC on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification (COM (2002) 21 final — 2002/0022(COD)). Published in the Official Journal, C126E, 28 May 2002, p. 332.
- Proposal for a safety directive. Developing a common approach to rail safety. This clarifies responsibilities by developing common safety methods, targets and indicators to apply in every European Union country. Mutually recognised safety certificates

must give access to the network. Transparent information on safety must be made public.

- Amendment of the Interoperability Directives (COM (2002) 22): Published in the Official Journal, C126E, 28 May 2002, p. 312. Proposal amending the existing directives for interoperability: (Directives 96/48 and 2001/16)
- Regulation on the European Agency (COM (2002) 23), Published in the Official Journal, C126E, 28 May 2002, p. 323: Proposal for Regulation: Setting up an effective steering body: the European Railway Agency.
- Amendment of Directive 91/440 (COM (2002) 25), Published in the Official Journal, C291E, 26 November 2002, p. 1. Proposal amending Directive 91/440 on opening of the market, as amended by directive 2001/12. Extending and speeding up opening of the rail freight market.
- Recommendation on the COTIF (COM (2002) 24). Recommendation for a Council decision. Joining the Intergovernmental Organisation for International Carriage by Rail.

National Regulations

These European Directives have to be transposed into National Law for the Railway System in each Member State and they should have entered into force before the above-mentioned dates.

Apart from that, other national legislation may exist in different countries, covering regulation, organisation and safety issues, namely Safety Management Plans. They shall be compliant in any case with the European Directives.

I.3.1.2 Application Summary

Radio Navigation systems can be applied in a great variety of applications in the railways. The use of this kind of systems in the rail domain (mainly GNSS systems) is experimenting an important growth in these last years. Radio Navigation systems for railways are suitable for many of the applications but most of the time complemented with other systems due to demanding performances required by rail in terms of accuracy, availability and safety.

The applications to be served can be divided in two main types: safety-related and not safety-related applications. Currently, the situation is that Radio Navigation systems (basically GNSS) are used combined or alone in non-safety applications while for safety related applications the use of these systems has to overcome the natural reluctance of railway undertakings to introduce new technology when safety is concerned.

Application	Current Status	Critical		
	Existing	Radionav	Safety	Mission
Automatic Train Control and Protection (Signaling)	Yes	No	Yes	Yes
Level Crossing Protection	Yes	No	Yes	Yes
Track-side personnel Protection	Yes	No (tbc)	Yes	No
Management of emergencies	Yes	No (tbc)	Yes	No
Passenger Information	Yes	Yes	No	Yes

Tracing and tracking of vehicles (Fleet management)	Yes	Yes	No	Yes
Cargo Monitoring	Yes	Yes	No	Yes
Supervision of train tilting	Yes	Yes	No	Yes
Traffic Management Systems (Dispatching)	Yes	No	No	Yes
Infrastructure survey	Yes	Yes	No	No

Table 22 - Rail application summary

I.3.2 Automatic Train Control and Protection

I.3.2.1 Overview

The objective of a train protection application is, in the event of driver error, to prevent a train proceeding beyond the point of danger, and to prevent the speed of the train exceeding the permissible limit. This is a safety-related application. It consist on the safe determination of position, speed and direction of train movement in order to supervise the safe movement of the train up to its stopping point (End of Movement Authority). This application requires the combination of several functions (or lower level applications) which in turn are strongly dependent of the accurate and safe determination of position and speed of the trains:

- Calculation of End of Movement Authority: The End of Movement Authority is normally a main-signal showing “danger” at the rear of the preceding train or any location where the train speed should equal zero. For the end of movement authority, the required train speed profile is then calculated backwards against the direction of the train. This function requires demanding accuracy and integrity requirements.

- Train location: The determination of position, speed and movement direction of the train in its route. This function is currently performed by a combination of sensors and devices both on-board and installed in the infrastructure. Usually the position of the train is calculated as longitudinal distance travelled from a reference point (for example in ETCS). A safety margin is usually included to account for the errors inherent to the position determination by any means. Improving accuracy of the odometry will lead to the reduction of safety margins and thus to improve the capacity of the lines.

- Speed profile calculation: The calculation by the trainborne equipment of the speed profile based on the infrastructure data (end of movement authority) and Train Location.

- Train integrity and train length monitoring: A train integrity system shall ensure that the train is complete before transmitting its location. This function is sometimes performed by the ATP system or by external systems (interlocking) complementing the ATP.

- Train separation: This application is intended to maintain the distance between two trains where this function is not provided by interlocking or blocking systems. Behind the first train, a safety margin must be calculated which respects transmission time, deceleration rate of the train and train position error. The control centre that guarantees the train separation must know the speed, location, direction and identity of each train in its controlling area.

There are several ATP/ATC systems working in Europe in different countries. These are usually proprietary systems which impede interoperability between different countries equipped with different systems. To account for this situation, a new standard for ATP systems has been developed in Europe, called ETCS (included in ERTMS). ETCS principles are similar to other ATP systems and Train Location (and rest of functions described above) are vital functions inside ETCS. Train Location functions are currently performed by a combination of onboard sensors plus spot transmission systems located on the track serving as reference point and calibration of errors. With this kind of systems, the current safety levels required by this application are met.

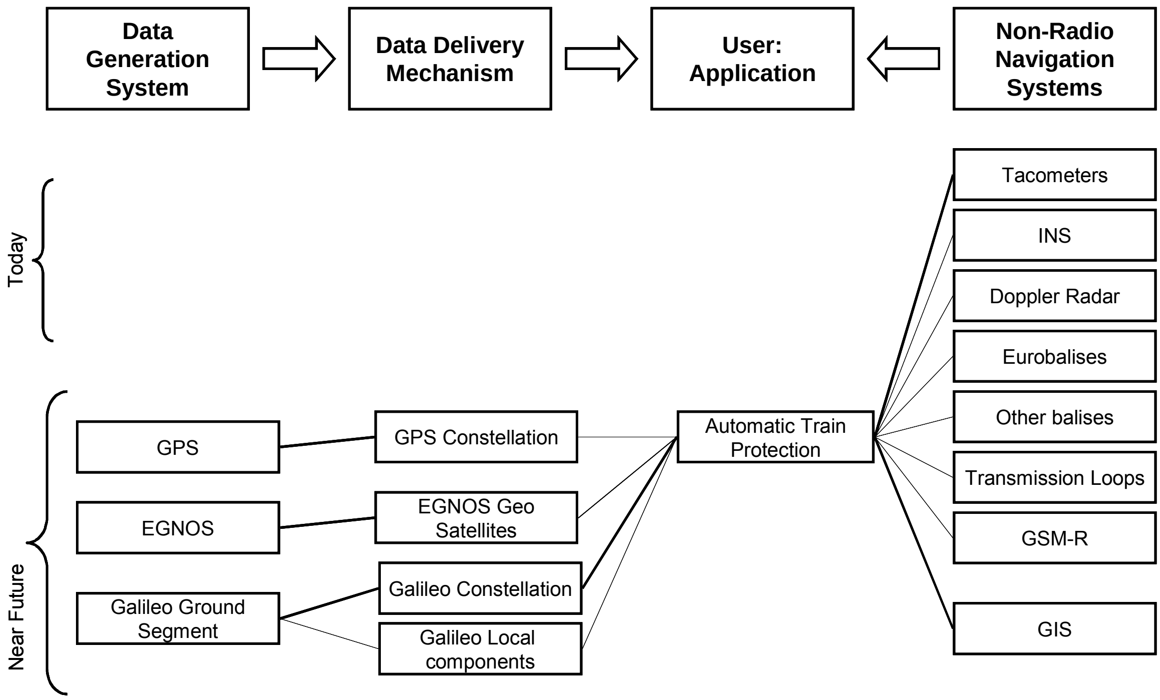
The requirements of an ATP application are for Location, Speed, Time and Direction.

Radio Navigation systems are not currently used for this kind of application. The management of safety during periods of technological change requires careful attention. First, the reasons for the change have to be identified. These are then analysed for their potential to influence the safety of the railway operations. The intended change must not go ahead unless it can be demonstrated that the railway is at least as safe after the change as it was before. Therefore, it has to be demonstrated that the safety levels required in railways can be met with RN systems. GPS or Network-based systems do not provide integrity information. This problem is currently being solved with the appearance of EGNOS and GALILEO systems. Several pilot projects nowadays in Europe are studying (from a theoretical point of view) the implementation of GNSS Navigation in ERTMS/ETCS.

This application is also mission critical, as the operation of the system strongly depends on the dependability of the location data.

I.3.2.2 Service Delivery

Service Delivery Diagram



Navigation performances required

Automatic Train Control and Protection (Signaling)	Accuracy	Availability	Integrity	Coverage	Continuity	Fix Rate

Location	Near singularities (switches, crossings, etc.)	± 1 m	>99.98%	Alert limit: 2.5 m TTA: 1s	All line	>99.98%	1 s
	Plain line (low traffic line)	± 25 m	>99.98%	Alert limit: 50 m TTA: 1s	All line	>99.98%	
	Plain line (conventional and high speed)	± 10 m	>99.98%	Alert limit: 20 m TTA: 1s	All line	>99.98%	
	Across track	± 1 m	>99.98%	Alert limit: 2.5 m TTA: 1s	All line	>99.98%	
Speed	Near singularities (switches, crossings, etc.)	±(0.5m/s 2 + 1%			All line	>99.98%	
	Plain line (low traffic line)	±(0.5m/s 2 + 3%					

I.3.2.3 Application environment

ATP needs for coverage are concentrated in rail lines and their neighbourhood (control centres, for example). In this sense, lines extend over entire regions and countries and in virtue of new interoperability directives and High Speed European corridors, need for coverage will extend for one country to another in Europe.

Lack of coverage and continuity in the railway environment (tunnels, bridges, stations) requires that RN systems were complemented by other systems (local elements or on-board sensors, for example).

Communications

Communications are essential in ATP systems as there is an intrinsic need of communicating information between the trackside part of the systems and the on-board part. Basically, the train sends to the trackside subsystem its position and speed and the trackside subsystem calculates the route of the train taking into account the position of all the trains under its control (the case of ETCS).

Short range, point-to-point, communication media (spot transmission system) are usually used for this application like, for instance, the Eurobalise in ETCS.

In the recent years, and in parallel with the development of the ETCS standards, a new standard for communication in railways has been adopted: the GSM-R standard. GSM-R radio communication is based in conventional GSM but with a dedicated frequency band, special requirements (able to work at high speed up to 500 km/h, high quality of service parameters) the adoption of railway specific services. GSM-R standard guarantees the performances required for this safety-related application. Safety is preserved by means of an additional layer in the communication architecture. This layer provides the required integrity data and data verification, both for the messages and the entities communicating.

The communication layer provides the required reliability in the information transportation.

Overview of receivers and applications products

A radio-navigation receiver will be a part of the whole location function for the train (a part of the train location equipment). Most of ATP systems are non-standardised proprietary systems; therefore, there is not need for certification of these products against systems specifications.

However, these products have still to comply with European EMC, RAMS normative, on-board equipment normative (CENELEC, ETSI), etc. There also exists national regulation for electronic equipment to be installed on-board the train.

In case of ETCS system, as it is a European standard for interoperability, components of this subsystem (on-board equipment, balises, etc.) have to be certified against these standards. In the ETCS approach, location equipment is part of the on-board subsystem (it is just a function inside the On-board equipment) so that it does not need to be certified in this sense, unless the introduction of radio-navigation systems for location could affect interoperability. In this case it should be included as another component of the standard and require certification for use.

The cost of an ATP (ETCS) on-board equipment is currently around 155.000 €. That will limit the cost of a location equipment to around 1/8 of the total price and so the price of a RN receiver as a part of it.

I.3.2.4 Service Availability

GNSS (or other radio-navigation systems) are not used nowadays for ATP application for the reasons given above. In case of use of GNSS in the future, the type of service to be used shall guarantee the service in any case. A service disruption will not lead to an accident as these systems are designed in a fail-safe philosophy, that is, in case of system failure, the train stops.

Therefore, location service disruption has a tremendous impact on exploitation and operation of railway lines. Fallback systems could be used to avoid this situation, but then the economical and operational benefits of using GNSS as main system should be carefully justified.

Fallback systems would probably be used in any case, due to safety reasons (need of redundancy). However, if GNSS is the main system, fall-back systems (on-board sensors, etc.) could not maintain the same level of performances as main system for a long period and so, normal operation of the line will also be affected. Back-up measures to operate the line should be adopted (speed restrictions, etc.).

Fallback and redundant systems can cope with a few seconds or minutes' disruption in service without the operation of the line being affected. Short-term and long-term service disruption will lead to consequences explained before, that is operation of the line in a degraded mode, with the economical impact it implies.

The philosophy for the rest of the systems forming this application is the same, that is, safety is guaranteed because trains are stopped but performance of the line is affected. Systems or subsystems used in this application are not usually based in external services.

In a future context, the use of GNSS for these applications, as safety-of-life application should be regulated at an institutional level (Government, Railway Undertakings, Railway Regulators).

Threat	*Risk*	*Consequences*	*Mitigation difficulty/cost*

System failure	*L*	*H*	*H*
Location function failure	*L*	*H*	*H*
Receiver/antenna failure	*M*	*M*	*L*
Onboard Interference	*L*	*H*	*M*
External Interference	*L*	*H*	*M*
Ionospheric	*L*	*M*	*M*
Jamming	*L*	*H*	*M*
Spoofing	*L*	*H*	*H*

I.3.2.5 Service Charges

Positioning services are not currently used for this application. In a future context, GNSS safety-of-life services are needed in order to guarantee service and performances. The use of safety-of-life services and the charges should be decided and implemented.

GSM-R is a private network that railway undertakings own and operate it. This is an internal service.

I.3.3 Level Crossing Protection

I.3.3.1 Overview

Some railways require trains to stop or reduce speed when approaching level crossing if the protection equipment is defective. Level crossings shall not be free for use by road traffic and pedestrians if there is unacceptable uncertainty about the position and speed of approaching trains. In this case trains may be required to slow or stop.

The protection systems of the level crossing need also the location information of a train approaching the level crossing. Besides, information about the location, identification, status and other conditions concerning the level crossing must be transmitted to trains.

This application is also safety critical and mission critical as the system failure can lead to an accident or interruption in train services

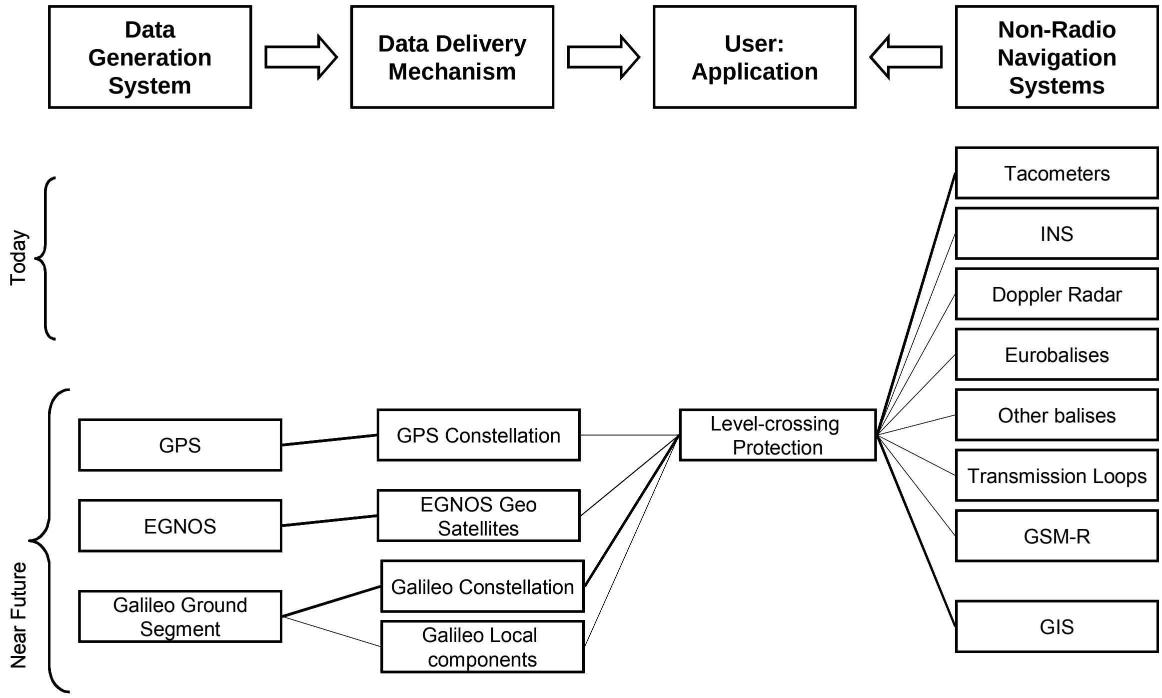
No RN systems are currently in use for this application for the same reasons exposed before. There exist also some pilot projects in Europe studying the implementation of GNSS for this application.

Traditional location systems in railway, trackside-based, as track circuits or axle counters are use to detect the presence of the train in the neighbourhood of the level crossing.

The requirements of this application are for Location, Speed and Direction.

I.3.3.2 Service Delivery

Service Delivery Diagram



Navigation Performances Required

Level Crossing Protection	**Accuracy**	**Availability**	**Integrity**	**Coverage**	**Continuity**	**Fix Rate**
Location (Along track)	25 m	> 99.98%	Alert limit: 50 m TTA: 7s	Level crossing vicinity	99.98%	1 s
Speed	< 2Km/h	N/A	N/A	N/A	N/A	N/A

I.3.3.3 Application environment

In general, for all the railway applications, needs for coverage are concentrated in lines and its neighbourhood (control centres, for example).

In this particular case, integrity, coverage, continuity and availability shall be guaranteed in the surroundings of a level crossing within an interval along the line of about 2 Km (that is, 2 Km after and before the level-crossing).

Lack of coverage and continuity could be overcome by means of additional systems (complementary track-based systems or local elements, for example).

Communications

In most of the railway applications, the communication between trackside and on-board parts of the systems is essential. In this case, as for the ATP application, train position has to be communicated to the trackside level-crossing protection system in a safe manner.

Train position can be determined by means of a RN systems (plus complementary systems), sent to the control centre and then back to the level-crossing, or alternatively, train position is sent directly to the level crossing.

Nowadays, current positioning systems send information to the level-crossing through conventional dedicated twisted-pair communications.

Radio communications could be also used as long as safety and reliability is preserved, so that dedicated radio networks are indicated for this case. GSM-R is a good candidate for transmission of safety related information (nor only ATP) in railway.

Overview of receivers and applications products

A typical configuration of a product for this kind of application would be an on-board location equipment (formed by a RN receiver plus complementary systems), a communication system for transmitting position to the control centre or to the level-crossing.

For safety related applications, the trend in railway is to have dedicated systems owned and operated by the railway authorities instead of a services provided by an external operator, unless required performances and guarantee of service is achieved. This situation is about to be solved by new systems like EGNOS and future GALILEO, which seem indeed suitable for this kind of applications.

As before, both on-board and trackside equipment have to comply with European and national EMC and RAMS normative, or other environmental specifications (CENELEC, ETSI), etc. There also exists national regulation for electronic equipment to be installed on-board the train.

There is not any standard specification for this kind of products in Europe.

Cost of current positioning systems used for this application, installed in the tracks, ranges from 5.000 – 8.000 € per unit depending on the technology used. More than one unit is used for one level-crossing (two or more) plus the installation costs.

I.3.3.4 Service Availability

GNSS (or other radio-navigation systems) are not used nowadays for this application for the reasons given above. In case of use of GNSS in the future, type of location service to be used shall guarantee the service in any case. A service disruption will not lead to an accident as this kind of systems are design in a fail-safe philosophy, that is, in case of system failure, the train decreases the speed or stops and the level-crossing is closed for road traffic and other users, therefore affecting the normal operation of the line and of the crossing road.

Therefore, location service disruption has also a big impact on exploitation and operation of railway lines where level-crossing exists. Fall-back systems could be used to avoid this situation, but then the economical and operational benefits of using GNSS as main system should be carefully justified.

Fall-back systems (track-based detection systems, etc.) would probably be used in any case, due to safety reasons (need of redundancy) and are able to maintain the required level of performances needed for a normal operation of the line. Therefore, the use of GNSS-based location will be only justified for economical reasons, for example, use of on-board equipment instead of track-based equipment, more difficult to install and maintain.

The effect of intermittent, short term or long term service disruption is the same, as fall-back and redundant systems can cope with all this situations in the same way. In case fall-back methods will not be used, the line will be operated in a degraded mode with the economical impact it implies.

The philosophy for the rest of the systems forming this application is the same, that is, safety is guaranteed because trains are stopped in case of system failure. Systems or subsystems used in this application are not usually based in external services.In a future context, the use of GNSS for these applications, as safety-of-life is implicated, should be regulated at an institutional level (Government, Railway Undertakings, Railway Regulators).

Threat	***Risk***	***Consequences***	***Mitigation difficulty/cost***
System failure	*L*	*H*	*H*
Location function failure	*L*	*H*	*H*
Communications failure	*L*	*H*	*M*
Receiver/antenna failure	*M*	*M*	*L*
Onboard Interference	*L*	*H*	*M*
External Interference	*L*	*H*	*M*
Ionospheric	*L*	*M*	*M*
Jamming	*L*	*H*	*M*
Spoofing	*L*	*H*	*H*

I.3.3.5 Service Charges

There are not currently neither radio navigation services nor other kind of services in use for this application. GNSS safety-of-life services are needed in order to guarantee service and performances. GNSS safety-of-life services charges will be defined.

I.3.4 Track-side Personnel Protection

I.3.4.1 Overview

Personnel working on or close to the track must be protected from trains using the track or adjacent tracks. Speed restrictions may apply or the train may be prevented from entering the work zone completely. Alternatively, personnel working must be warned when a train is approaching the working area.

Therefore, personnel position shall be determined and communicated to the train control centre so that temporal speed restrictions can be issued and train position along the track can also be determined in order to warn people working in the track. Reliable and safe communications are as important as positioning information in this kind of application.

RN systems are not currently used for this application, as the required performances (coverage, continuity, reliability, etc.) are not met by current navigation systems. GNSS could be used as main system complemented by additional systems (redundancy) as well as a fall-back system.

Currently, for location of the working team, manual or semiautomatic procedures are used to prevent accidents in these circumstances; for example, track section is artificially occupied by shunting it with a special bar.

Train positioning when arriving to the working zone is determined by traditional methods when they exist, but it is rarely communicated to the workers.

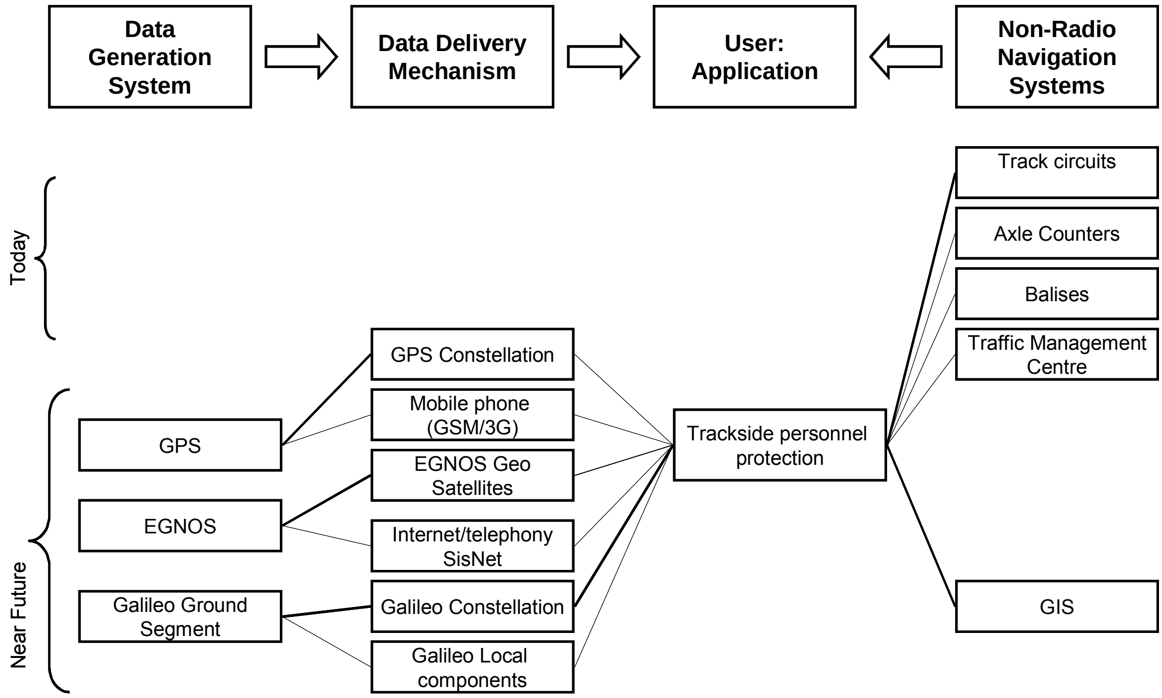
Therefore, any new system (RN systems, for example) will improve this situation at least as a complementary or supporting system (a source of information). That is, position of the working team as determined by the RN system will not be used to issue temporary speed restrictions for the train automatically, but only for information purposes.

This is considered also a safety application as the system failure can lead to an accident. It is also a mission critical application.

The requirements of this application are for Location, Speed and Direction.

I.3.4.2 Service Delivery

Service Delivery Diagram



Navigation Performances Required

Track-side Personnel Protection	Accuracy	Availability	Integrity	Coverage	Continuity
Location	±500m.	99.98%	Alert limit: 2.5x the precision required. Time to alarm = 1sec.	All line	TBD

I.3.4.3 Application environment

For location of trains, as in the previous case, the need for coverage and continuity are for the whole line and its neighbourhood.

For location of mobile workers, coverage, continuity and availability shall be guaranteed in the surroundings of the working zone (protected zone). This requirement concerns the whole line, as works can be done in any location of the line.

In zones without radio or navigation coverage (inside tunnels, closed stations) navigation shall be assured by other means.

Communications

As explained before, reliable communications are essential for this application.

Dedicated private-owned radio-communication systems are currently used for this kind of application.

Public communications are only used for informative purposes.

Again, GSM-R offers good reliability and other performances for this kind of application.

- Overview of receivers and applications products

A typical configuration of a product for this kind of application would be an on-board location equipment (formed by a RN receiver plus complementary systems), a communication system for transmitting train position to the control centre, or alternatively a location service.

For the working team, the mobile equipment combining positioning and communications will the product to be developed.

Current location services are only suitable for information and supporting purposes (not for automatic issuing of speed restrictions for the train). However, the use of these services will mean an improvement.

As before, both on-board and trackside equipment have to comply with European and national EMC and RAMS normative, or other environmental specifications (CENELEC, ETSI), etc. There also exists national regulation for electronic equipment to be installed on-board the train.

There is not any standard specification for this kind of products in Europe.

Portability and low cost will be the drivers for the mobile equipment to be used by workers.

I.3.4.4 Service Availability

GNSS (or other radio-navigation systems) are not used nowadays for this application for the reasons given above. In case of use of GNSS in the future, the type of location service to be used shall guarantee the service in any case.

For the case of locating the workers, a service disruption will not lead to an accident as this kind of systems shall be designed in a fail-safe philosophy, that is, in case of system failure, the train would decrease the speed or stop when approaching the working zone, as it does nowadays, therefore affecting the normal operation of the line.

Therefore, location service disruption has also an impact on exploitation and operation of railway lines.

In the present situation, fall-back systems are rarely used so that lines are usually operated in a degraded mode when works are being carried out. That is why the use of radio-navigation system will improve the current situation, even if service disruption may exist.

Anyway, if GNSS is used for this application and no fall-back systems exists (but only manual procedures) the service should be guaranteed.

The effect of intermittent, short term or long term service disruption is the same, as fall-back and redundant systems do not exist and the line will be operated in a degraded mode with the economical impact it implies.

In a future context, the use of GNSS for these applications, as safety-of-life is involved, should be regulated at an institutional level (Government, Railway Undertakings, Railway Regulators).

Threat	*Risk*	*Consequences*	*Mitigation difficulty/cost*
System failure	*L*	*H*	*H*
Location function failure	*L*	*H*	*H*
Communications failure	*M*	*H*	*M*
Receiver/antenna failure	*M*	*M*	*L*
Onboard Interference	*N/A*	*N/A*	*N/A*
External Interference	*L*	*H*	*M*
Ionospheric	*L*	*M*	*M*
Jamming	*L*	*H*	*M*
Spoofing	*L*	*H*	*H*

I.3.4.5 Service Charges

Positioning services are not currently used for this application. GNSS safety-of-life services are needed in order to guarantee service and performances.

I.3.5 Management of emergencies

I.3.5.1 Overview

The management of emergencies can be greatly improved if an accurate, continuous location of the train is available, allowing the emergency teams to optimise their operations.

In the event of an accident, it is important to know the location of the train in the line, so that rescue teams can reach the place of the accident. For this kind of application the geographical position of the train shall be provided and it shall be expressed in co-ordinates understandable to railway personnel and the emergency services, which normally use different coordinate systems.

Location of the rescue team could be also convenient, to optimise the trajectory to be followed by the rescue team to the place of the accident.

In the current situation, train positioning is determined by conventional methods (interlocking systems, track circuits) when they are available. Many Low Density Lines have not got any of these positioning systems, and train position is undetermined between two stations. That is a drawback for the emergency rescue teams.

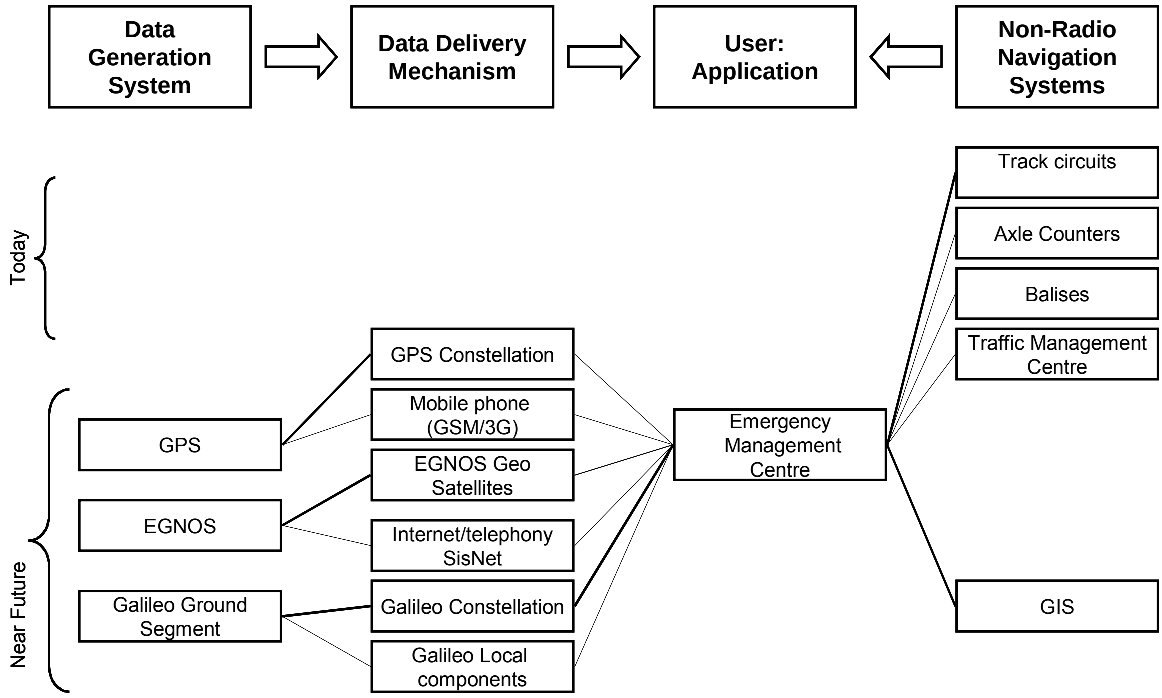
The requirements of this application are for Location, Time and Direction.

This application is not considered mission critical. It cannot be considered strictly a safety application, although accuracy and dependability of the information can have an influence in the final number of casualties in an accident.

As in the previous case, this application is also strongly dependent on communications availability and reliability as the position of the train need to be transmitted immediately to the rescue services centre.

I.3.5.2 Service Delivery

Service Delivery Diagram



Navigation Performances required

Management of emergencies	Accuracy	Availability	Integrity	Coverage	Continuity
Location	±500m.	99.98%	Not required	All line	TBD

I.3.5.3 Application environment

For location of trains, as in the previous case, the need for coverage and continuity are for the whole line and its neighbourhood.

In zones without radio or navigation coverage (inside tunnels, closed stations) navigation and communications should be assured by other means.

Communications

Reliable mobile communications are essential for this application.

Dedicated private-owned radio-communication systems are currently used for this kind of application.

Public communications are only used for informative purposes when coverage is possible.

Again, GSM-R offers good reliability and other performances for this kind of application.

- Overview of receivers and applications products

A typical configuration of a product for this kind of application would be an on-board location equipment (formed by a RN receiver plus complementary systems), a communication system for transmitting train position to the control centre, or alternatively a location service.

For the rescue team, mobile equipment for communications (including location, but not mandatory) will be the product to be developed.

As before, on-board equipment has to comply with European and national EMC and RAMS normative or other environmental specifications (CENELEC, ETSI), etc. There also exists national regulation for electronic equipment to be installed on-board the train.

Current radio-navigation services (GNSS) are suitable for this application for information purposes. Although continuity of service and availability of the information are not guaranteed by current RN systems, the lack of any kind of information in many of the current low density lines means that the use of this systems is certainly an improvement.

There is not any standard specification for this kind of products in Europe.

Portability and low cost will be the drivers for the mobile equipment to be used by the rescue team.

I.3.5.4 Service Availability

GNSS (or other radio-navigation systems) are not used nowadays for this application. In lines equipped with traditional location systems (track-based) the position of the train is already monitored but in many low density lines this kind of systems does not exist and it is not possible to know the position of a train (in the event of an accident) between two adjacent stations. That is why the use of radio-navigation system will improve the current situation, even if service disruption may exist.

In case of use of GNSS in the future, the type of location service to be used shall guarantee the service in any case as fall-back systems may not exist and effectiveness of location of trains will lead to effectiveness in solving the incidents. Thus, guarantee of service has not only an impact in human lives but also in the operation of the line.

A short term or long term service disruption can have a strong impact in the effectiveness of the rescue team work, so that human lives can be in danger. Intermittent service disruption will not have a major impact.

In a future context, the use of GNSS for these applications, as safety-of-life is indirectly involved, should be regulated at an institutional level (Government, Railway Undertakings, Railway Regulators).

Threat	***Risk***	***Consequences***	***Mitigation difficulty/cost***
System failure	*L*	*H*	*H*
Location function failure	*L*	*H*	*H*
Communications failure	*M*	*H*	*M*
Receiver/antenna failure	*M*	*M*	*L*
Onboard Interference	*L*	*H*	*M*
External Interference	*L*	*H*	*M*
Ionospheric	*L*	*M*	*M*
Jamming	*L*	*H*	*M*
Spoofing	*L*	*H*	*H*

I.3.5.5 Service Charges

Positioning services are not currently used for this application. GNSS safety-of-life services are needed in order to guarantee service and performances.

I.3.6 Traffic Management Systems (Dispatching)

I.3.6.1 Overview

The objective of this application is to improve the regulation of traffic based of the accurate, real-time information of the positions of the trains in the controlled area. Railway traffic managers control the movement of trains by making judgements of the position and speed of the trains, and anticipation of their future performance. Comparison of predicted and actual performance can be used to pre-empt future difficulties. Adequate management of traffic (accurate positioning and real time communications) can improve train headway and thus increase the capacity of the line. This kind of systems will be also very useful in determining and allocating responsibilities when a failure of a train of a infrastructure subsystem occurs, thus affecting the rest of the services.

That last item implies strong requirements in terms of accuracy and integrity of the information received.

The requirements are for Location, Time, Speed and Direction.

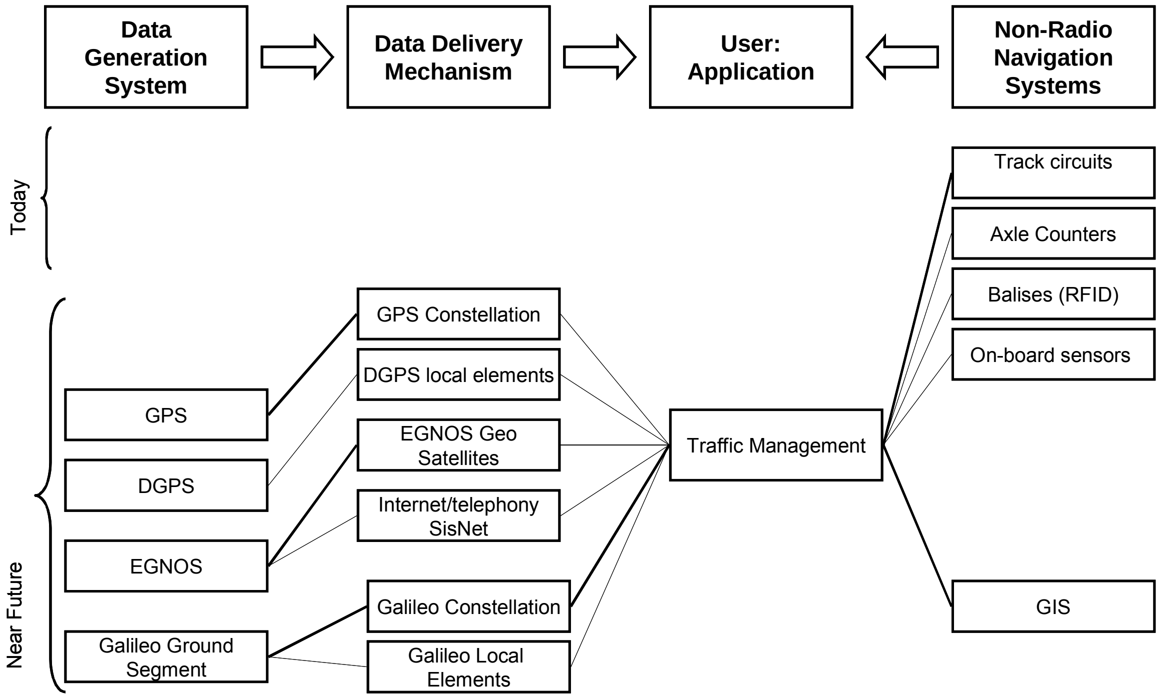
This is a non-safety critical application and safety relies on signalling and ATP, not in the traffic management layer. It is a mission critical application because failure of interruption in service can provoke the interruption in operation of trains.

RN systems are not currently in use in Europe for this kind of applications because of the strong requirements in availability, service guarantee and even integrity.

Integrity here is not related to safety, but on confidence (truth) in the information, needed when assigning responsibilities to each party.

I.3.6.2 Service Delivery

Service Delivery Diagram



Navigation Performances Required

Traffic Management Systems	**Accuracy**	**Availability**	**Integrity**	**Coverage**	**Continuity**
Location	± 50m.	99.9%	TBD	All line	TBD

I.3.6.3 Application environment

For this application, the need for coverage and continuity are for the whole line and its neighbourhood, extending also into stations and terminals. Need of information of train position can extend from one line to another and thus from one region to another and even from one country to another in virtue of new trans-European corridors to be created.

In case of intermodal traffic, need for coverage can extend also to wider regions to cover other modes of transport.

Lack of coverage due to the special railway environment is important for this application, as accuracy, continuity and availability of positioning information is rather restrictive. Therefore, complementary systems or local elements shall be used.

Communications

Communications are also essential for this application. Position of trains anywhere in its route shall be communicated to the traffic control centre in real time. The update frequency of the information would depend on the final implementation of the application.

The requirements for real time, reliability and availability of communications are very high.

Several possibilities for the communications can be used nowadays depending of the location technology used and other factors:

- Dedicated private-owned fixed communication for transmitting train location to management centre, in case of track-based location and identification systems.
- Dedicated private-owned radio communications for transmitting information of the train location to the management centre.

In this case, public communications do not offer the performance requirements needed unless special agreements between communication operators and Railway Undertakings ensure the required performances.

Overview of receivers and applications products

A typical configuration of a product for this kind of application would be on-board location equipment (formed by a RN receiver plus complementary systems), a communication system for transmitting train location to the management centre.

The on-board equipment shall identify uniquely a train in the traffic control centre.

A GIS of the lines to be regulated will be also necessary.

There is not any standard at the moment for this kind of systems although a European standard will be created in the near future for traffic management systems, in the framework of ERTMS. In this sense, standardisation of location equipment will not take place for this application, but inside ETCS application (which is a lower level layer of ERTMS) if needed.

Nevertheless, on-board equipment have to comply with European and national EMC and RAMS normative, or other environmental specifications (CENELEC, ETSI), etc. There also exists national regulation for electronic equipment to be installed on-board the train.

Current radio-navigation services (GPS) are not suitable for this application as the performances required are not still achieved.

The same costs considerations mentioned for the ATP application are applicable here.

I.3.6.4 Service Availability

GNSS (and other radio-navigation systems) are not used nowadays for this application because of the strong accuracy and availability requirements. Complementary systems (or local elements) are essential due to the lack of GNSS coverage in stations or other points of the line.

Service disruption will imply a failure of the information system (lack of position information to track the train) or, if manual procedures are used to regulate traffic, operation in degraded mode. Therefore, location service disruption has a tremendous impact on exploitation and operation of railway lines. Fall-back systems offer similar level of performances so that operation of the system will not be degraded.

A short term or long term service disruption can have a strong impact in the system performance and lead to a system failure o degraded situation as mentioned before.

Intermittent service disruption will not have a major impact.

The use of a location service with guarantee of service for this application appears to be essential. Guarantee of service is also an important point if GNSS or RN systems intend to compete with other kind of systems (fix systems installed in the track), apart from economical considerations.

Fall-back systems (track-based systems, on-board sensors, etc.) could be used to complement GNSS, but increasing the price of the product. It has to be taken into account that many of these systems could perform the same function alone with similar level of performances.

The competitive advantages of the GNSS solution are slightly better performances, price and the fact that permanent equipment shall not be installed in the track (provided that service is guaranteed). Besides, GNSS solution will ease the interoperability of Traffic Management systems between different countries, as required by the future ERTMS standard.

In a future context, the use of GNSS for this application should be regulated at an institutional level (Government, Railway Undertakings, Railway Regulators). Commercial agreements with service providers will be also possible.

Threat	***Risk***	***Consequences***	***Mitigation difficulty/cost***
System failure	*L*	*H*	*H*
Location function failure	*L*	*H*	*H*
Communications failure	*L*	*H*	*M*
Receiver/antenna failure	*M*	*M*	*L*
Onboard Interference	*L*	*H*	*M*
External Interference	*L*	*H*	*M*
Ionospheric	*L*	*M*	*M*
Jamming	*L*	*H*	*M*
Spoofing	*L*	*H*	*H*

I.3.6.5 Service Charges

There are not currently neither radio navigation services nor other kind of services in use for this application.

GNSS safety-of-life services or commercial services with guarantee of service are needed.

I.3.7 Fleet Management

I.3.7.1 Overview

The tracking of assets (rolling stock, wagons) is crucial to achieve an optimised use of an operator fleet. The accurate determination of position and kilometres covered by a resource can ease the maintenance of a vehicle. The vehicles can be monitored everywhere at every time of their life-cycle.

Long-term management and planning of the use of rolling-stock, the composition of train and the preparations for maintenance are facilitated if a more automated tracking of these resources can be made. Because of the de-centralised nature of the rolling-stock owners' and lessors' industry, some autonomy in the derivation of this data is required.

The requirements and for Location, Speed, Time and Direction.

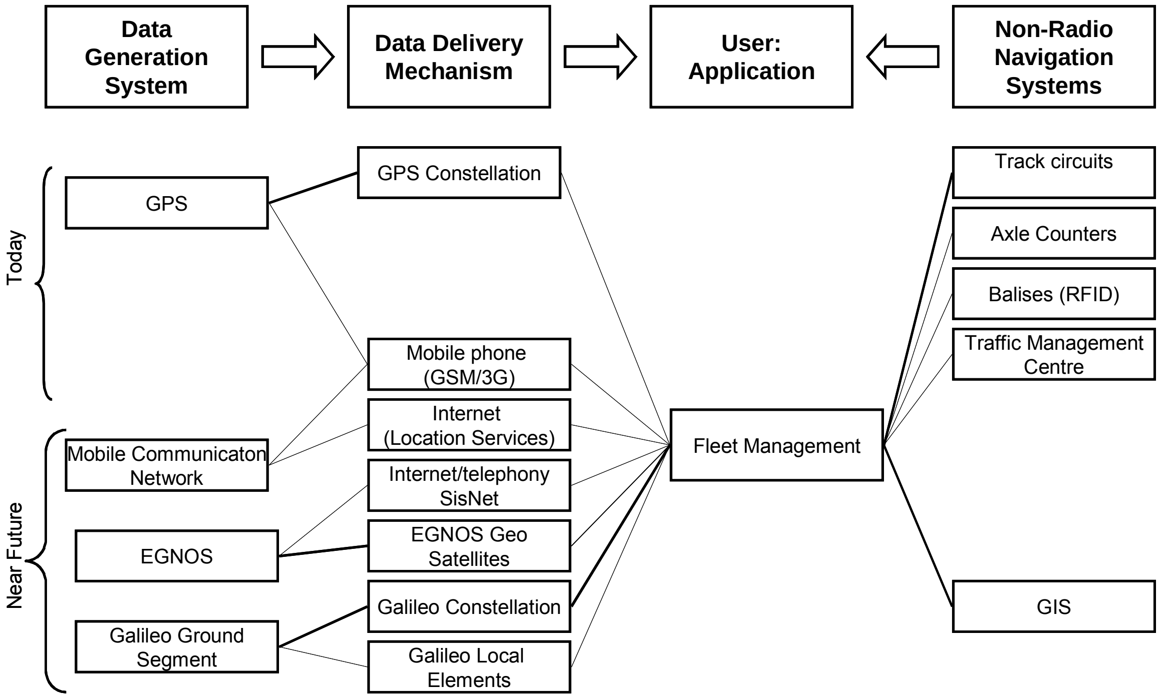
This is a non-safety critical but a mission critical application.

RN systems currently in use in Europe for this kind of applications is GNSS (GPS).

Also information systems based on manual introduction of information about the assets are in use or complemented with track-based location and identification equipment, as RFID systems.

I.3.7.2 Service Delivery

Service Delivery Diagram



Navigation Performances Required

Fleet Management	**Accuracy**	**Availability**	**Integrity**	**Coverage**	**Continuity**	**Fix rate**
Location	± 50m.	99.9%	Not required	All line	TBD	Once each 15 min (tbc)

I.3.7.3 Application environment

For location of rolling stock, as in the previous case, the need for coverage and continuity are for the whole line and its neighbourhood but it extends also to freight terminals, multimodal terminals or maintenance dependencies. Need of information of train position can extend from a line to another and thus from a region to another. Besides, in case of intermodal information, need for coverage can extend also to wider regions to cover other modes of transport.

Lack of coverage due to the special railway environment is less important for this application, as accuracy, continuity and availability of positioning information is not very restrictive. The only critical point is at the closed stations or terminals where other complementary systems or local elements should be used to track the rolling stock while loading, unloading or maintenance procedures are being carried out.

Communications

Communications are also essential for this application. Position of rolling stock, wagons, etc. has to be communicated to the operator management centre, where the management of the fleet is made.

Several possibilities for the communications can be used nowadays depending of the location technology used and other factors:

- Dedicated private-owned fixed communication for transmitting train position to management centre, in case of track-based location and identification systems.
- Dedicated private-owned radio communications for transmitting information of the rolling stock position to the management centre.
- Public mobile communications for communicating rolling stock position to the control centre (GSM, GSM-SMS, GPRS).

Overview of receivers and applications products

A typical configuration of a product for this kind of application would be on-board location equipment (formed by a RN receiver plus complementary systems), a communication system for transmitting rolling stock position to the management centre.

Complementary systems are not mandatory for this kind of application, except for closed stations or terminals.

As before, on-board equipment has to comply with European and national EMC and RAMS normative, or other environmental specifications (CENELEC, ETSI), etc. There also exists national regulation for electronic equipment to be installed on-board the train.

Current radio-navigation services (GPS) are suitable for this application for information purposes. The location service provider can provide either the raw position information or the projected final position of the asset (translated to a position in the track and in the line) by means of a GIS of the line.

There is not any standard specification for this kind of product in Europe although there already are some projects aiming at building a common specification and a common information system and database for this kind of systems, in order to manage assets and freight across the borders in Europe.

Portability and low cost will be the drivers for the mobile equipment to be used on board the trains.

Price for conventional positioning and identification elements like RFID tags are:

- 70 € per tag. One tag can track one asset.
- 7000 € per reader. One reader tracks every asset that passes through it at a distance of 5 meters maximum.

The cost for a mobile GPS+GSM unit is about 1.200 € and a GIS application about 6.000 €.

In this case, price per unit for mobile equipment to be installed in wagons is very important, as the cost of the system depend on the quantity of assets to be tracked and it is very high.

I.3.7.4 Service Availability

GNSS (and other radio-navigation systems) are used nowadays for this application alone or combined with other complementary systems. Complementary systems are important where there is the need of tracking assets in closed terminals and maintenance facilities.

Service disruption will imply a failure of the information system (lack of position information to track the vehicles) or operation in a degraded mode, if manual procedures are used to provide information about vehicle position. Fall-back systems offer similar level of performances so that operation of the system will not be degraded.

A short term or long term service disruption can have a strong impact in the system performance and lead to a system failure (if no fall-back systems exists), so that tracking of vehicles is not possible. Intermittent service disruption will not have a major impact.

To cope with this situation, the use of a commercial agreement that guarantees the service level will be a solution. A cost-benefit analysis for implementing this solution should be made by Railway Undertakings.

Guarantee of service is also an important point if GNSS or RN systems intend to compete with other kind of systems (fix systems installed in the track), apart from economical considerations.

Open service could be also suitable but with the drawbacks already mentioned.

Fall-back systems (track-based systems, on-board sensors, etc.) could be used for complementing GNSS, but it will increase the price of the final product, taking into account that many of these systems could perform the same function alone with similar level of performances, for example RFID system. Anyway, complementary systems or local elements could be essential in particular locations without GNSS coverage (terminals).

The competitive advantage of GNSS solution are slightly better performances, price and the fact that permanent equipment shall not be installed in the track (provided that service is guaranteed to some extent). Another advantage of GNSS solution is that it eases the interoperability of fleet management systems between different countries.

The use of service should therefore be regulated by commercial agreements (service level agreements) between railway undertakings and location services operators.

Threat	***Risk***	***Consequences***	***Mitigation difficulty/cost***
System failure	*L*	*H*	*H*
Location function failure	*L*	*H*	*H*
Communications failure	*L*	*H*	*M*
Receiver/antenna failure	*M*	*M*	*L*
Onboard Interference	*L*	*H*	*M*
External Interference	*L*	*H*	*M*
Ionospheric	*L*	*M*	*M*
Jamming	*L*	*H*	*M*
Spoofing	*L*	*H*	*H*

I.3.7.5 Service Charges

In current applications, GPS positioning service is used for free. In case of Assisted-GPS (not fully implemented for this application), the position service provider is the communication network operator, therefore service charges shall be agreed with it.

The same would occur with more simple network-based positioning systems (GSM-based). Current prices for a position report are similar for example to a SMS message. Communication operators usually have special agreements for prices with railway undertakings, both for positioning and communication services.

In the future context of EGNOS and GALILEO, service operators and the charges will be established in the near future.

I.3.8 Passenger Information

I.3.8.1 Overview

This is a non-safety application that can benefit easily from radio-navigation systems in a short term. We can distinguish between pre-trip information (outside the train) and on-trip information onboard the train.

Most existing passenger information systems are located in stations where indicator boards give information about the actual arrival time and destination of the next trains. The provision of pre-trip information to passengers who have not yet arrived at a station or terminus is relatively limited, although there are already some examples of pre-trip information through internet or mobile phone. On-board information is being currently implemented in many railway systems in Europe. On-board information requires a communication link with the track-side or an on-board positioning system together with a map of the line. RN systems are very suitable for this kind of application.

It is also useful to provide this kind of information to passengers in transit between different transport modes. This would imply the integration of such services into a single information source, which will require the interoperability and compatibility of different location and navigation systems.

The performance requirements for such information are not very restrictive.

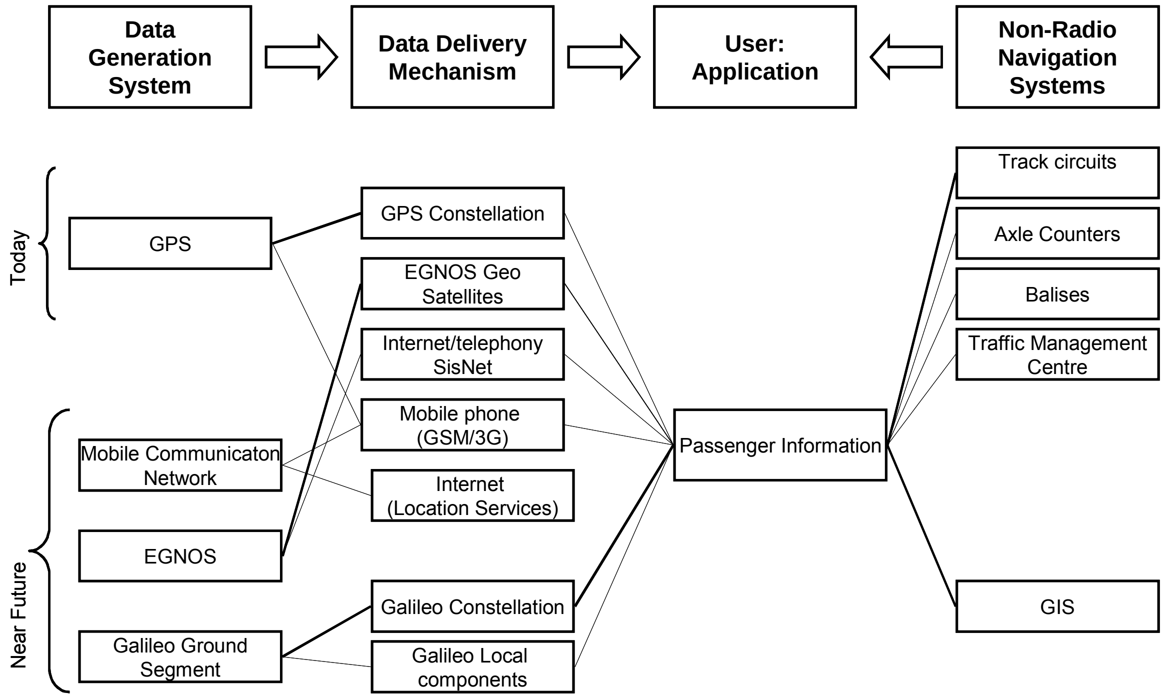
The requirements and for Location, Speed, Time and Direction.

This is a mission critical application if there are nor supplementary systems to cope with service interruption or failure.

RN systems are currently in use in Europe for this kind of applications, namely GNSS.

I.3.8.2 Service Delivery

Service Delivery Diagram



Navigation Performances Required

Passenger Information	**Accuracy**	**Availability**	**Integrity**	**Coverage**	**Continuity**
Location	±100m.	99.5%	Not required	All line	TBD

I.3.8.3 Application environment

For location of trains, as in the previous case, the need for coverage and continuity are for the whole line and its neighbourhood. Need of information of train position can extend from a line to another and thus from a region to another. Besides, in case of intermodal information, need for coverage can extend also to wider regions to cover other modes of transport.

Lack of coverage due to the special railway environment is less important for this application, as accuracy, continuity and availability of positioning information is not very restrictive. The only critical point is at covered stations where other complementary systems or local elements should be used to position the train in the correct track (very important information for passengers).

Communications

Communications are also essential for this application. Train position along the line has to be computed and transmitted to the Control Centre that afterwards, would dispatch it to the indicator boards in the stations.

Several possibilities for the communications could be used nowadays depending of the location technology used and other factors:

- Dedicated private-owned fixed communication for transmitting train position to control centre, in case of track-base location systems.

- Dedicated private-owned fixed communication for transmitting passenger information to the indicators in the stations.
- Dedicated private-owned radio communications for transmitting information from the train position to the control centre and then to the stations.
- Public mobile communications for communication train position to the control centre (GSM, GSM-SMS, GPRS).

External communication services are suitable for these applications, as long as the operator provides a minimum quality of service.

Overview of receivers and applications products

A typical configuration of a product for this kind of application would be an on-board location equipment (formed by a RN receiver plus complementary systems), a communication system for transmitting train position to the control centre, or alternatively a location service.

Complementary systems are not mandatory for this kind of application.

As before, on-board equipment have to comply with European and national EMC and RAMS normative, or other environmental specifications (CENELEC, ETSI), etc. There also exists national regulation for electronic equipment to be installed on-board the train.

Current radio-navigation services (GPS) are suitable for this application for information purposes. The location service provider can either provide the raw position information or the projected final position of the train (translated to a position in the track and in the line) by means of a GIS of the line.

There is not any standard specification for this kind of products in Europe although there already exists an initiative to build a common specification for them, taking into account the requirements of interoperability of systems along the European corridors. Passenger Information systems will be also part of the ETML, the future European standard for traffic management and regulation (included in ERTMS architecture).

Portability and low cost will be the drivers for the mobile equipment to be used on board the trains.

Price for conventional positioning elements (track circuits, axle counters) ranges from 5.000 – 8.000 € per unit, plus installation costs. The cost for a mobile GPS+GSM unit is about 1.200 € and a GIS application about 6.000 €.

I.3.8.4 Service Availability

GNSS (and other radio-navigation systems) are used nowadays for this application alone or combined with other complementary systems.

Service disruption will imply a failure of the information system (lack of information to be presented to passengers) or operation in a degraded mode, if fall-back systems or manual procedures are used to provide information to passengers.

To cope with this situation the use of a commercial type service than guarantees the service will be a solution. A cost-benefit analysis for implementing this solution should be made by Railway Undertakings. Passenger information means quality of service (transport service offered by railways) as perceived by the user (passenger), and that is one of the main points that drives a railway system nowadays. Therefore, guarantee of service is also an important point if GNSS or RN systems intend to compete with other kind of systems (track-based), apart from economical and performances considerations.

An open service without guarantee of service could be suitable also but with the drawbacks already mentioned.

A short term or long term service disruption can have a strong impact in the system performance and lead to a system failure (if not fall-back systems exists), so that information cannot be provided to users. Intermittent service disruption will not have a major impact.

Fall-back systems (track-based systems, on-board sensors, etc.) could be used complementing GNSS, but it will increase the price of the final product unnecessarily, taking into account that many of these systems could perform the same function alone with similar level of performances. Complementary systems or local elements would be useful in case of excessive lack of coverage in the line.

The competitive advantage of GNSS solution are slightly better performances, price and the fact that permanent equipment shall not be installed in the track (provided that service is guaranteed to some extent).

The use of service should therefore be regulated by commercial agreements (service level agreements) between railway undertakings and location services operators.

Threat	***Risk***	***Consequences***	***Mitigation difficulty/cost***
System failure	*L*	*H*	*H*
Location function failure	*L*	*H*	*H*
Communications failure	*L*	*H*	*M*
Receiver/antenna failure	*M*	*M*	*L*
Onboard Interference	*L*	*H*	*M*
External Interference	*L*	*H*	*M*
Ionospheric	*L*	*M*	*M*
Jamming	*L*	*H*	*M*
Spoofing	*L*	*H*	*H*

I.3.8.5 Service Charges

In current applications, GPS positioning service is used for free. In case of Assisted-GPS (not fully implemented for this application), the position service provider is the communication network operator, therefore service charges shall be agreed with it.

The same occurs for more simple network-based positioning systems (GSM-based). Current prices for a position report are similar for example to a SMS message. Communication operators usually have special agreements for prices with railway undertakings, both for positioning and communication services.

In the future context of EGNOS and GALILEO, service operators and the charges will be established in the near future.

I.3.9 Cargo monitoring

I.3.9.1 Overview

The importance of accurate information for freight customers, particularly accurate estimates of the arrival of trains at depots, is inestimable. Unplanned late arrival can result in delays to unloading that seriously disrupt the running of subsequent services.

Complete train, individual containers or even goods can be tracked by radio-navigation systems potentially through multiple modes of transport, thereby requiring the integration of management information from multiple service providers and requiring the interoperability of different systems.

Tracking of freight containers by radio-navigation systems is applicable also for intermodal transport. When the transportation of freight is truly multi-modal across a wide national area, the requirement of a single solution across all modes could be easily met by GNSS.

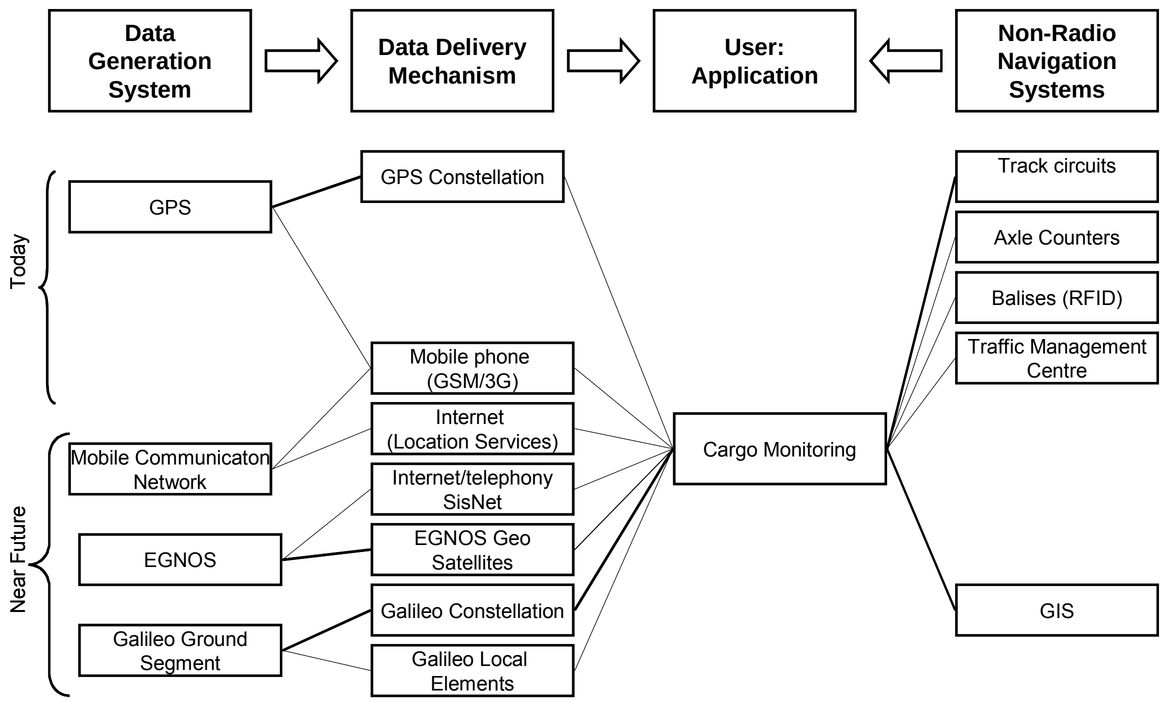
The requirements are for Location, Speed, Time and Direction.

This is a non-safety critical application but it is mission critical if there are not complementary systems acting as back up. Anyhow, in case of dangerous goods transportation, safety can be concerned in the event of an accident. Reliability and availability requirements for positioning and communications are then important.

RN systems currently in use in Europe for this kind of applications are basically GNSS (GPS, EGNOS). They can work together with complementary systems as radio-beacons (DSRC systems).

I.3.9.2 Service Delivery

Service Delivery Diagram



Navigation Performances Required

Cargo Monitoring	**Accuracy**	**Availability**	**Integrity**	**Coverage**	**Continuity**

Location	± 100 m.	98 %	Not required	All line	TBD

I.3.9.3 Application environment

For location of cargo and goods, as in the previous case, the need for coverage and continuity are for the whole line and its neighbourhood but it extends also to freight terminals and multimodal terminals. Need of information about train position can extend from one line to another and thus from one region to another. Besides, in case of intermodal information, need for coverage can extend also to wider regions to cover other modes of transport.

Lack of coverage due to the special railway environment is less important for this application, as accuracy, continuity and availability of positioning information is not very restrictive (in the case of dangerous goods transport more stringent requirements should be placed). The only critical point is at the closed stations or terminals where other complementary systems or local elements should be used to track the rolling stock while loading or unloading procedures that are being carried out.

Communications

Communications are also essential for this application. Position of freight anywhere in its route has to be communicated to the operator management centre. This information is then transmitted to the client by means of e-mail, internet or mobile phone.

Several possibilities for the communications can be used nowadays depending of the location technology used and other factors:

- Dedicated private-owned fixed communication for transmitting freight location to management centre, in case of track-based location and identification systems.
- Dedicated private-owned radio communications for transmitting information of the freight location to the management centre.
- Public mobile communications for communicating freight location to the management centre (GSM, GSM-SMS, GPRS).

Overview of receivers and applications products

A typical configuration of a product for this kind of application would be on-board location equipment (formed by a RN receiver plus complementary systems), a communication system for transmitting freight location to the management centre.

To track and identify the goods independently from their container or wagon can be very difficult, so location of goods is associated to location of its container.

Complementary systems or local elements are not mandatory for this kind of application, but for closed stations or terminals.

As before, on-board equipment have to comply with European and national EMC and RAMS normative, or other environmental specifications (CENELEC, ETSI), etc. There also exists national regulation for electronic equipment to be installed on-board the train.

Current radio-navigation services (GPS) are suitable for this application. The location service provider can either provide the raw position information or the projected final position of the container (translated to a position in the track and in the line) by means of a GIS of the line.

There is not any standard specification for this kind of products in Europe although there already are some projects aiming at building a common specification and a common information system and database for this kind of systems, in order to manage assets and freight across the borders in Europe.

Portability and low cost will be the drivers for the mobile equipment to be used on board the wagons and containers.

Price for conventional positioning and identification elements like RFID tags are:

- 70 € per tag. One tag can track one asset.
- 7000 € per reader. One reader tracks every asset that passes through it at a distance of 5 meters maximum.

The cost for a mobile GPS+GSM unit is about 1.200 € and a GIS application about 6.000 €.

In this case, price per unit for mobile equipment to be installed in wagons is very important, as the cost of the system depend on the quantity of assets to be tracked and it is very high.

I.3.9.4 Service Availability

GNSS (and other radio-navigation systems) are used nowadays for this application alone or combined with other complementary systems. Complementary systems or local elements are important only where there is the need of tracking assets in closed multimodal and freight terminals.

Service disruption will imply a failure of the information system (lack of position information to track the goods) or operation in a degraded mode if manual procedures are used to provide information about vehicle position. Fall-back systems can cover the same functionality so that operation of the system will not be degraded.

A short term or long term service disruption can have a strong impact in the system performance and lead to a system failure (if no fall-back systems exists), so that monitoring of goods is not possible. Intermittent service disruption will not have a major impact.

To cope with this situation the use of a commercial agreement that guarantees the service level will be a solution. A cost-benefit analysis for implementing this solution should be made by Railway Undertakings.

Guarantee of service is also an important point if GNSS or RN systems intend to compete with other kind of systems (fixed systems installed in the track), apart from economical considerations.

Open service could be suitable also but with the drawbacks already mentioned.

Another solution for service disruption is the use of fall-back systems (track-based systems, on-board sensors, etc.) complementing GNSS, but it will increase the price of the final product unnecessarily, taking into account that many of these systems could perform the same functionality, for example RFID systems. Complementary systems or local elements are only essential in particular locations without GNSS coverage (some terminals).

The competitive advantage of GNSS solution are slightly better performances, price and the fact that permanent equipment shall not be installed in the track (provided that service is guaranteed to some extent). GNSS or radio navigation, represents the best solution when freight routes extend to one country to another, easing the interoperability between different countries.

The use of service should therefore be regulated by commercial agreements (service level agreements) between railway undertakings and location services operators.

Threat	*Risk*	*Consequences*	*Mitigation difficulty/cost*
System failure	*L*	*H*	*H*
Location function failure	*L*	*H*	*H*
Communications failure	*L*	*H*	*M*
Receiver/antenna failure	*M*	*M*	*L*
Onboard Interference	*L*	*H*	*M*
External Interference	*L*	*H*	*M*
Ionospheric	*L*	*M*	*M*
Jamming	*L*	*H*	*M*
Spoofing	*L*	*H*	*H*

I.3.9.5 Service Charges

In current applications, GPS positioning service is used for free. In case of Assisted-GPS (not fully implemented for this application), the position service provider is the communication network operator, therefore service charges shall be agreed with it.

The same would occur for more simple network-based positioning systems (GSM-based). Current prices for a position report are similar for example to a SMS message. Communication operators usually have special agreements for prices with railway undertakings, both for positioning and communication services.

In the future context of EGNOS and GALILEO, service operators and the charges will be established in the near future.

I.3.10 Infrastructure Survey

I.3.10.1 Overview

To help Infrastructure asset management through knowledge of their location. The location of track and other infrastructure items and parameters (for example permissible speed) can be an important part of a route database for use on-board by the train operators.

Positioning in the context of infrastructure servicing and testing is also able to deliver benefits, primarily due to the lack of detailed geographical and associated databases on railway infrastructure. Specific applications include:

- Track magnet proving
- Diagnosis of permanent way/track layout measurements
- Coverage planning and accurate positioning of radio infrastructure
- Ultrasonic rail inspection train

For many of the above-mentioned applications, traditional means of determining position such as track circuits do not provide enough accuracy and may not necessarily be available in the track section of interest.

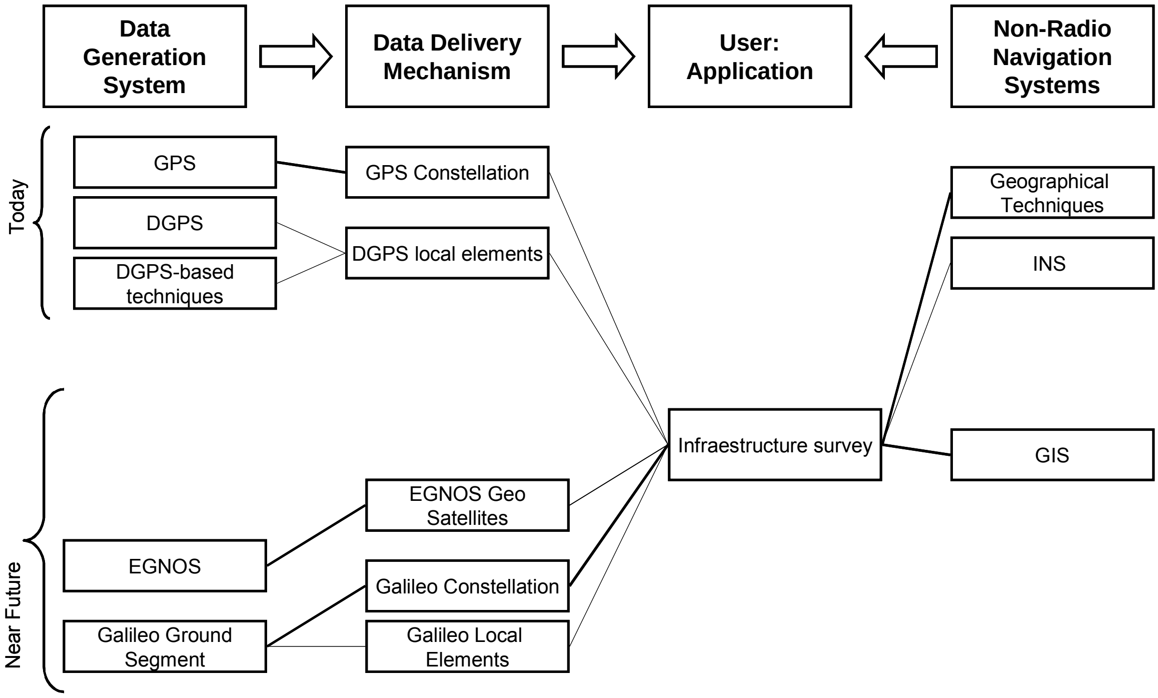
The railway infrastructure shall be defined by its position in a co-ordinate system for surveying purposes. It shall be possible to transform these co-ordinates into a co-ordinate system applicable to the definition of movement authorities and their enforcement.

This application is not safety-critical neither mission critical, although depending of the kind of data to be surveyed integrity can be required (for example, track co-ordinates and track description for ATP).

RN systems currently in use in Europe for this kind of applications are GPS, DGPS techniques, RTK techniques, etc. Special software post-processing tools are used to obtain accuracy up to centimetres and even millimetres. Other complementary systems as high quality INS sensors are also used.

I.3.10.2 Service Delivery

Service Delivery Diagram



Navigation Performances Required

Infrastructure Survey	Accuracy	Availability	Integrity	Coverage	Continuity
Location	± 1 cm.	99%	Not required[145]	All line	TBD

I.3.10.3 Application environment

Needs for coverage are concentrated in lines and its neighbourhood, but in particular for this application, coverage can be restricted to local areas where the accurate survey is performed, during the duration of the survey.

145 Depending on the type of data to be surveyed, it can imply safety requirements or not.

Lack of coverage and continuity in the railway environment (tunnels, bridges, stations) requires that RN systems be complemented with other systems (local elements, INS, for example).

Local differential stations are essential for this application due to the high requirements for accuracy and availability.

Communications

Communications are not used in this application as data collected during surveying procedures is recorded and post-processed of line. Internal communications like the communication of DGPS corrections to the mobile are not considered here.

Overview of receivers and applications products

Special Differential GPS and RTK techniques are used for this application. These are usually proprietary solutions based on special and dedicated equipment owned by a company.

Companies specialised in the field, own the equipment and provide the service (the survey of selected zone).

Equipment usually consists on a receiver in a reference point (differential station) plus a mobile receiver surveying the selected asset plus on-line or post-processing techniques to compare both and obtain the required performances.

Currently, there is not any standard for these systems in Europe.

I.3.10.4 Service Availability

GPS-based techniques are already used in Europe for this kind of application.

For places without GNSS coverage, supplementary surveying techniques should be used.

Long-term service disruption will imply lack of data to perform the survey if additional techniques are not used. Depending on the need of the client, fall-back techniques could be use to cope with the situation, but with lower level of performances, leading to worst results.

Intermittent service disruption will not have major impact.

The use of positioning services for this application is likely to be regulated by means of institutional agreements (geographic surveys of the railways properties, etc.) or by commercial agreements (service level agreements) between railway undertakings and location services operators.

I.3.10.5 Service Charges

In current applications, GPS positioning service is used for free.

Usually this kind of service is provided by individual companies that establish a commercial agreement with the Railway Undertaking.

I.3.11 Supervision of train tilting

I.3.11.1 Overview

The use of tilting trains improves the comfort of the passenger. When the tilting system detects the presence of a curve in the track, it generates an artificial tilting of the coaches. Up to know the detection of curves to generate tilting is being done through a combination of accelerometers and other sensors.

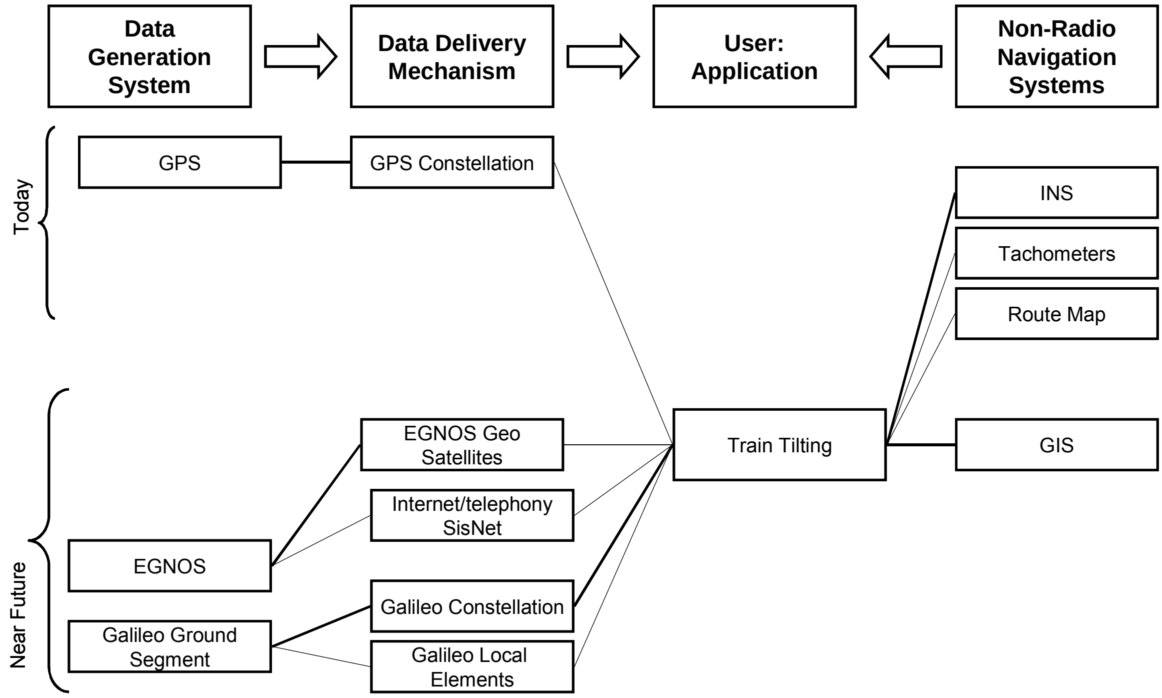
The use of radio-navigation systems along with track information (curve radius, location, etc) to locate train in the curves is currently being used to improve the performance of these systems. The use of a digital map of the line to detect curves is essential.

This application is non safety critical but mission critical if there are not complementary systems acting as back up.

RN systems currently in use in Europe for this kind of applications are GPS (complemented with route maps and on-board sensors).

I.3.11.2 Service Delivery

Service Delivery Diagram



Navigation Performances Required

Train Tilting	Accuracy	Availability	Integrity	Coverage	Continuity
Location	± 5 m.	99.5%	Not required146	All line	TBD

I.3.11.3 Application environment

For this application, the need for coverage and continuity are for the whole line and its neighbourhood and it extends also to stations and terminals. Need of information of train position can extend from one line to another and thus from one region to another and even from one country to another in virtue of new trans-European corridors to be created.

146 Depending on the type of data to be surveyed it can imply safety requirements or not.

Lack of coverage due to the special railway environment is important for this application, as accuracy, and availability of positioning information are important. Therefore, complementary systems or local elements should be used.

Communications

Communications are not important for this application, as the control of tilting of trains, as well as train positioning, are performed by an on-board system.

In network-based positioning is used in the future for this application, the position determined by the network would have to be transmitted to the train. The same network infrastructure could be used for the communications. However, current performances of network-based positioning do not meet the requirements for this application.

Overview of receivers and applications products

A typical configuration of a product for this kind of application would be on-board location equipment (formed by a RN receiver plus complementary systems as INS). An on-board GIS (or digital map) of the line is also necessary.

On-board equipment have to comply with European and national EMC and RAMS normative, or other environmental specifications (CENELEC, ETSI), etc. There also exists national regulation for electronic equipment to be installed on-board the train.

Current radio-navigation services (GPS) are suitable for this application and are already in use.

A route map (GIS) of one line can cost around 3.000 €.

I.3.11.4 Service Availability

GNSS is used nowadays for this application alone or combined with other complementary systems. Complementary systems are important to cope with the lack of GNSS coverage in the railway environment.

Service disruption will imply a failure of the tilting system (lack of position information to generate tilting) if fall-back systems are not used. Fall-back systems offer similar level of performances so that operation of the system will not be degraded.

A short term or long term service disruption can have a strong impact in the system performance and lead to a system failure (if not fall-back systems exists). Intermittent service disruption will have also an impact, because the short mission time of the application.

To cope with this situation the use of a commercial agreement that guarantees the service level will be a solution. A cost-benefit analysis for implementing this solution should be made by Railway Undertakings. Guarantee of service is also an important point if GNSS or RN systems intend to compete with other kind of systems (on-board sensors), apart from performances and economical considerations.

Open service could be suitable also but with the drawbacks already mentioned.

Another solution for service disruption is the use of fall-back systems (on-board sensors, etc.) to complement GNSS. Fall-back systems are likely to be used as explained before.

In this case, the competitive advantage of the GNSS solution are its better performances (provided that service is guaranteed to some extent).

The use of service should therefore be regulated by commercial agreements (service level agreements) between railway undertakings and location services operators.

Threat	*Risk*	*Consequences*	*Mitigation difficulty/cost*
System failure	*L*	*H*	*H*
Location function failure	*L*	*H*	*H*
Communications failure	*L*	*H*	*M*
Receiver/antenna failure	*M*	*M*	*L*
Onboard Interference	*L*	*H*	*M*
External Interference	*L*	*H*	*M*
Ionospheric	*L*	*M*	*M*
Jamming	*L*	*H*	*M*
Spoofing	*L*	*H*	*H*

I.3.11.5 Service Charges

In current applications, GPS positioning service is used for free.

In the future context (EGNOS and GALILEO) service operators should be defined and commercial service charges will be agreed between these operators and the railway undertakings.

I.4 Road

I.4.1 Market Specific

I.4.1.1 Institutional Environment

In the road sector there is no comparable institutional environment available like e.g. IMO activities in the maritime domain or ICAO activities in the aviation domain, which addresses the use of navigation systems, devices and services on the level of legal binding regulations. Nevertheless there are organisations on global, regional and national level, which address institutional aspects of the road sector:

On global level various national and regional ITS organisations are addressing (beside technical aspects) the institutional environments for the road sector. Following non-European ITS organisations have been founded:

- ITS America
- ITS Australia
- ITS Canada
- ITS Chile
- ITS Japan
- ITS Korea
- ITS Malaysia
- ITS Singapore

- ITS South Africa
- ITS Taiwan

The European representative in the ITS community is ERTICO. ERTICO is a Europe-wide, not-for-profit, public/private partnership for the implementation of Intelligent Transport Systems and Services (ITS). Set up in 1991 based on an initiative of the European Commission as well as of members of European ITS industry and national governments, ERTICO is open to any European organisation or international organisation operating in Europe. ERTICO is a company under Belgian law with equal shareholding Partners. Its activities are financed by annual fees from its Partners and by project funding. The activities of ERTICO include the eSafety initiative, v projects, fora, various committees and initiatives, as well as the organisation and participation of congresses and other events. For example the Hazardous Goods Committee is one of ERTICO's activities, which has a strong focus on institutional aspects.

On the national and local level there is a significant number of European ITS organisations:

- Czech Telematic Transport Association
- Connekt (former ITS Netherlands)
- ITS Czech Republic
- ITS United Kingdom
- ITS France or ITS France/ATEC
- ITS Finland
- ITS Munich
- ITS North Denmark
- ITS Norway
- ITS Spain
- ITS Sweden
- TTS Italia

Beside the ITS community mentioned above, which is formed by the car industry, transport telematics industry and involved service providers (including producers of digital maps and GIS companies) the institutional environment of the road sector is represented by the various national ministries and administrations, which are responsible for transport telematics:

Austria	Ministry of Transport, Innovation and Technology
Belgium	(Flanders) - Ministry of the Flemish Community
	(Walloon Region) - Ministry of Equipment and Transport
Czech Republic	Ministry of Transport
Denmark	Ministry of Transport
	Danish Road Directorate
Finland	Finnra - Finnish National Road Administration

	Ministry of Transport and Communications
France	Ministère de l'Equipement, des Transports, du Logement, du Tourisme et de la Mer
Germany	Federal Ministry of Transport, Building and Housing
Greece	Ministry for the Environment, Physical Planning and Public Works
Hungary	Ministry of Informatics and Communications
	Ministry of Economy and Transport
Ireland	Department of the Environment
	Department of Transport
	National Road Authority
Italy	Ministry of Infrastructure and Transport
Luxembourg	Administration des Ponts et Chaussées
The Netherlands	Ministry of Transport, Public Works & Water Management
Norway	Norwegian Public Roads Administration
Poland	General Directorate of National Roads and Motorways
Portugal	General Directorate of Land Transport
	Portuguese Road Administration
	Ministry of Internal Affairs
Slovenia	Ministry of Transport
Spain	Direccion General de Trafico
Sweden	Swedish National Road Administration
	Ministry for Industry, Employment and Communications
Switzerland	Swiss Federal Roads Authority
United Kingdom	Department for Transport

Recent developments related to the introduction of GPS-based road pricing systems (Switzerland: introduced in 2001, Germany: scheduled for October 2004) are examples for the growing importance of the institutional environment for the road sector in the following years. The envisaged commercial service of Galileo, which will address amongst others the needs of providers of commercial road transport telematic services, is another example for the future prominence of institutional aspects in the road domain.

I.4.1.2 Application Summary

Application	Current Status		Critical	
	Existing	Radionav	Safety	Mission
Autonomous Route Guidance	Yes	Yes	No	Yes

Central Route Guidance	Yes	Yes	No	Yes
Fleet Management (Standard Freight)	Yes	Yes	No	Yes
Fleet Management (Hazardous Freight)	Yes	Yes	Yes	Yes
Emergency Call	Yes	Yes	Yes	Yes
Theft Protection	Yes	Yes	No	Yes
Traffic Information (FCD)	Yes	Yes	No	Yes
Traffic Information (Other sources)	Yes	No	No	Yes
Road Pricing	Yes [147]	Yes	No	Yes
ADAS	No	Yes	Yes	Yes

Table 23 – Road application summary

I.4.2 Overview

I.4.2.1 Route Guidance (Autonomous, Central)

Route Guidance either autonomous (using a digital road map on CD/DVD in the car) or central (calculation of the route at the service centre and transmission via GSM/GPRS to the customer) is state-of-the-art in transport telematics today.

Radionavigation (GPS) is used either alone (e.g. low cost PDA-based systems) in combination with odometers, gyros and map-matching algorithms (fix installed high-end systems).

Route guidance used in the mass market is not safety critical (except route guidance used by safety and security related user groups e.g. police, fire brigades, ambulances, etc.).[148] The correct functionality of GPS is mission critical for both route guidance methods mentioned. High-end systems combined with additional sensors and algorithms are able compensate short GPS outages (e.g. in tunnels) but are not able to provide full mission functionality in the long term.

I.4.2.2 Fleet Management (Standard Freight, Hazardous Freight)

Fleet Management applications to track standard freight are state-of-the-art in transport telematics today and such systems are used by many transport companies for international, national and regional operations. GNSS-based fleet management for hazardous goods is under implementation in various stages and in early use.

Radionavigation (GPS) is used. Some companies use DGPS.

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147 Switzerland: GPS is used to detect the status inside/outside Switzerland, to check the distance calculation and as time reference. Germany: GPS / GSM based system under implementation.

148 Route guidance for safety & security related user communities is described within the Road section of the ERNP, due to the facts that the products used are in general very similar to products for the mass market and this application is usually based on on-board units without extended interfaces to dedicated operation centres. Fleet management applications for safety & security related user communities, are described in the Public Safety chapter of the ERNP, because dedicated systems with proprietary communication links are generally.

Fleet Management for standard freight is not safety critical. For fleet management used by safety authorities e.g. police, fire brigades, ambulances, etc. see I.5.2. Fleet Management for hazardous goods is safety critical. The correct functionality of GPS is mission critical for both applications.

I.4.2.3 Emergency Call

Emergency call systems are state-of-the-art in transport telematics today. Some systems require a manual initialisation by the driver in case of an emergency, other systems can be initiated automatically by shock-detectors or air-bag sensors.

Radionavigation (GPS) is used.

The correct functionality of GPS is safety and mission critical for emergency call applications.

I.4.2.4 Theft Protection

Theft Protection systems are state-of-the-art in transport telematics today.

Some Theft protection systems use radionavigation (GPS), others use long wave signal transmitters installed at a hidden place in the car. GPS based systems send the position of the stolen vehicle via GSM to a service centre, whereas long wave systems are tracked by mobile long wave receivers. GPS based systems offer the advantage of global coverage, whereas long wave systems can track stolen vehicles even inside of trucks or garages.

The correct functionality of GPS is mission critical for theft protection applications. Due to the fact that in general material assets are on risk and the health or life of persons is not endangered Theft Protection applications is not safety critical.

I.4.2.5 Traffic Information (FCD, Other sources)

The integration of traffic information derived from conventional sources like infrared sensors, induction loops, video cameras, congestion spotters, etc. is state-of-the-art in transport telematics today. The use of Floating-Car-Data (FCD) is under implementation by several transport telematics providers.

Radionavigation (GPS, DGPS) is used.

The use of traffic information is not safety critical. The use of GPS for FCD is mission critical even if outages of a certain percentage of the FCD-vehicles can be tolerated (depending on traffic situation and geographical distribution of the FCD vehicles).

I.4.2.6 Road Pricing

Road Pricing for highways, dedicated road sections, tunnels and bridges is introduced in many European countries. Toll collection for or dedicated areas (e.g. inner cities) is under investigation.

In most countries either vignettes or toll stations are used. In Switzerland a GPS receiver is part of an automatic road pricing on-board unit to detect the status inside/outside Switzerland, to check the distance calculation and as time reference. In Germany a GPS / GSM based system under implementation.

Radionavigation is not safety critical if used for road pricing applications, but if Radionavigation is the only or the dominating system used to determine the position of the vehicle it is mission critical.

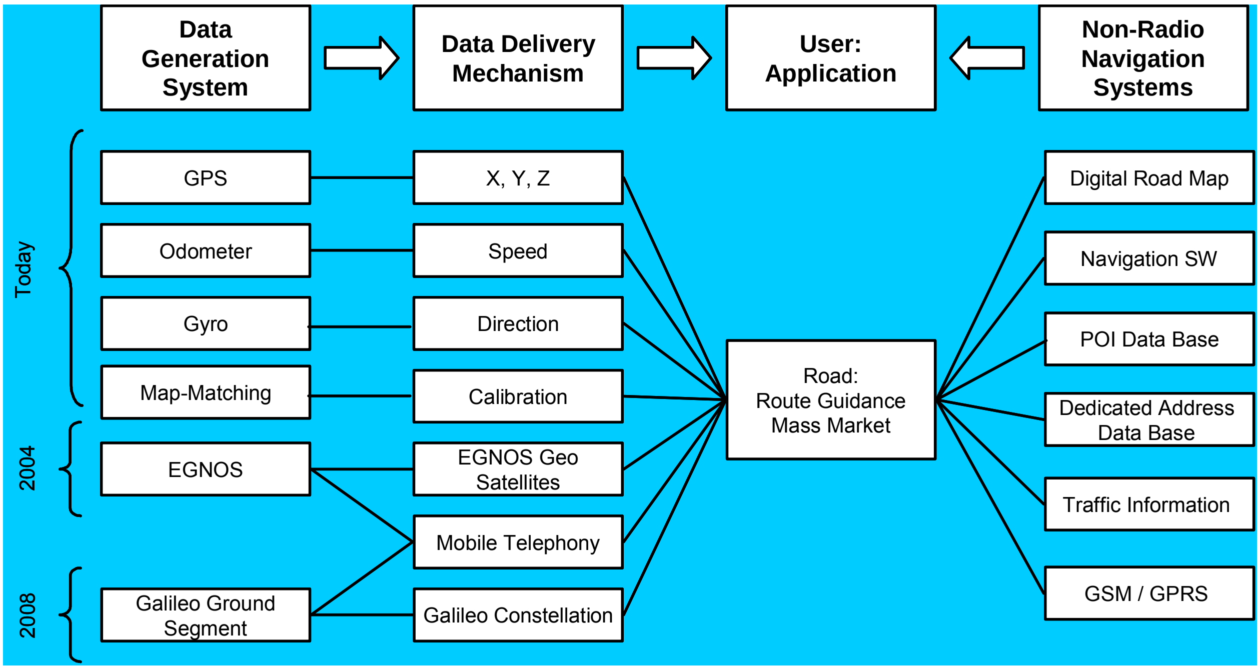
I.4.2.7 ADAS

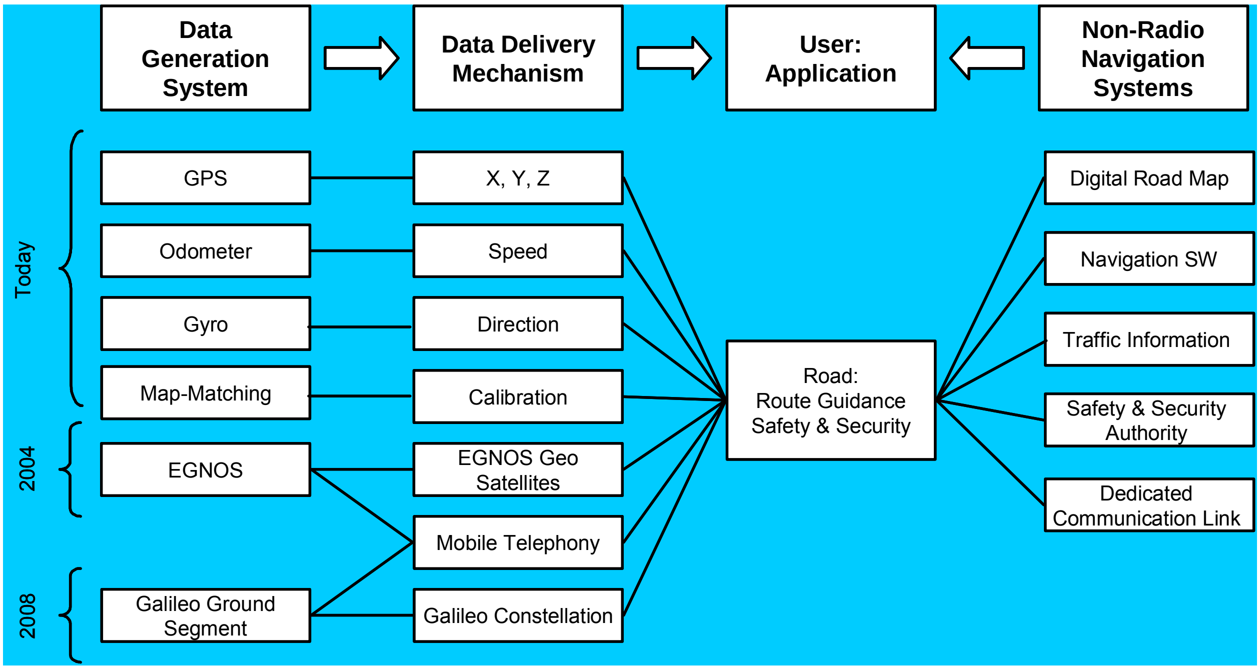
Advanced Driver Assistance Services like lane departure warning, route pre-sight, automatic light adaptation, intelligent speed adaptation, etc. are under investigation at the moment.

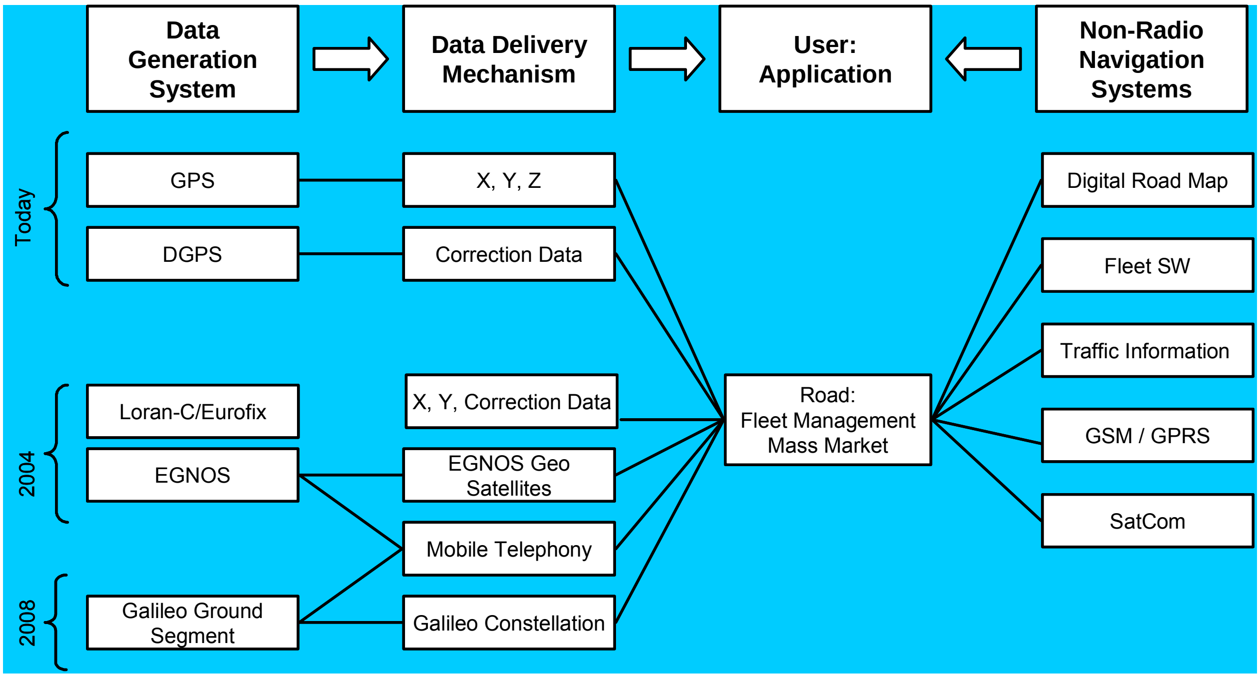
DGPS will be required

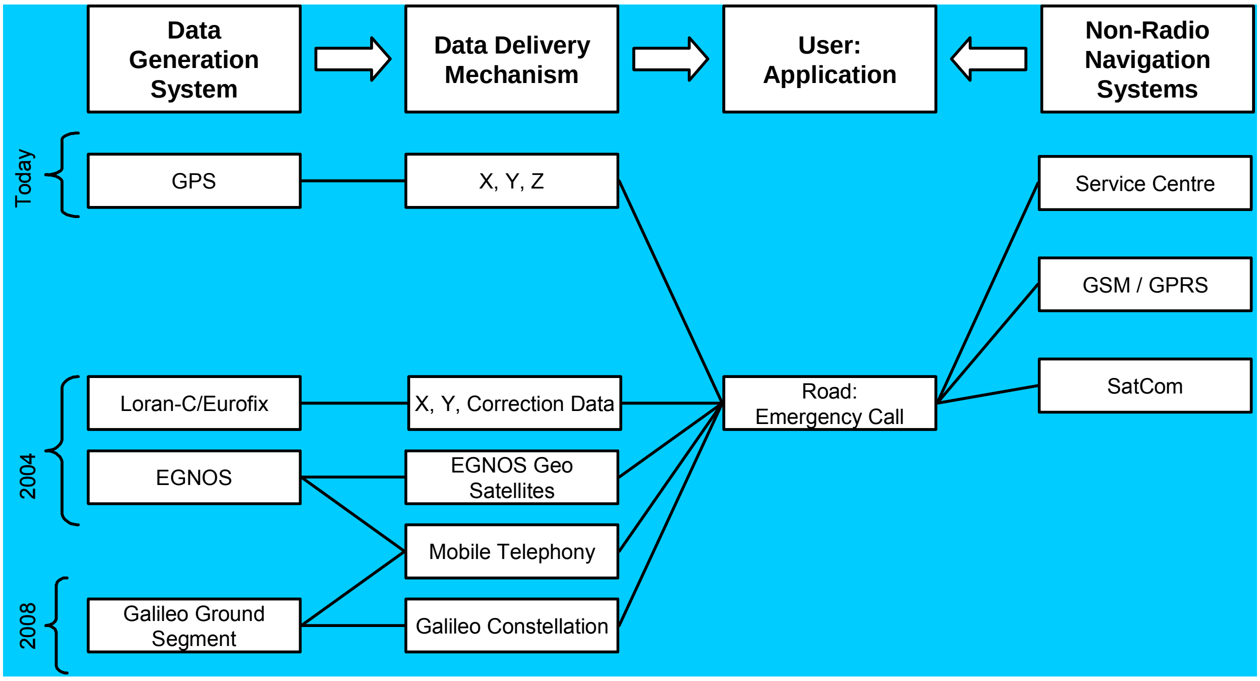
The Radionavigation system(s) used will be both, mission and safety critical for ADAS applications.

I.4.3 Service Delivery






Data Generation System
Data Delivery Mechanism
User: Application
Non-Radio Navigation Systems
Today
2004
2008
GPS
DGPS
Loran-C/Eurofix
EGNOS
Galileo Ground Segment
X, Y, Z
Correction Data
X, Y, Correction Data
EGNOS Geo Satellites
Mobile Telephony
Galileo Constellation
Road:
Fleet Management
Mass Market
Digital Road Map
Fleet SW
Traffic Information
GSM / GPRS
SatCom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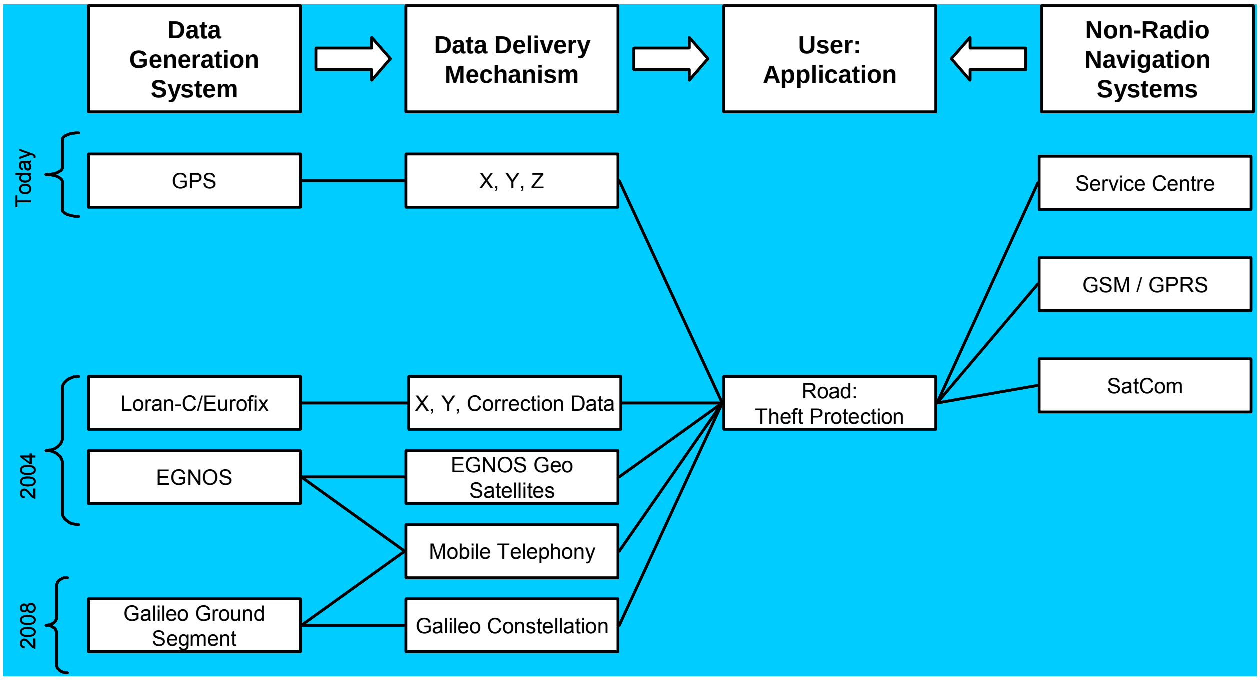
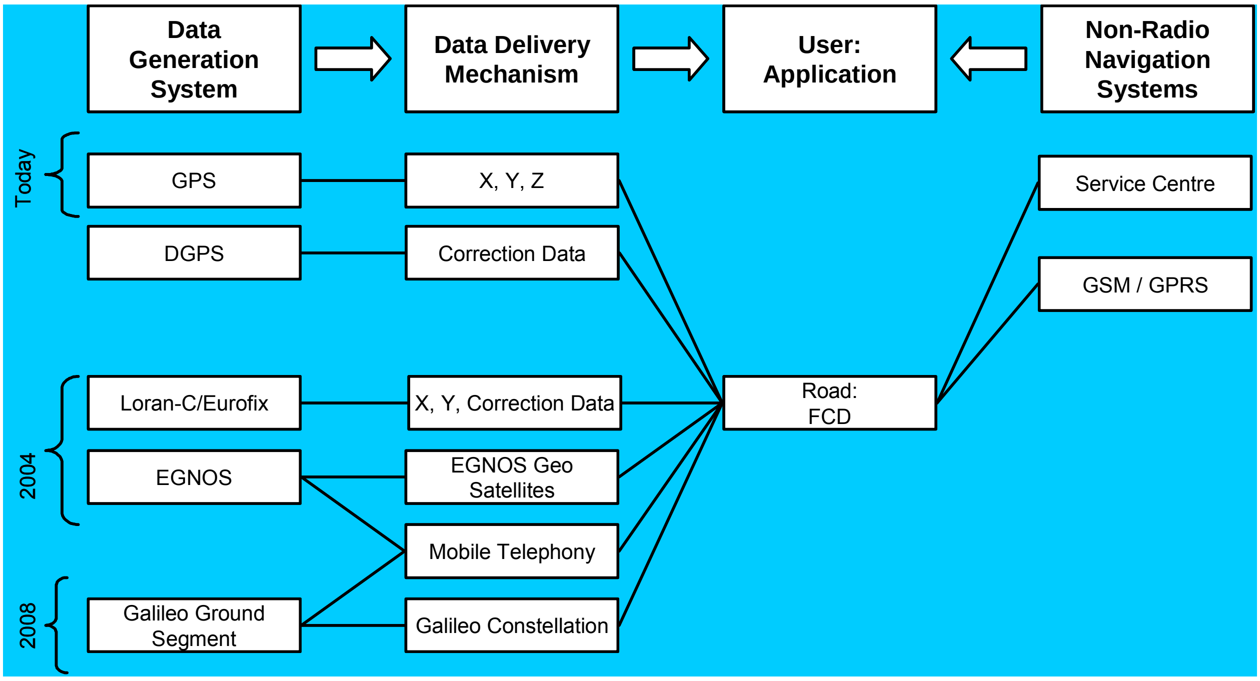
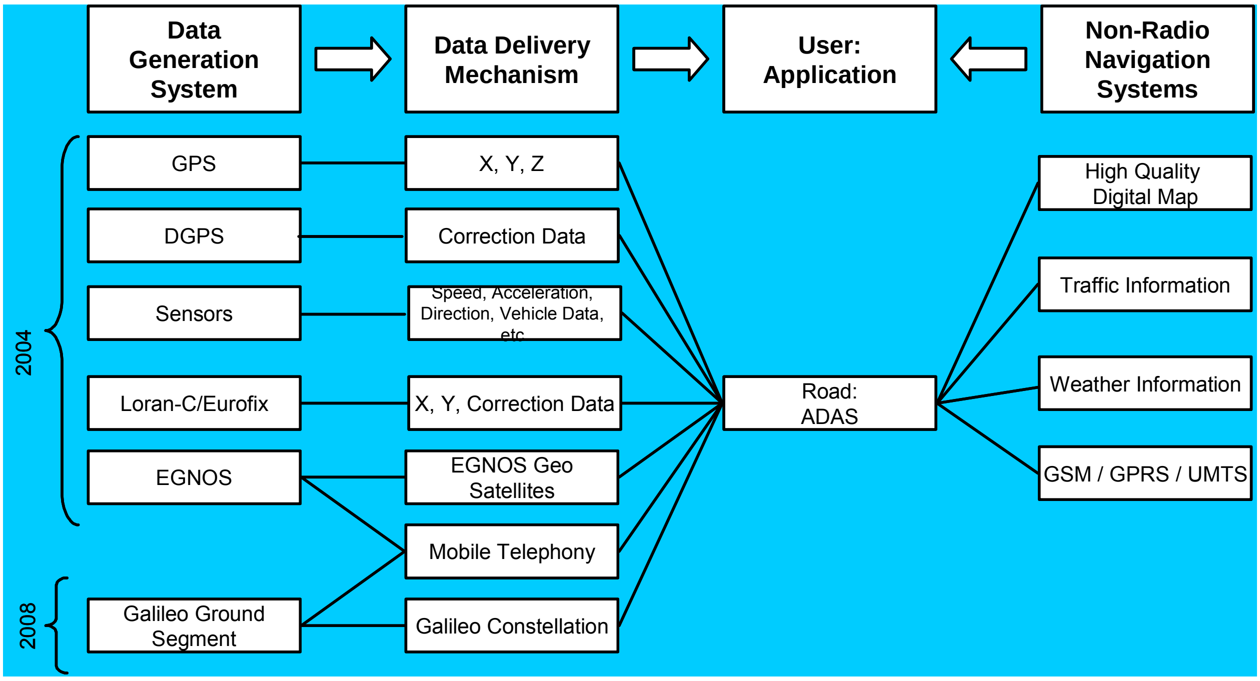
Road:
Emergency Call
Service Centre
GSM / GPRS
SatCom





Note: No figure for Road Pricing provided, due to variety and differences of national approaches



Application	Accuracy (95%)	Integrity (%)	Time to Alarm	Availability (%)
Route Guidance Mass Market	5 – 10 m	99	1 Min.	99
Route Guidance Safety & Security	5 – 10 m	> 99	< 1 Min.	> 99
Fleet Management Mass Market	5 -100 m	98	1 Min.	98
Emergency Call	3 – 50 m	> 99	Sekunden	> 99
Theft Protection	3 – 100 m	99	Minuten	99
FCD	2 - 3 m	98	1 Min.	98
Road Pricing	5 - 10 m	> 99	10 Sek.	> 99
ADAS	0,5 - 2 m	>> 99	Sekunden	> 99

Source: German Radionavigation Plan, 2004 (modified)

The application environment of the road applications described above includes various types of streets (highways, major roads, minor roads) in different geographic environments (lowlands, mountains, river basins, etc. remote, rural, urban, etc.) with small scale characteristics (tunnel, garage, urban canyon, crossings, etc.).

Following communication links are relevant for road applications:

	GSM	GPRS	HSCSD	UMTS	SatCom	Bluetooth	WLAN	Trunked Radio	TETRA	TETRAPOL	Others: RDS/TMC	Others: DAB	Others: Road Sensors Microwave	Others: Road Sensors Infrared
Road Use	Yes	Yes	Yes	Not yet	Yes	Not yet	Not yet	Yes	Not yet	To some extend in combination with safety & security related route guidance	Yes	Yes	Yes	Yes
Frequencies	900 MHz 1800 MHz	900 MHz 1800 MHz	900 MHz 1800 MHz	1885-2025 MHz 2110-2200 MHz	1.6 GHz 2,5 GHz	2,4 GHz	2,4 GHz (IEEE 802.11b, IEEE 802.11g) 5 GHz (IEEE 802.11a)	417-437 MHz	420-430 MHz	380-390 MHz	87.5 - 108 MHz	47 - 68 MHz 174 - 240 MHz 1452 - 1467,5 MHz	2.4 GHz 5.8 GHz	$5*10^{13}$ - $4*10^{14}$ Hz
Data Rate	9,6 kbps	up to 171,2 kbps	up to 115,2 kbps	384 kbps – 2 Mbps	2,4 kbps - 64 kbps.	723 kbit/sec	11 Mbit/sec IEEE 802.11b, 54 Mbit/sec IEEE 802.11a 54 Mbit/sec IEEE 802.11g				130 bps	64 kbps	64 kbps	1 Mbps
Coverage	Regional	Regional	Regional	Local	Global	Local (~10 m)	Local (~30-100 m)	Local (~50km)	Local/Regional	Local/Regional	Regional	Regional	Local (~50m)	Local (~3m)
Applications	Route	Route	Route	Route	Fleet	Route	Route	Fleet	Commercial	In combination with safety &	Traffic	Traffic	Traffic	Traffic

	Guidance Fleet Management Emergency Call Theft Protection FCD Road Pricing ADAS	Guidance Fleet Management Emergency Call Theft Protection FCD Road Pricing ADAS	Guidance Fleet Management Emergency Call Theft Protection FCD Road Pricing ADAS	Guidance Fleet Management Emergency Call FCD ADAS	Management Emergency Call Theft Protection	Guidance ADAS	Guidance ADAS	Management	applications	security related route guidance	Information	Information	Information	Information
Usage	High	Medium	Medium	Under implementation	Low	N/A	N/A	Low	N/A	Limited	High	Medium	Low	Low

For the road sector a variety of different products is available. The German market, which is well developed in the domain of transport telematic devices, is used as a case study to demonstrate the variety of products available.

Receivers and applications products for first-installation:

Automobil-hersteller	**Kontakt**	**Name und Besonderheiten**	**Basierend auf**	**ca. Preis € inkl. MwSt.**
Alfa Romeo	www.alfa-romeo.de	´Integrated Control System´; Radio-Navigationssystem mit Farbzentraldisplay, CC-Spieler, RDS/TMC fähig	´Siemens Integrated Driver Information System´	1600,-
Audi	www.audi.de	´Audi Navigationssystem´; Radio-Navigationssystem mit Kombiinstrument für Pfeilanzeige ´Audi Navigationssystem plus´; Farbzentraldisplay RDS/TMC, GSM TV-Tuner optional	Bosch Blaupunkt ´RNS´ Bosch Blaupunkt ´RGS´ + TMC-Radio	1400,- 2700,- 750,-
BMW	www.bmw.de	´BMW Radio-Navigation (606)´ mit Monochromdisplay für Pfeilanzeige am Gerät und auf dem Zentraldisplay, TMC, CC-Spieler Radio-Navigationssystem mit Farbzentraldisplay, TV-Tuner und GSM	´Carin 522´ VDO Dayton ´MS5000´	1850,- k.A.
Citroen	www.citroen.de	Unterschiedliche Navigationsgeräte mit Zentraldisplay für Pfeilanzeige, bzw. mit Monochromdisplay inkl. div. Erweiterungen (Radio,Telefon, CD-Spieler ...) ´Navigationssystem 1´; Radio-Navigationssystem mit Monochromdisplay und CD Spieler ´Navigationssystem 2´; Radio-Navigationssystem mit Farbdisplay (16:9) und CD Spieler	Zusammenarbeit mit Siemens Siemens VDO-Dayton	von 1300,- bis 2600,- 1300,- 1800,-
Daimler Chrysler	www.daimlerchrysler.de	´MB Audio 30 APS´; Radio-Navigationssystem mit Zentraldisplay für Pfeilanzeige, GSM/TMC ´Command´; mit Multifunktionsdisplay, GSM/TMC	Zusammenarbeit mit Becker; ´Becker Traffic Pro´ Zusammenarbeit mit Bosch Blaupunkt; ´TravelPilot DX-N´	1050,- bis 2050,- 1750,- bis 2700,-
Fiat	www.fiat.de	Radio-Navigationssystem mit Zentraldisplay für Pfeilanzeige Navigationssystem mit Farbdisplay	Bosch Blaupunkt ´TravelPilot RNS 149´ Magneti Marelli ´RoutePlaner 200 NAV´	1100,- 2100,-

Endausrüster Systeme Alfa Romeo – Fiat

Auto-mobil-hersteller	Kontakt	Name und Besonderheiten	Basierend auf	ca. Preis € inkl. MwSt.
Ford	www.ford.de	Radio-Navigationssystem mit Zentraldisplay für Pfeilanzeige ´Ford TravelPilot´; Radio-Navigationssystem mit Zentraldisplay für Pfeilanzeige ´Radio-Navigationssystem RNS´ mit Farbdisplay, optional Telematiksystem über GSM (D2)	Becker ´Traffic Pro 4720´ Bosch Blaupunkt ´TravelPilot DX-R´ Bosch Blaupunkt ´TravelPilot´	1600,- 1750,- 2200,-
Honda	www.honda.de	´Navigationssystem RNS´ mit Pfeilanzeige	Bosch Blaupunkt ´TravelPilot RNS´	1500,-
Jaguar	www.jaguar.com	Navigationssystem mit Farbdisplay DVD-Radio-Navigationssystem mit Zentraldisplay für Pfeilanzeige Integriertes DVD-Navigationssystem mit Farbdisplay, 2 ½D-Darstellung und Touchscreenbedienung	Denso Zusammenarbeit mit Alpine Alpine	2400,- 1600,- 2450,-
Lancia	www.lancia.de	Radio-Navigationssystem mit Pfeilausgabe Satelliten-Navigationssystem mit GSM (keine Dynamisierung)	Bosch Blaupunkt ´Travelpilot RNS´ ´Siemens Integrated Driver Information System´	1100,- 1900,-
Mitsubishi	www.mitsubishi-motors.de	´Perfect Harmony 4500´; Radio-Navigationssystem mit Farbdisplay für Pfeilanzeige und CD Spieler DVD-Navigationssystem mit Farbdisplay	Zusammenarbeit mit Mitsubishi Electronics Zusammenarbeit mit Mitsubishi Electronics und Aisin (SW)	1700,- 3150,-
Nissan	www.nissan.de	´Birdview´; 2 ½D-Navigationssystem mit ausfahrbarem Farbdisplay	Zusammenarbeit mit Xanavi (SW)	2300,-
Opel	www.opel.de	´NCDR 1100´ Radio-Navigationssystem mit Pfeilanzeige ´NCDR 1500´ Radio-Navigationssystem mit Pfeilanzeige, Telematik- und GSM-Einheit, TMC ´NCDR 2011´ Radio-Navigationssystem mit Kombi-anzeige zur Pfeildarstellung ´NCDC 20013´ Radio-Navi-Kombigerät mit Farbdisplay ´NCDC 20015´ Radio-Navi-Kombigerät mit monochromem oder Farbdisplay, Telematik- und GSM-Einheit, TMC	Alle in Zusammenarbeit mit Siemens	bis 2300,- bis 2600,- bis 1400,- 1050,- bis 2000,-

Endausrüster Systeme Ford – Opel

Auto-mobil-hersteller	Kontakt	Name und Besonderheiten	Basierend auf	ca. Preis € inkl. MwSt.
Peugeot	www.peugeot.de	Radio-Navigationssystem mit Zentraldisplay für Pfeilausgabe Radio-Navigationssystem mit Pfeilausgabe Radio-Navigationssystem mit Farbdisplay	Zusammenarbeit mit Siemens Bosch Blaupunkt TravelPilot´ Zusammenarbeit mit VDO-Dayton	1250,- 1250,- 1900,-
Porsche	www.porsche.com	Radio-Navigationssystem mit Zentraldisplay für Pfeilanzeige, TMC Cassetten-Radio-Kombi-Navigationssystem ´PCM´ und GSM-Telefon	Becker Traffic Pro Siemens Integrated Driver Information System	2000,- 2450,-
Renault	www.renault.de	´Carminat´ Navigationssystem mit Farbdisplay, TMC Optional: Telematiksystem	Zusammenarbeit mit VDO; Dayton MS 5000 Sagem	1650,- k.A.
Rover	www.rover.de	Navigationssystem mit Zentraldisplay für Pfeilausgabe Navigationssystem mit Farbdisplay und TV-Tuner	Zusammenarbeit mit Alpine	1800,- 2850,-
Seat	www.seat.de	Radio-Navigationssystem ´MFD´ mit Farbdisplay	Zusammenarbeit mit Bosch Blaupunkt	2350,-
Skoda	www.skoda-auto.de	Radio-Navigationssystem ´MFD´ mit Farbdisplay, TMC	Bosch Blaupunkt TravelPilot	2050,- bis 2470,-
Toyota	www.toyota.de	´TNS 200´ Radio- Navigationssystem mit Pfeilausgabe Navigationssystem mit ausfahrbarem Farbdisplay ´GS300, 430, RX 300´ Radio-Kombi-Navigationssystem mit Touchscreen für zus. Klima- und Audiobedienung	Alle in Zusammenarbeit mit Aisin	1050,- 2300,- 3200,-
Volvo	www.volvocars.de	Radio-Navigationssystem mit Pfeilanzeige ´RTI-Radio-Navigationssystem´ mit ausfahrbarem Farbdisplay, TMC und DVD	Zusammenarbeit mit Mitsubishi Electronics Zusammenarbeit mit Mitsubishi Electronics	1950,- 2300,-
VW	www.volkswagen.de	´VW-Radio- Navigationssystem´ mit Pfeilanzeige über Kombiinstrument ´VW-Radio-Navigationssystem MCD´ mit Pfeilanzeige, TMC ´VW-Radio- Navigationssystem´ mit Multifunktionsdisplay	Bosch Blaupunkt ´TravelPilot RGN´ Bosch Blaupunkt ´TravelPilot´ Bosch Blaupunkt TravelPilot RGS plus Radio	1550,- 1700,- 2350,-

Endausrüster Systeme Peugeot – Volkswagen

Receivers and applications products for aftermarket (Stand alone systems without gyro / odometer interfaces):

Hersteller	AuCon Systems	L.O.S. Logic Operator
Produktbezeichnung	**AC 2002**	**PILOS**
Ausführung	Mobiler Car-PC	Mobiler Car-PC
Firmensitz	22709 Hamburg	21220 Seeretal
www	www.aucon.de	
Preis ca. [€]	2450,-	975,-
Digit. Karte Lieferant		
Lieferant	Tele Atlas	Tele Atlas
www	www.teleatlas.de	www.teleatlas.de
Unterstützte Länder	A, Benelux, CH, D, I	D
Speichermedium	CD	CD
Preis ca. [€]	130,-	130,-
Systemschnittstellen	RS232, 24V Adapter bzw. 12V-Zigarettenanzünderanschluß	RS232, RS485
Ortungssensorik: GPS/Gyroskop/Odometer.	+/-/-	+/-/-
Display Typ	Touchscreen TFT-Farbdisplay	Touchscreen monochr. Display
16:9/Diagonale [cm]	-/16	-/12,5
Besonderheiten		
Bedienung/Zielauswahl über	Touchscreen am Gerät	Touchscreen am Gerät
Infrarot-Fernbedienung	Nein	Nein
Darstellung: Karte/Pfeil	+/+	-/+
Kreuzungszoom	Ja	Nein
2 ½-D-Ansicht	Nein	Nein
Vorschlag Fahrspur		Nein
Sprachausgabe	Ja	Ja
Stauumfahrfunktion: manuell/dynamisch (TMC)	k.A./-	k.A./-
Besonderheiten	Stand-Alone System	Stand-Alone System

Receivers and applications products for aftermarket (Stand alone systems with gyro / odometer interfaces):

Hersteller	Alpine Electronics	Blaupunkt	Blaupunkt	Blaupunkt
Produktbezeichnung	**NVE-N077PS**	**TravelPilot DX-N**	**TravelPilot DX-R 70**	**TravelPilot RNS**
Ausführung	Navigationssystem	1-DIN Navigationssystem	Radio-Navigationssystem	1-DIN Radio-Navigationssystem
Firmensitz	40878 Ratingen	31132 Hildesheim	31132 Hildesheim	31132 Hildesheim
www	www.alpine.de	www.blaupunkt.de	www.blaupunkt.de	www.blaupunkt.de
Preis ca. [€]	2800,-	1950,-	1540,-	1000,-
Digitale Karte Lieferant	NavTech	Tele Atlas	Tele Atlas	Tele Atlas
www	www.navtech.com	www.teleatlas.com	www.teleatlas.com	www.teleatlas.com

Hersteller	Alpine Electronics	Blaupunkt	Blaupunkt	Blaupunkt
Produktbezeichnung	**NVE-N077PS**	**TravelPilot DX-N**	**TravelPilot DX-R 70**	**TravelPilot RNS**
Unterstützte Länder	A, ADA, Benelux, CH, D, DK, E, F, FL, GB, I, MC, P, RSM, Süd-S, V	Alpen (A, CH), Benelux (B, NL, L), D, GB, F, I, Iberisch (E, P), Skandin. (DK, N, S), USA	Alpen (A, CH), Benelux (B, NL, L), D, GB, F, I, Iberisch (E, P),Skandin. (DK, N, S), USA	Alpen (A, CH), Benelux (B, NL, L), D, GB, F, I, Iberisch (E, P),Skandin. (DK, N, S), USA
Speichermedium	DVD	CD	CD	CD
Preis ca. [€]	340,-	120,-	120,-	120,-
Systemschnittstellen	RGB, TMC, Nokia-Link	TMC		
Ortungssensorik: GPS/Gyroskop/Odometer	+/+/+	+/+/+	+/+/+	+/+/+
Display Typ	TFT-Farbdisplay	TFT-Farbdisplay	Monochr. Display	Monochr. Display
16:9/Diagonale [cm]	+/k.A.	-/12,5	-/7,4	-/7,4
Besonderheiten	Motorisch aus-/einfahrbar	Kugelfußbefestigung, autom. Helligkeit-, manuelle Kontrast-regelung	Bedienung und Anzeige in einem Gerät, Helligkeits- und Kontrast-einstellung	Bedienung und Anzeige in einem Gerät, Helligkeits- und Kontrast-einstellung
Bedienung Zielauswahl über	Infrarot Fernbedienung	Infrarot Fernbedienung	Bedienung am Gerät	Bedienung am Gerät
Infrarot Fernbedienung	Ja		Optional (Audio)	Optional
Darstellung: Karte/Pfeil	+/+	+/+	-/+	-/+
Kreuzungszoom	Ja	Ja	Nein	Nein
2 ½-D Ansicht	Ja (nur bei Autobahnen)	Nein	Nein	Nein
Vorschlag Fahrspur	Ja (nur bei Autobahnen)	Nein	Nein	Nein
Sprachausgabe	Ja	Ja	Ja	Ja
Stauumfahrfunktion: manuell/dynamisch (TMC)	+/+	+/optional	+/+	-/-
Besonderheiten		Optional ist ein aus-/-einfahrbares Display erhältlich	Kein CD-Betrieb während Navigation	Kein CD-Betrieb während Navigation

Error! Reference source not found. Alpine - Blaupunkt

Hersteller	Clarion	Clarion	Harmann / Becker	Kenwood
Produktbezeichnung	**NVS 613**	**NAX9500E**	**Traffic Pro**	**KNA-DV2200**
Ausführung	1-DIN Navigationssystem	1-DIN Radio-Navigationssystem	1-DIN Radio-Navigationssystem	
Firmensitz	64546 Mörf.-Walldorf	64546 Mörf.-Walldorf	76307 Karlsbad	63150 Heusenstamm
www	www.clarion.de	www.clarion.de	www.becker.de	www.kennwod.de
Preis ca. [€]	1800,-	2300,-	1530,-	2555,- + Display
Digitale Karte Lieferant	Tele Atlas	Tele Atlas	NavTech	NavTech

Hersteller	Clarion	Clarion	Harmann / Becker	Kenwood
Produktbezeichnung	**NVS 613**	**NAX9500E**	**Traffic Pro**	**KNA-DV2200**
www	www.teleatlas.de	www.teleatlas.de	www.navtech.com	www.navtech.com
Unterstützte Länder	Kern (D, F, I, GB), Benelux, Alpen	Kern (D, F, I, GB), Benelux, Alpen	Komplett Westeuropa auf einer DVD	Komplett Westeuropa auf einer DVD
Speichermedium	CD	CD	DVD	DVD
Preis ca. [€]	120,-	120,-		200,-
Systemschnittstellen			CD-Wechsler, Tel-In	Je nach Displayversion mit integriertem TV-Tuner, DVD-Player und Radio
Ortungssensorik: GPS/Gyroskop/Odometer	+/+/+	+/+/+	+/+/+	+/+/+
Display Typ	TFT-Farbdisplay	Farbdisplay	Monochr. Display	Farbdisplay
16:9/Diagonale [cm]	+/14,5	+/17	-/11,5	-/16,5
Besonderheiten	motorisch aus-, einfahrbar			Touchpanel KVT-920DVD: DVD-Video
Bedienung/Zielauswahl über	Bedienung am Gerät		Drehregler	
Infrarot Fernbedienung	Ja	Ja	k.A.	Ja (Audio+Video) optional (Navi.)
Darstellung: Karte/Pfeil	+/+		-/+	+/+
Kreuzungszoom	Nein	Ja	Nein	Ja
3-D-Ansicht	Ja	Nein	Nein	Ja
Vorschlag Fahrspur		Nein	Nein	Nein
Sprachausgabe	Ja	Ja	Ja	Ja
Stauumfahrfunktion: manuell/dynamisch (TMC)	k.A./-	-/-	+/+	+/-
Besonderheiten			CD-Betrieb während Navigation möglich	Je nach Displayversion mit integriertem TV-Tuner, DVD-Player und Radio

Error! Reference source not found. Clarion - Kenwood

Hersteller	Magneti Marelli	Panasonic	Pioneer Electronics
Produktbezeichnung	**RPNAV200N**	**CN-DV2000**	**AVIC 8 DVD**
Ausführung			1-DIN Navigationssystem, separates Display

Hersteller	Magneti Marelli	Panasonic	Pioneer Electronics
Produktbezeichnung	**RPNAV200N**	**CN-DV2000**	**AVIC 8 DVD**
Firmensitz	74078 Heilbronn	22525 Hamburg	47877 Willich
www	www.magnetimarelli.com	www.panasonic.de	www.pioneer.de
Preis ca. [€]	1900,-	2040,-	3100,-
Digitale Karte Lieferant	NavTech/Megneti-Marelli	NavTech	NavTech
www	www.navtech.com www.magnetimarelli.com	www.navtech.com	www.navtech.com
Unterstützte Länder	Komplett Westeuropa, Norwegen und Finnland	Komplett Westeuropa auf einer DVD	Komplett Westeuropa auf einer DVD
Speichermedium	CD	DVD	DVD
Preis ca. [€]		350,-	
Systemschnittstellen		DVD- und CD-Player	PCMCIA-Slot
Ortungssensorik: GPS/Gyroskop/Odometer	+/+/+	+/+/-	+/+/+
Display Typ	Farbdisplay	Farbdisplay	TFT-Farbdisplay
16:9/Diagonale [cm]	-/14,5	+/14,7	+/16,5
Besonderheiten	Lautsprecher integriert		Splittscreen Möglichkeit
Bedienung/Zielauswahl über	Fernbedienung		Fernbedienung und Spracherkennung
Infrarot Fernbedienung	Nein	Ja	Ja
Darstellung: Karte/Pfeil	+/+		+/+
Kreuzungszoom	Nein	Ja	Ja
3-D-Ansicht	Nein	Nein	Ja (Fahrerperspektive)
Vorschlag Fahrspur	Nein	Nein	
Sprachausgabe	Ja	Ja	Ja
Stauumfahrfunktion: manuell/dynamisch (TMC)	+/-	+/-	+/+
Besonderheiten		Mit DVD- und CD-Player	

Error! Reference source not found. Magneti Marelli - Pioneer

Hersteller	VDO-Dayton	VDO-Dayton	VDO-Dayton
Produktbezeichnung	**MS -4200**	**MS -5000**	**MS –6000**
Ausführung	1-DIN Radio-Navigationssystem	1-DIN Navigationssystem, separates Display	1-DIN Navigationssystem
Firmensitz	35576 Wetzlar	35576 Wetzlar	35576 Wetzlar
www	www.vdodayton.de	www.vdodayton.de	www.vdodayton.de
Preis ca. [€]	1550,-	1800,-	2700,-
Digitale Karte Lieferant	Tele Atlas/NavTech	Tele Atlas/NavTech	Tele Atlas/NavTech
www	www.teleatlas.com www.navtech.com	www.teleatlas.com www.navtech.com	www.teleatlas.com www.navtech.com
Unterstützte Länder	West- und Mitteleuropa, CAN, USA	West- und Mitteleuropa, CAN, USA	West- und Mitteleuropa, CAN, USA
Speichermedium	CD	CD	CD
Preis ca. [€]	130,- (Teleatlas)	130,- (Teleatlas)	130,- (Teleatlas)
Systemschnittstellen	CD-Wechsler, Telefon-In	TV-Tuner, GSM-Modul, Rückfahrkamera, Video, Spielekonsole	TV-Tuner, GSM-Modul, CD-Wechsler, TMC-Receiver
Ortungssensorik: GPS/Gyroskop/Odometer	+/+/+	+/+/+	+/+/+
Display Typ	Monochr. Display	Anti-Reflex-Farbdisplay	TFT-Farbdisplay
16:9/Diagonale [cm]	-/6,7	-/14,5	-/16,25
Besonderheiten		Splittscreen-Möglichkeit	motorisch aus-/einfahrbar, Splittscreen-Möglichkeit
Bedienung/Zielauswahl über	Bedienung am Gerät	Infrarot-Fernbedienung	Infrarot-Fernbedienung
Infrarot Fernbedienung	Ja	Ja	Ja
Darstellung: Karte/Pfeil	-/+	+/+	+/+
Kreuzungszoom	Nein	Ja	Ja
3-D-Ansicht	Nein	Nein	Nein
Vorschlag Fahrspur	Nein		
Sprachausgabe	Ja	Ja	Ja
Stauumfahrfunktion: manuell/dynamisch (TMC)	+/+	+/+	+/+
Besonderheiten			

Error! Reference source not found. VDO

I.4.4 Service Availability

I.4.4.1 Assessment for Route Guidance, Fleet Management, Theft Protection, and FCD

Threat	*Risk*	*Consequences*	*Mitigation difficulty/cost*
System failure	*M*	*M*	*M*
Power supply failure	*L*	*L*	*L/M*
Receiver/antenna failure	*L*	*L*	*M*
Onboard Interference	*L/M*	*M*	*H*
External Interference	*L*	*L/M*	*H*
Ionospheric	*L*	*L*	*M*
Jamming	*L*	*L/M*	*M*
Spoofing	*L*	*L/M*	*H*

I.4.4.2 Assessment for Emergency Call, Road Pricing, Safety & Security related Route Guidance and ADAS

Threat	*Risk*	*Consequences*	*Mitigation difficulty/cost*
System failure	*M*	*H*	*M*
Power supply failure	*L*	*H*	*L/M*
Receiver/antenna failure	*L*	*H*	*M*
Onboard Interference	*L/M*	*H*	*M*
External Interference	*L/M*	*H*	*M*
Ionospheric	*L*	*H*	*M*
Jamming	*M*	*H*	*M*
Spoofing	*L*	*H*	*H*

I.4.5 Service Charges

For the road sector a variety of different services is available. The German market, which is well developed in the domain of transport telematic devices, is used as a case study to demonstrate the variety of services available.

I.4.5.1 Telematic services:

Serviceanbieter	**ComRoad**	**Tegaron Telematik**	**Tegaron Telematik**	**Tegaron Telematik**
www	www.comroad.com	www.tegaron.de	www.tegaron.de www.audi.de/-telematics	www.tegaron.de

Bezeichnung	Off-Board-Navigation	TEGARON Scout	Audi Telematics II	Mercedes-Benz DYNAPS
Abruf/-Auslösung	Abruf über spezielles Telematikendgerät mit Positionsangabe	Abruf über spezielles Telematikendgerät mit Positionsangabe	Abruf über spezielles Telematikendgerät mit Positions-angabe	Abruf über spezielles Telematikendgerät mit Positionsangabe
Inhalt	Zukünftig Anforderung von Informationen, die zur dynamischen Off-Board-Navigation erforderlich sind	Dynamische Off-Board-Navigation	Einmaliger oder auch zyklischer Empfang von Verkehrs-informationen zur Routenberechnung und deren Dynamisierung bei zyklischem. Empfang	Einmaliger oder auch zyklischer Empfang von Verkehrs-informationen zur Routenberechnung und deren Dynamisierung bei zykl. Empfang; inkl. TeleAid
Verfügbarkeit	Rund um die Uhr	rund um die Uhr	rund um die Uhr	rund um die Uhr
Endgerät	StreetGuard (In car telematic Computer, GSM Telefon, GPS) mit zusätzlichem PocketPC zur Visualisierung und Bedienung	**C**ar **I**nterface **B**ox mit GPS-Empfänger und Anschlüssen für GPS-Antenne, Mobiltelefon und oder PDA. Ausgabe der Routenempfehlung erfolgt auf Compaq iPAQ oder Trium Mondo als Piktogramm und akustisch. Unterstützte Mobiltelef.: Siemens S25, C35, S35, M35 und SL45, Nokia 7110, 6210 und 6250	Abgestimmt auf Fahrzeuge von Audi	Abgestimmt auf Fahrzeuge von Mercedes
Endgerätepreis	k.A.	k.A.	k.A.	k.A.
D1/D2/eplus/-Viag	k.A.	+/+/-/-	+/+/-/-	+/+/-/-
Grundgebühr/-Monat €	k.A.	Keine	24,- bis 29,- inkl. SMS	24,- bis 29,- inkl. SMS
Kosten pro Abruf € (ohne Verb.endgelt)	k.A.	1,- bei Updatefunktion zus. 0,5 für jedes Update (nur bei Änderung)	Keine	Keine

I.5 Public Safety/Law Enforcement

I.5.1 Market Specific

I.5.1.1 Institutional Environment

The public safety market has traditionally been managed at a Member State. However, there are indications of increased co-operation between Member States on issues such as:

- Civil protection and international security
- Warning and informing citizens in the event of major disasters/events
- Management of safety & security related fleets (e.g. police, fire brigades, ambulances, etc.)
- Location-enhanced emergency calls (termed ‘E-112’).

Due to the facts that civil protection and international security applications are carried out by intelligence services and national security is affected the information available to the public on those applications is very limited. However it can be estimated, that it is small a niche market for specialised companies with dedicated customised products. For these reasons civil protection and international security applications will not be addresses in detail by the ERNP.

Warning and informing citizens in the event of major disasters/events is traditionally performed by radio and television broadcasting and dedicated activities (e.g. vehicles equipped with loudspeakers, direct information, etc.) in the affected area. Radionavigation systems could be helpful, either for the rescue forces to detect, monitor and manage a disastrous event; or to locate citizens within the affected area (in case they carry a combined positioning/communication device such as mobile phone, PDA, laptop, etc. equipped with Radionavigation capability).

The management of safety & security related fleets (e.g. police, fire brigades, ambulances, etc.) is another application for which Radionavigation systems can be used. Due to many differences to standard fleet management applications (see chapter **Error! Reference source not found.**) related to the types of products available, communication links used, importance of requirements, etc. it will be described in the Public Safety chapter. The different national institutional environments apply to the use of Radionavigation systems for the management of safety and security related fleets.

The implementation of E112 is the application, which is of utmost importance for the public safety / law enforcement domain and is expected to improve essentially the safety of European citizens.

National governments represented by the Ministries of Interior build in general the national institutional environment for public safety / law enforcement applications including the implementation of E112. In addition to the various Ministries of Interior the national regulatory bodies responsible for the harmonisation of frequencies are involved.

To explain the institutional background for the implementation of E112 in Europe some information on the institutional aspects related to the implementation of an enhanced emergency call in the USA (E 911) are necessary. In 1996, the FCC implemented a legislation that obliged all mobile operators to implement mobile positioning solutions across their networks for the purpose of enhancing emergency 911 calls. This legislation clearly specified the performance requirements of this public safety service, thus forcing operators to implement one of a number of high accuracy positioning solutions including E-OTD and A-GPS. This regulatory programme has been severely delayed due to technical difficulties in implementing the necessary solutions and has ultimately led to financial penalties being placed upon a number of operators for failing to comply within timescales.

To avoid such a situation the EC initiated the Coordination Group on Access to Location Information by Emergency Services (CGALIES) as a public/private partnership between public service and private sectors to find harmonised, find timely and financially sound solutions. The work of CGALIES and additional studies carried out in close cooperation with CGALIES complemented and facilitated the political discussion in the European Parliament and the Council on a new regulatory framework. In 2002, Europe decided to allow operators to implement positioning determination technologies at a rate defined by their own commercial justification rather than adopt a similar approach to the US. That said, with the adoption of the new regulatory package, the Council and the European Parliament have made the forwarding of emergency caller location by operators obligatory. Article 26 from the Directive on universal service and users' rights relating to electronic communications networks and services (2002/22/EC of 7 March 2002)2 states that:

"Member States shall ensure that undertakings which operate public telephone networks make caller location information available to authorities handling emergencies, to the extent technically feasible, for all calls to the single European emergency call number 112".

This provision established a legal requirement on operators, both fixed and mobile, for delivering location enhanced 112 (or ‘E-112’) to emergency services across Europe and became national legislation in July 2003.

In close conjunction with this new provision is the need to protect users’ privacy rights. This is dealt with in the new Directive concerning the processing of personal data and the protection of privacy in the electronic communications sector (at the time of writing, in second reading in the Council and the European Parliament). However, Article 10 from the Directive specifies that in the case of emergency calls, rights for life and for health protection take precedence over rights for privacy and therefore, data processing may be used in some cases without the user’s consent. The exception for emergency authorities allows for the temporary denial or absence of consent of a subscriber or user for the processing of location data, on a per-line basis for organisations dealing with emergency calls and recognised as such by a Member State. Any technical solutions for location enhancement must therefore meet the requirements for privacy protection.

In addition to the institutional environment addressed above the standardisation organisations described in the chapter I.6.1.1 are parts of the institutional environment for E112, too.

I.5.1.2 Application Summary

Application	Current Status		Critical	
	Existing	Radionav	Safety	Mission
Civil protection and international security	Yes	Yes	Yes	Yes
Disaster Warning	Yes	No	Yes	Yes
Fleet Management – Safety & Security	Yes	Yes	Yes	Yes
E112	Yes	Yes	Yes	Yes

Table 24 – Public safety/law enforcement application summary

I.5.2 Overview

I.5.2.1 Civil protection and international security

Civil protection and international security applications are existing today

GPS-based positioning / navigation systems for automotive- and pedestrian-use for civil protection and international security applications are in operation to some extend. In general such devices are combined with other tracking systems and dedicated communication links used by the safety authorities.

Civil protection and international security applications are both safety and mission critical

I.5.2.2 Disaster Warning

Disaster Warning applications are existing today but only conventional systems and methods are used to detect, monitor, manage the disaster and inform the citizens (radio and television broadcasting and dedicated activities e.g. vehicles equipped with loudspeakers, direct information, etc. in the affected areas).

Radionavigation systems are not used for disaster warning applications today.

Disaster warning applications are both safety and mission critical.

I.5.2.3 Fleet Management for safety and security related applications

The use of fleet management systems to track safety and security related fleets (e.g. police, fire brigades, ambulances, etc.) is disperse within the European countries. In some countries / for some safety & security authorities such applications are state-of-the-art in other countries / authorities radionavigation based fleet management systems are under implementation or envisaged for future use.

Existing systems are based on radionavigation (GPS).

Fleet Management for safety and security related applications is both safety critical and mission critical.

I.5.2.4 E112

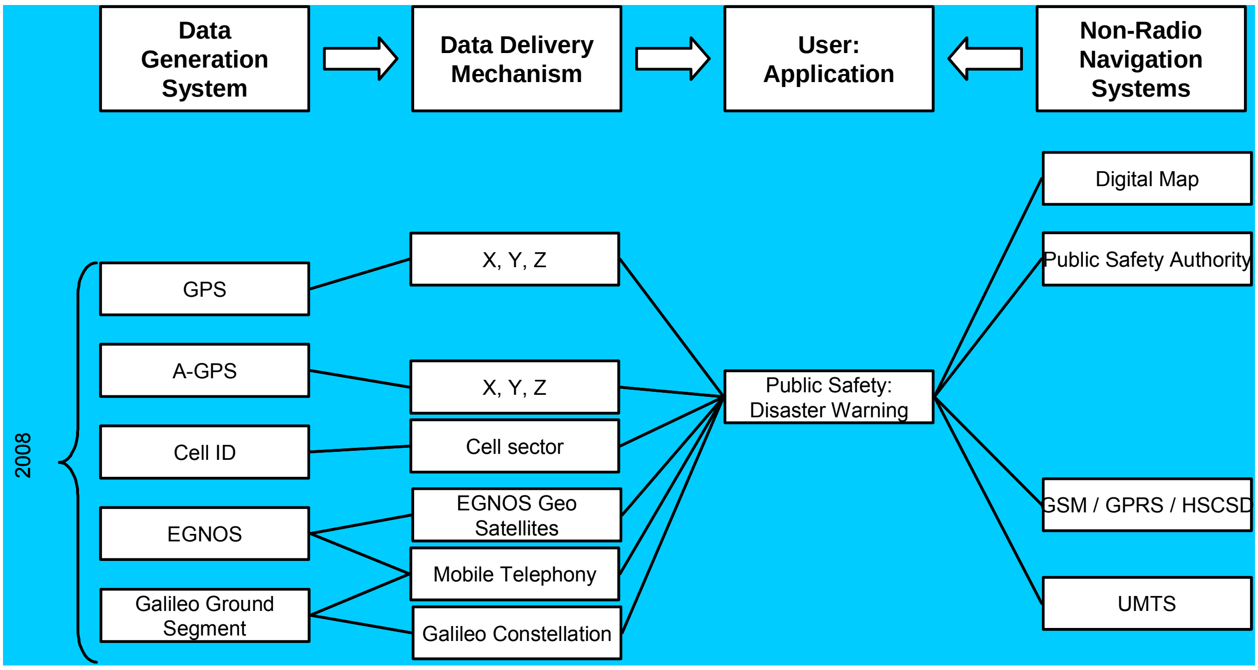
E112 is under implementation at the moment. The national governments are currently in the process to adopt the EC directive.

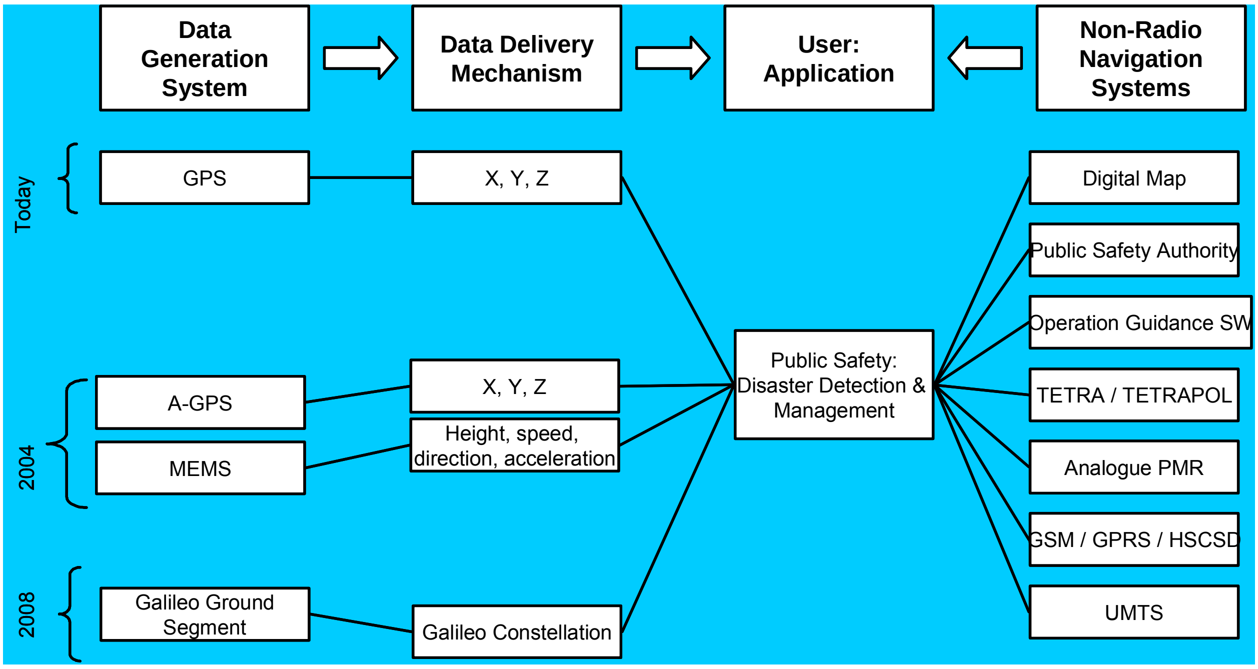
The market driven approach selected by the EC for the short term future does not oblige network providers to implement a specific technology to meet regulated parameters. Therefore in the first stage of E112 implementation a variety of technical solutions (and performance parameters) from cell ID to A-GPS is expected to be available.

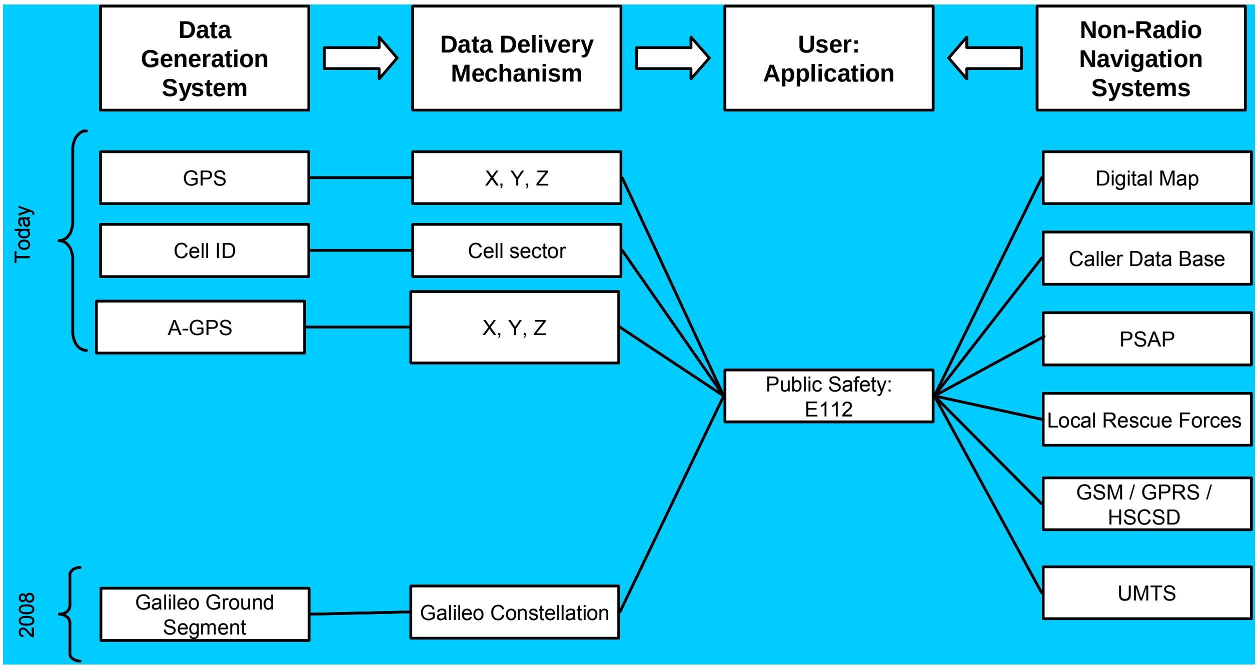
E112 is both safety and mission critical.

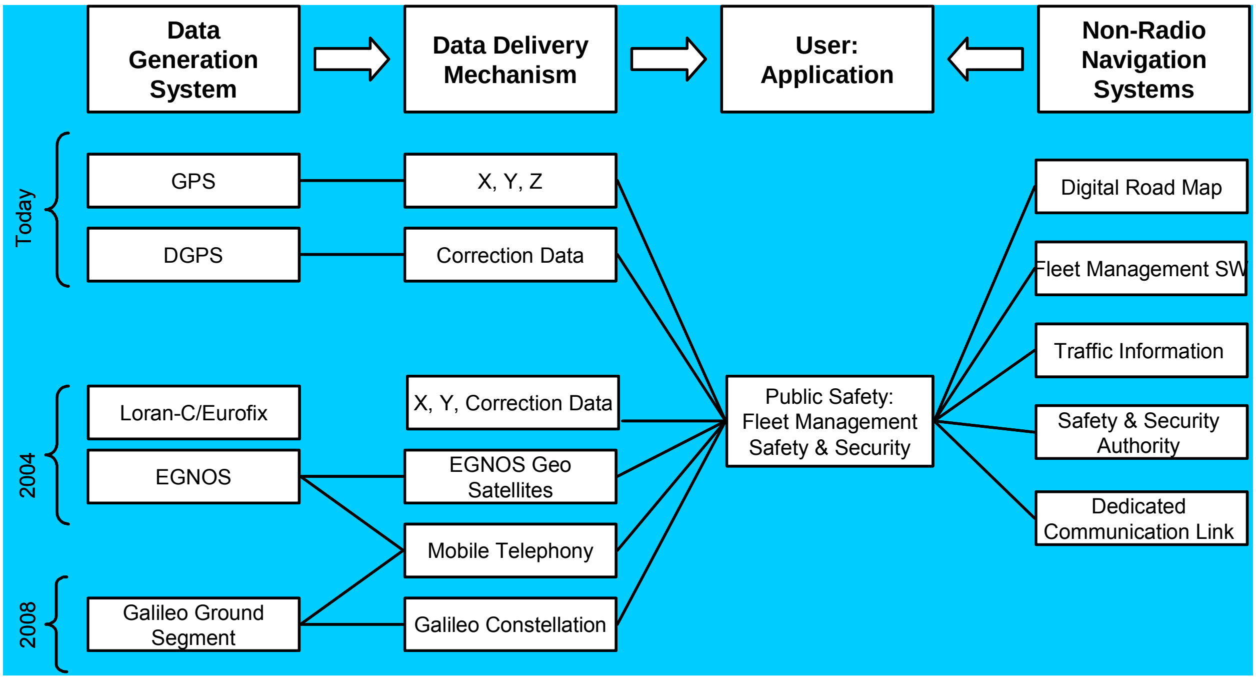
I.5.3 Service Delivery

No detailed information on civil protection and international security applications available




Data Generation System
Data Delivery Mechanism
User: Application
Non-Radio Navigation Systems
Today
GPS
X, Y, Z
2004
A-GPS
MEMS
X, Y, Z
Height, speed, direction, acceleration
2008
Galileo Ground Segment
Galileo Constellation
Public Safety: Disaster Detection & Management
Digital Map
Public Safety Authority
Operation Guidance SW
TETRA / TETRAPOL
Analogue PMR
GSM / GPRS / HSCSD
UMTS


Data Generation System
Data Delivery Mechanism
User: Application
Non-Radio Navigation Systems
Today
GPS
Cell ID
A-GPS
X, Y, Z
Cell sector
X, Y, Z
2008
Galileo Ground Segment
Galileo Constellation
Public Safety: E112
Digital Map
Caller Data Base
PSAP
Local Rescue Forces
GSM / GPRS / HSCSD
UMTS



I.5.4 Performance requirements (RNP);

No detailed information on civil protection and international security applications available

I.5.4.1 Disaster Warning

Application	Accuracy (95%)	Integrity (%)	Time to Alarm	Availability (%)
Disaster Warning	100 m	> 99	<< 1 Min.	> 99

Application	Accuracy (95%)	Integrity (%)	Time to Alarm	Availability (%)
Fleet Management Safety & Security	5 -10 m	> 99	< 1 Min.	> 99

I.5.4.2 E112

Call Routing

Urban	Suburban	Rural
~ 1 km	~ 10 km	up to ~ 35 km

Dispatching of rescue forces

Emergency services indicate that it can be useful for an emergency centre to receive as quickly as possible a first rough estimate of the caller's location (and to receive later the accurate positioning information mentioned below). The required accuracy for this initial positioning information is generally situated between 200 and 300 m (for all environments).

This initial position should be available approximately 7 seconds after the call is initiated.

Caller localisation

	Indoor	Urban	Suburban	Rural	Highway Crossroads
Caller can provide general information	10 - 50 m	10 - 50 m (25 - 150 m)	30 - 100 m (50 - 500 m)	50 - 100 m (100 - 500 m)	20 - 100 m (100 - 500 m)
Caller cannot provide any information	10 - 50 m	10 - 50 m (10 - 150 m)	10 - 100 m (10 - 500 m)	10 - 100 m (10 - 500 m)	10 - 100 m (10 - 500 m)

Emergency services requirements related to accuracy are not limited to horizontal accuracy but also concern vertical accuracy. Vertical accuracy requirements for "Mobile Caller finding" are approximately 10 - 15 m (thus enabling to make the distinction between 3-4 floors in a multi-store building.

The caller's position mentioned above must be available within 30 seconds of call initiation.

Call Cluster Detection

Emergency services also indicate that the availability of location information could be used not only to determine the caller's location but to recognise that several calls are for the same incident too ("Call cluster"). The associated accuracy requirements are approximately 150 m in urban environment and 500 m in suburban and rural environments.

In such a case, location information must be available before the call is handled, that is to say a few seconds after the initiation of the call.

Note on integrity:

Emergency services also pay a lot of attention to the reliability of the location information. Consequently, emergency services want to be provided not only with a mobile position estimate (X,Y,Z co-ordinates) but also with an indication of the reliability associated to this position estimate. Typically, the level of reliability could be indicated through the provision of a geographical area (e.g. a circle centred on the position estimate and with a radius equal to the required accuracy) and of a probability that the real position effectively belongs to the geographical area. 67% can be considered as the minimum acceptable reliability level associated to the accuracy requirements mentioned in the tables above, but it is probable that a refinement of this requirement would lead to a more demanding reliability (>95%).

Source: CGALIES – Final Report, 2002

Due to the character of the E112 application reliable location information shall be provided for all kinds of environments in which emergency situations appears. This includes the environments listed above (indoor, urban, suburban, rural, highway, crossroads) and others (remote, mountains, coast, rivers, etc.). Intention of E112 is to provide enhanced safety and security to mobile European citizens in whatever environment.

	GSM	GPRS	HSCSD	UMTS	SatCom	Bluetooth	WLAN	Trunked Radio	TETRA	TETRAPOL
Public Safety Use	Yes	Yes	Yes	Not yet	Not yet	Not yet	Not yet	Not Yet	Yes	Yes
Frequencies	900 MHz 1800 MHz	900 MHz 1800 MHz	900 MHz 1800 MHz	1885-2025 MHz 2110-2200 MHz	1.6 GHz 2,5 GHz	2,4 GHz	2,4 GHz (IEEE 802.11b, IEEE 802.11g) 5 GHz (IEEE 802.11a)	417-437 MHz	420-430 MHz	380-390 MHz
Data Rate	9,6 kbps	up to 171,2 kbps	up to 115,2 kbps	384 kbps – 2 Mbps	2,4 kbps - 64 kbps.	723 kbit/sec	11 Mbit/sec IEEE 802.11b, 54 Mbit/sec IEEE 802.11a 54 Mbit/sec IEEE 802.11g			
Coverage	Regional	Regional	Regional	Local	Global	Local (~10 m)	Local (~30-100 m)	Local (~50km)	Local/Regional	Local/Regional
Applications	No information on civil protection and international security applications available Potential for Disaster Warning Alredy used for E112	No information on civil protection and international security applications available Potential for Disaster Warning Envisaged for E112	No information on civil protection and international security applications available Potential for Disaster Warning Envisaged for E112	No information on civil protection and international security applications available Potential for Disaster Warning Envisaged for E112	No information on civil protection and international security applications available Potential for Disaster Warning	No information on civil protection and international security applications available	No information on civil protection and international security applications available Potential for Disaster Warning	No information on civil protection and international security applications available Potential for Disaster Warning	No information on civil protection and international security applications available Potential for Disaster Warning	No information on civil protection and international security applications available Disaster Management
Usage	High potential for disaster warning and	High potential for disaster warning and	High potential for disaster warning and	High potential for disaster warning and	Potential for disaster warning / management	Potential for disaster management (e.g. map	High potential for disaster warning /	Potential for disaster warning / management	Potential for disaster warning and	Disaster management Fleet

	E112	E112	E112	E112	and E112	exchange)	management and E112	and E112	E112	Management

For civil protection and international security applications there is no information on recievers and products available.

Equipment for disaster mangement applications is under development e.g. by various EC and ESA studies. It is estimated that there is no market for specific equipment for disaster warning.

Management of safety and security related fleed is generally carried out by dedicated / modified products with proprietary communication links.

For E112 mobile phones with either handset- or network-based localisation technologies is required. Localisation based on cell ID was already implemented within some countries with minor financial effort to existing handsets. Enhanced technologies i.e. E-OTD and A-GPS require either significant financial investments into the network infrastructure (E-OTD) respective a high penetration of dedicated handsets (A-GPS). Processing of localisation information and call routing requires integration into existing GSM and currently build-up UMTS infrastructure, as well as standardised interfaces to Public Safety answering Point (PSAPs). ETSI is defining such interfaces on request of the EC at the moment.

I.5.5 Service Availability

I.5.5.1 Assessment for civil protection and national security

Threat	***Risk***	***Consequences***	***Mitigation difficulty/cost***
System failure	*L*	*H*	*H*
Power supply failure	*M*	*H*	*M*
Receiver/antenna failure	*M*	*H*	*L*
Onboard Interference	*M*	*H*	*L*
External Interference	*L*	*H*	*M*
Ionospheric	*L*	*H*	*M*
Jamming	*H*	*H*	*M*
Spoofing	*H*	*H*	*H*

I.5.5.2 Assessment for disaster warning / management

Threat	***Risk***	***Consequences***	***Mitigation difficulty/cost***
System failure	*L*	*H*	*H*
Power supply failure	*M*	*H*	*M*
Receiver/antenna failure	*M*	*H*	*L*
Onboard Interference	*M*	*M*	*L*
External Interference	*L*	*H*	*M*
Ionospheric	*L*	*M*	*M*
Jamming	*M*	*H*	*M*
Spoofing	*L*	*H*	*H*

I.5.5.3 Assessment for Safety & Security related Fleet Management

Threat	Risk	Consequences	Mitigation difficulty/cost
System failure	M	H	M
Power supply failure	L	H	L/M
Receiver/antenna failure	L	H	M
Onboard Interference	L/M	H	M
External Interference	L/M	H	M
Ionospheric	L	H	M
Jamming	M	H	M
Spoofing	L	H	H

I.5.5.4 Assessment for E112

Threat	Risk	Consequences	Mitigation difficulty/cost
System failure	L	H	H
Power supply failure	M	H	M
Receiver/antenna failure	M	H	L
Onboard Interference	M	M	L
External Interference	L	H	M
Ionospheric	L	M	M
Jamming	M	H	M
Spoofing	L	H	H

I.5.6 Service Charges

The public safety applications discussed within this chapter are in general under responsibility of national safety and security authorities and financed by public funds. In case co-operation with network providers is required (e.g. localisation of hijackers, etc.) legal agreements or unsolicited co-operation between take place. Due to the fact that the implementation of enhanced localisation technologies for E112 will require significant investments for network and/or handset modification, the implementation is currently depending on the LBS business model and the upcoming roll-out of high-end LBS of the different network providers. In the USA the FCC mandate leads to increased fees for the customers.

I.6 LBS/Mass Market

I.6.1 Market Specific

I.6.1.1 Institutional Environment

Following organisations form the current institutional environment for LBS for the mass market:

The Location Interoperability Forum (LIF) is an industry initiative to promote the development of LBS launched on September 26th, 2000. It is a non-standards-setting open forum founded by Motorola, Ericsson and Nokia. LIF intends to influence standards bodies to achieve its goals. Those goals are the following:

Define a simple and secure access method that allows user appliances and Internet applications to access location information from the wireless networks irrespective of their underlying air interface technologies and positioning methods.

Promote a family of standards-based location determination methods and their supporting architectures, such as the ones based on CellSector-ID, Cell-ID and Timing Advance, E-OTD (GSM), AFLT (IS-95), and MS-Based Assisted-GPS.

Establish a framework for contributing to the global standard bodies and specification organisations to define common methods and procedures for the testing and verification of the LIF-recommended access method and positioning technologies.

Over the last two years, much work has been undertaken to develop a standard API through the Location Interoperability Forum (LIF), now under the auspices of the Open Mobile Alliance (OMA).

The entities in charge of LBS Standards in Europe are the European Telecommunications Standards Institute (ETSI) and the Third Generation Partnership Project (3GPP). ETSI is a non-profit making organisation whose mission is to produce the telecommunications standards that will be used throughout Europe and beyond. 3GPP co-operates in the production of globally applicable Technical Specifications and Technical Reports for a 3rd Generation Mobile System based on evolved GSM core networks.

The OpenGIS Consortium (OGC) consist of more than 200 corporations. Its goal is the development of interface specifications that facilitate the use of spatial and location information in internet enabled mobile environments. Such interfaces need to be designed for compatibility across regions, vertical applications, classes of users, product classes and the networks built by the various communications service providers. With the OpenLS Initiative, OGC delivers open specification interfaces for interoperable LBS. The OGC introduced plans for harmonizing OpenLS specifications with other industry forums and standards organizations such as the LIF.

By February 2000, a local positioning workgroup was created by the Bluetooth Special Interest Group (SIG) with the purpose of describing how bluetooth should be used in positioning applications, the main usage scenarios and the technical implications to the bluetooth specifications. Its goal is to ensure device inter-operability for positioning applications. Positioning information shall be freely exchanged between bluetooth devices and be compatible with other positioning technologies, such as: GPS, network assisted GPS and cellular positioning technologies.

I.6.1.2 Application Summary

Application	Current Status	Critical

	Existing	Radionav	Safety	Mission
Information services	Yes	(Yes) [149]	No	Yes
Personal routing and navigation	Yes [150]	Yes	No	Yes
Tracking services	Yes	Yes	Yes [151]	Yes
Location based billing	Yes	No [152]	No	Yes
Gaming and entertainment	Yes	No [153]	No	Yes

Table 25 – LBS/mass market application summary

I.6.2 Overview

I.6.2.1 Information services

Location information services are available today. Location based information services combine the location of the user in real time with personalised content. The main content demanded during a location information service request is the search for infrastructure, events and other services provided in the area of the user. The question may be: "Where is next ..... to me?", "Find the next ......!" or "Get me a nearby ...." Some examples for points of interest are pharmacies, ATMs, restaurants, cinemas, petrol stations, parking and so on.

Location based information services are based on cell ID today. More enhanced positioning technologies (e.g. A-GPS) are under implementation for information services at the moment.

The correct functionality of the location technology used for information services is mission critical but not safety critical.

I.6.2.2 Personal routing and navigation

Personal routing and navigation online-services are not available today for mobile phones. Off-line PDA based solutions (with vector maps for automotive use and raster maps for pedestrian use) are entering the mass market at the moment. Routing and navigation applications on Symbian platform are under preparation, too and market entry is envisaged in the forthcoming years.

Location based information services are based on cell ID today. More enhanced positioning technologies (e.g. A-GPS) are being introduced for information services at the moment.

The correct functionality of the location technology used for routing and navigation services in the mass market is mission critical but not safety critical.

149 Some information services use A-GPS, most services use network based positioning techniques, e.g. cell-id

150 Some personal routing applications are already based upon A-GPS

151 E.g. Personal Protection Services

152 Based on cell id

153 Based on cell id

I.6.2.3 Tracking services

Tracking services are available today for various dedicated user groups e.g. elderly, risk patients, children, etc.

Today's person tracking services are based on GPS; some systems provide enhanced (indoor) capabilities by signal strengths measurements of an additional signal transmitted by the tracking device.

The correct functionality of the location technology used for routing and navigation services in the mass market is mission critical and for some applications (e.g. Personal Protection Services) safety critical.

I.6.2.4 Location based billing

Location based billing is state-of-the-art in mobile telephony today. It enables zone-based pricing flexibility, which allows different tariffs for different environments or locations. The individualised zones can vary from an area as small as a house to as large as a corporate campus.

Cell ID is used today for location based billing applications

The correct functionality of the location technology used for location based billing services is mission critical but not safety critical.

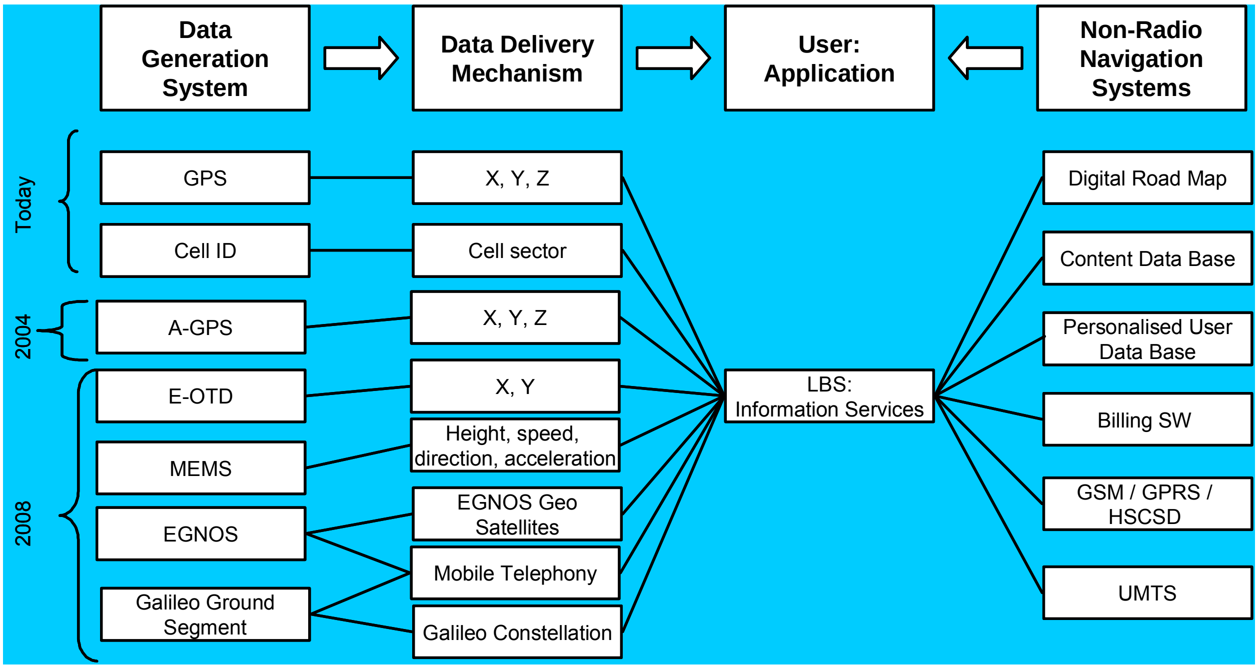
I.6.2.5 Gaming and entertainment

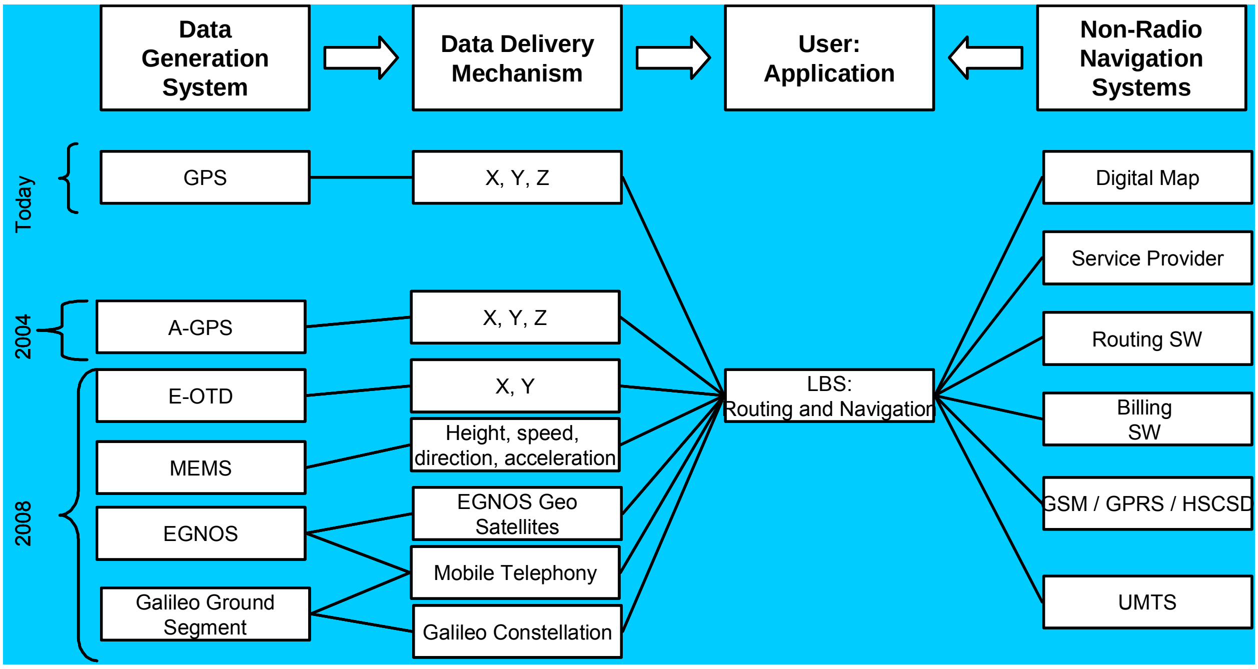
Location based gaming and entertainment do not yet exist on a large scale. However, first non commercial precursor applications (e.g. geo-caching) have started.

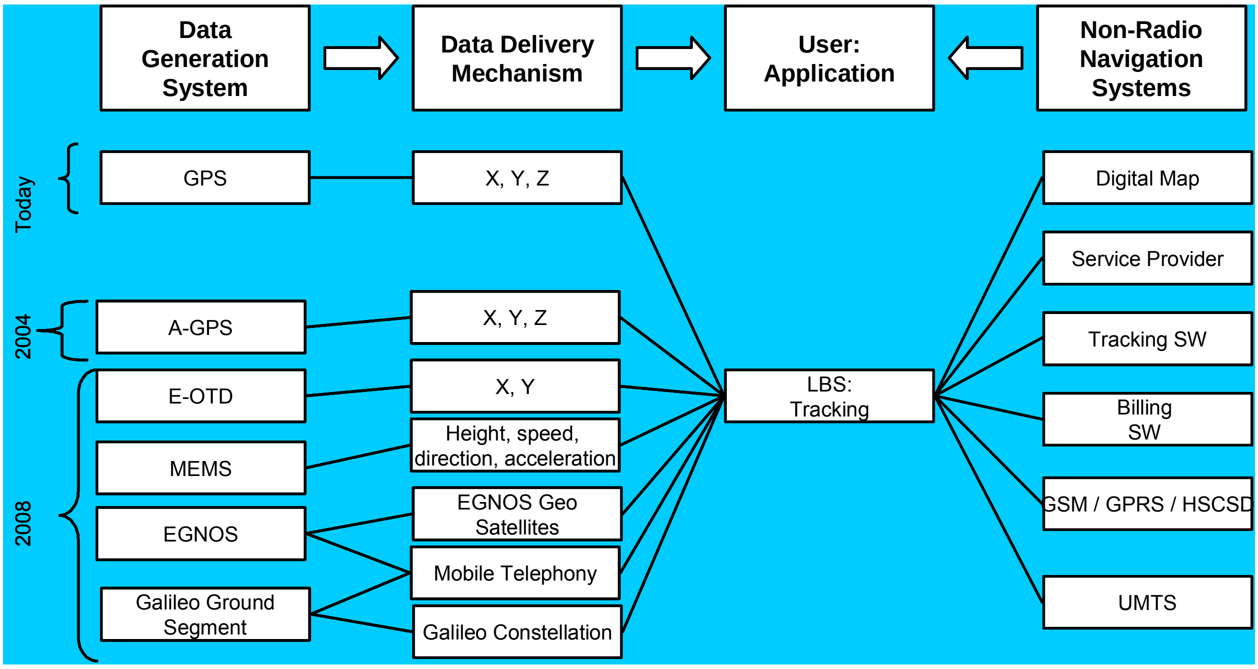
Various positioning technologies either satellite based or terrestrial could be used for the localisation of the mobile game-participants (depending on quality of localisation required by the specific game).

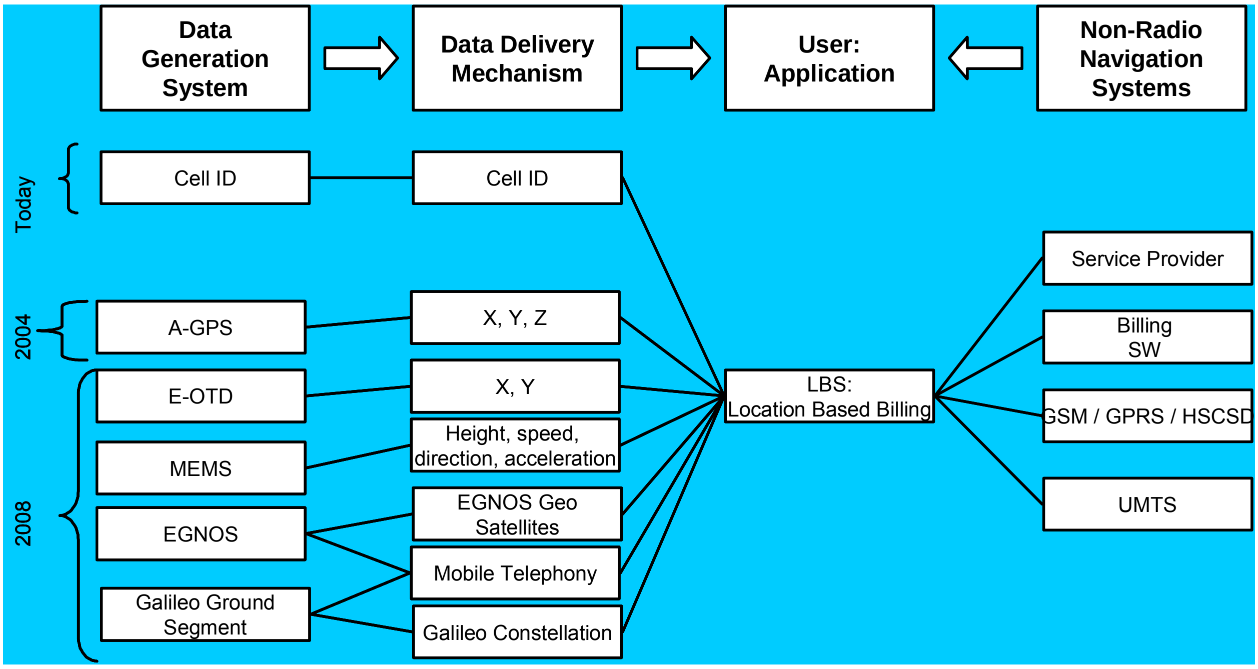
The correct functionality of the location technology used for mobile gaming and entertainment will be mission critical but not safety critical.

I.6.3 Service Delivery






Data Generation System
Data Delivery Mechanism
User: Application
Non-Radio Navigation Systems
Today
2004
2008
GPS
X, Y, Z
Digital Map
Service Provider
A-GPS
X, Y, Z
Tracking SW
E-OTD
X, Y
LBS: Tracking
Billing SW
MEMS
Height, speed, direction, acceleration
GSM / GPRS / HSCSD
EGNOS
EGNOS Geo Satellites
Mobile Telephony
UMTS
Galileo Ground Segment
Galileo Constellation


Data Generation System
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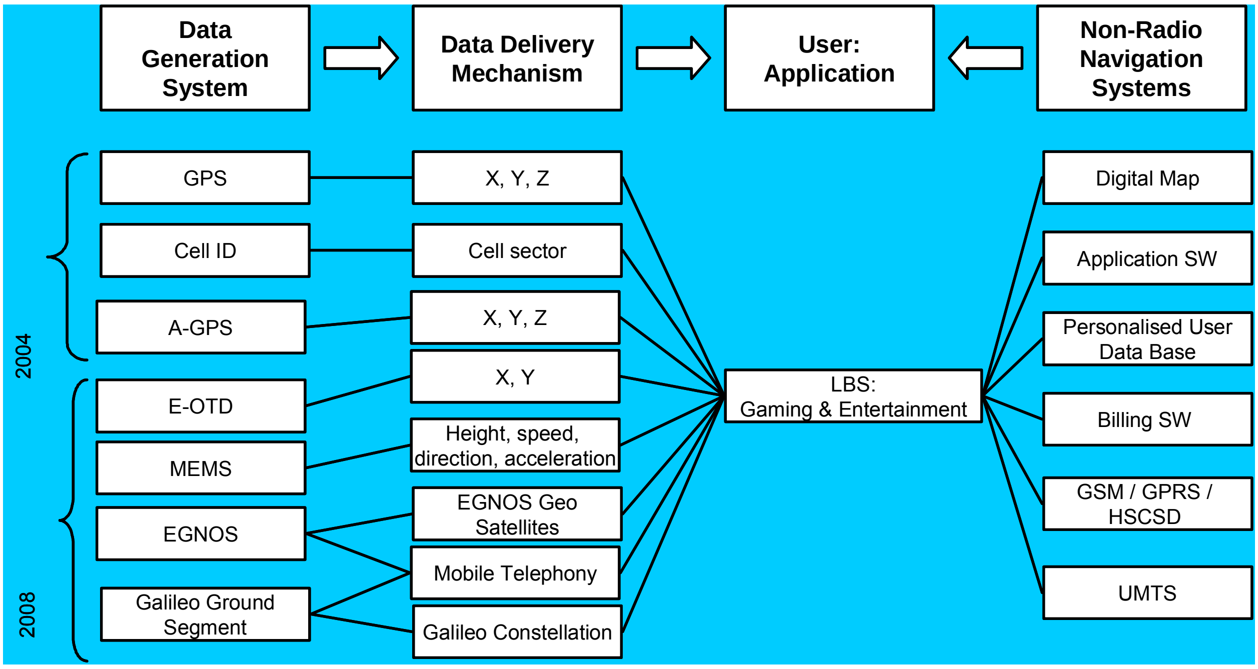


Information services

Parameter	Requirement
Accuracy	Areas of interest, point of interest [154]
Reliability	99% (1 incorrect measurement per 100)
Dimension	Defined area (cell), XY,
Coverage	Country
Availability	99% (10 min/24 h)
Latency of positioning information	< 30 sec. after a mobile originated call [155]

Source: LOCUS D2, 2001

Personal routing and navigation

Parameter	Requirement
Accuracy	10m
Reliability	98%
Dimension	X,Y,(Z)
Coverage	Country / Europe
Availability	98% (10 min/24 h)

154 According to free papers available at www.mobilepositioning.com the mass acceptance accuracy requirements for mobile yellow pages are 250 m.

155 According to free papers available at www.mobilepositioning.com, location information should be available at originated call.

Latency of positioning information	1 Minute

Tracking services

Parameter	Requirement
Accuracy	County, rural areas, > 10 m [156]
Reliability	99% (1 incorrect measurement per 100)
Dimension	Defined area (cell), XY,
Coverage	Country / Europe
Availability	99% (10 min/24 h)
Latency of positioning information	< 10 min. for an automatic request and on demand [157]

Source: LOCUS D2, 2001

Location based billing

Parameter	Requirement
Accuracy	Home zone (100 m) [158]
Reliability	99% (1 incorrect measurement per 100)
Dimension	Defined area (cell), XY,
Coverage	Country
Availability	99% (10 min/24 h)
Latency of positioning information	Call set-up duration, 3-10 sec., <30 sec.[159]

Source: LOCUS D2, 2001

Gaming and entertainment

Parameter	Requirement
Accuracy	10m
Reliability	98%

156 According to free papers available at www.mobilepositioning.com the mass acceptance accuracy requirements for fleet tracking are 30-125 m.

157 According to free papers available at www.mobilepositioning.com, location information should be available at intervals of 5 min or on-demand.

158 According to free papers available at www.mobilepositioning.com, the mass acceptance accuracy requirements are 250 m.

159 According to free papers available at www.mobilepositioning.com, location information should be available at originated call, received call and mid call.

Dimension	X,Y,(Z)
Coverage	Country / Europe
Availability	98% (10 min/24 h)
Latency of positioning information	1 Minute

The environment of the LBS applications described above include different areas. Due to the economic interests of network- and application-providers LBSs will (in general) focus on settled areas (exception: tracking services). Typical environments for LBS are urban and sub urban regions, as well as highways, major roads, railway lines, and hot spots like stations, airports, museums, etc. Especially regions with high density of business-, leisure- or holiday-travellers are preferred environments for LBS.

Following communication links are relevant for LBS applications:

	GSM	GPRS	HSCSD	UMTS	SatCom	Bluetooth	WLAN	TETRA
Road Use	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not yet
Frequencies	900 MHz 1800 MHz	900 MHz 1800 MHz	900 MHz 1800 MHz	1885-2025 MHz 2110-2200 MHz	1.6 GHz 2,5 GHz	2,4 GHz	2,4 GHz (IEEE 802.11b, IEEE 802.11g) 5 GHz (IEEE 802.11a)	420-430 MHz
Data Rate	9,6 kbps	up to 171,2 kbps	up to 115,2 kbps	384 kbps – 2 Mbps	2,4 kbps - 64 kbps.	723 kbit/sec	11 Mbit/sec IEEE 802.11b, 54 Mbit/sec IEEE 802.11a 54 Mbit/sec IEEE 802.11g	
Coverage	Regional	Regional	Regional	Local	Global	Local (~10 m)	Local (~30-100 m)	Local/Regional
Applications	Information services Personal routing and navigation Tracking services Location based billing	Information services Personal routing and navigation Tracking services Location based billing	Information services Personal routing and navigation Tracking services Location based billing	Information services Personal routing and navigation Location based billing Gaming and entertainment	Tracking services	Information services Personal routing and navigation Gaming and entertainment	Information services Personal routing and navigation Gaming and entertainment	Information services Personal routing and navigation Tracking services
Usage	High	High	High	Under implementation	Medium (dedicated applications in remote areas)	High	High	N/A

The development of receivers (mobile devices) for the LBS market is undertaken by device manufacturers, driven primarily by the commercial needs of the mobile operators. As such, these devices are manufactured in strict accordance with the standards developed within the institutional environment defined in Section H.6.1. These devices undergo exhaustive interoperability tests, but are not required to undertake specific type approval or certification other than that required in general terms by electronic equipment.

The receivers and systems are integrated by their very nature – modern devices include a range of communications media and many include multiple hybrid positioning capabilities. Applications are either provided on-board and/or centrally served, depending upon the complexity and stability of the application content.

I.6.4 Service Availability

Assessment for Information services, Personal routing and navigation (Mass Market), Gaming and entertainment

Threat	***Risk***	***Consequences***	***Mitigation difficulty/cost***
System failure	*M*	*M*	*M*
Power supply failure	*M*	*L*	*M*
Receiver/antenna failure	*M*	*L*	*M*
Onboard Interference	*M*	*M*	*H*
External Interference	*L*	*L/M*	*H*
Ionospheric	*L*	*L*	*M*
Jamming	*L*	*L/M*	*M*
Spoofing	*L*	*L/M*	*H*

I.6.4.1 Assessment for Tracking services, Location based billing

Threat	***Risk***	***Consequences***	***Mitigation difficulty/cost***
System failure	*M*	*M*	*M*
Power supply failure	*M*	*M*	*M*
Receiver/antenna failure	*M*	*M*	*M*
Onboard Interference	*M*	*M*	*M*
External Interference	*L/M*	*M*	*M*
Ionospheric	*L*	*M*	*M*
Jamming	*M*	*M*	*M*
Spoofing	*L*	*M*	*H*

I.6.5 Service Charges

LBS services are provided either directly by mobile operators or by Application Service Providers (ASPs) who route data and content through a mobile network. The provision of location information within these applications is, in general terms, under the control of the mobile operator who provides an integrated positioning/communications capability.

In today's immature market it is difficult to make generalities regarding service charges. Users of today's early applications are charged in bulk or on a pay-as-you-go basis for each location based enquiry or application request.

I.7 Agriculture

I.7.1 Market Specific

I.7.1.1 Institutional Environment

The agriculture sector is made up of farms, mostly family owned, but with a number owned by supermarket chains and animal feed manufacturers. Manufacturers of large agricultural machinery are the major players in this sector, and with the right applications, would allow very high market penetration. Auto steerage machinery is being developed for the future, with fully robotic machines introduced by 2010. Software companies supplying control and mapping software would also be potential users of positioning information.

There is a wide range of opportunities in this market for a low cost, reliable, accurate (decimetre level) positioning system and communications system, not only for land management and control of chemical input, but for robotic agricultural machinery. DGPS is used for applications such as precise ploughing, laying of fertiliser using parallel swathing and harvesting. Other potential applications are mapping farm boundaries, soil sampling, drainage routes.

There are European regulations for CAP fraud monitoring[160], covering on-the-spot-checks to enable verification of compliance with terms under which CAP funding is granted. European guidelines for chemical spraying also exist.

I.7.1.2 Application Summary

Application	Current Status		Critical	
	Existing	Radionav	Safety	Mission
Positioning for yield monitoring	Yes	Yes		Yes
Chemical spraying	Yes	Yes		Yes
Weed and pest control	Yes	Yes		Yes
Soil sampling	Yes	Yes		Yes
Crop dusting by aircraft	Yes	Yes		Yes
CAP fraud monitoring	Yes	Yes		Yes
Robotic agriculture	Yes	Yes		Yes

Table 26 – Agriculture application summary

160 Articles 15-23 of Regulation 2419/2001.

I.7.2 Positioning for Yield Monitoring

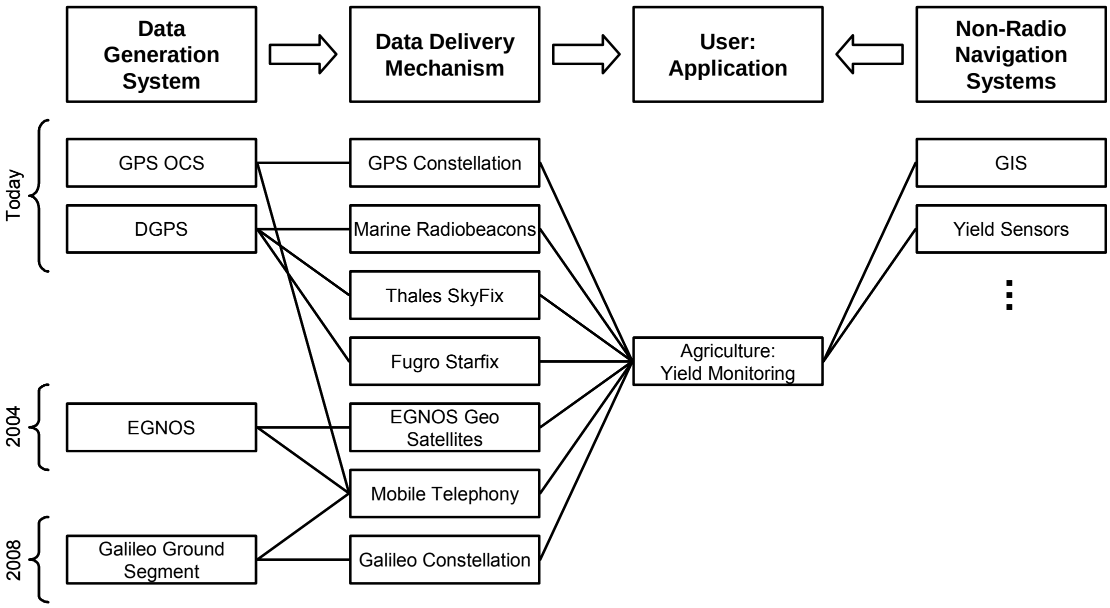
I.7.2.1 Overview

The application involves the positioning of agricultural machinery such as combine harvesters, whilst sensor equipment measures and logs fluctuations in yield. Positioning and yield data is used to produce a model of the farmland indicating high and low yield areas, which is used for the controlled application of fertilisers and pesticides.

Current systems used include GPS and DGPS, with differential corrections delivered by GSM, L-band satellite, Local Radio Network, Marine Radio Beacons, Radio LW, FM and the internet.

A positioning system for this application is mission critical, in light of its importance for cost-efficient application of chemicals, a source of the highest cost input on farms.

I.7.2.2 Service Delivery



Performance Requirements			
Positioning for Yield Monitoring	**Accuracy (95%)**	**Availability**	**Continuity**
Navigation Requirements	>1m	99%	10^{-5}

Positioning for Yield Monitoring	**Accuracy**	**Integrity requirements**	**Availability**	**Continuity requirements**
Timing Requirements	>10ms Absolute	100%	99%	100%

Yield monitoring is used across large areas of farmland, requiring regional uniform coverage across the region. The receiver needs to be small, robust, waterproof and able to withstand long periods of vibration, humidity and dust.

The positioning system should be fully supported by voice and data communications and support bi-directional high speed data. The receiver combines the GPS and differential correction signals to calculate position which is passed to a logging device and to a control interface, where it is displayed on a tracking display. Yield data from sensors is also sent to the control interface, which sends it on to the logging device, to be recorded with the position information, and simultaneously displayed on the tracking display.

In 2000, the basic cost of typical farm machinery (combine harvester) was £160 000, the cost of an L-band GPS system was £2500, the cost of a signal charger per annum was £500. A comparable radio beacon system was £500. The GPS element forms a small part of the cost – additional peripheral hardware and software add to the high cost. Not all machinery is fitted with GPS (it is optional) and upgrades to new machinery with DGPS and sensors fitted are unlikely as it is more cost-effective for a farmer to retro fit this equipment to existing machinery.

Some DGPS receivers allow only one option for correction, whilst others allow a choice of options.

I.7.2.3 Service Availability

Threat	***Risk***	***Consequences***	***Mitigation difficulty/cost***
System failure	*L*	*H*	*H*
Power supply failure	*M*	*H*	*L*
Receiver/antenna failure	*M*	*H*	*L*
Onboard Interference	*M*	*M*	*L*
External Interference	*L*	*H*	*M*
Ionospheric	*L*	*M*	*M*
Jamming	*L*	*H*	*M*
Spoofing	*L*	*H*	*H*

H = High. High risk means likely to be encountered more than once a year. High consequence means complete loss of use of the system. High mitigation difficulty/cost means that it is unlikely to be achieved.

M = Medium. Medium risk means likely to be encountered less than once a year. Medium consequence means system still usable but degraded. Medium mitigation difficulty/cost means achievable at significant cost.

L = Low. Low risk means unlikely to be encountered. Low consequence means that the system is still usable. Low mitigation difficulty/cost means achievable.

I.7.2.4 Service Charges

Service providers such as Fugro OmniSTAR and Racal provide a satellite differential service by subscription. Revenue is collected through a licence fee at 3 month, 1, 2 and 3 year rates via the service provider. Some satellite differential service providers offer farm licences that provide a differential service within a set radius of a base station at reduced rates. Marine radio beacon services are free although these suffer from radio wave propagation and range problems and electrical interference. EGNOS is expected to provide a free service.

I.7.3 Chemical Spraying

I.7.3.1 Overview

This application is to position the tractor using DGPS. The tractor is used as a multiple task tool for pulling spraying equipment, drilling seed etc. A visual aid inside the tractor indicates on or off track, so that the driver is able to steer the vehicle manually or automatically in a straighter line and determines exact paths with minimal overlap of travel. Previously collected data from the yield sensors is now utilised in controlling the flow rate of chemicals required. The position is constantly logged along with flow rate data to generate mapping models and provide a historic audit trail. European guidelines encourage leaving a 6m wide path clear of chemical next to any stream or river.

Current systems used include GPS and DGPS, with differential corrections delivered by GSM, L-band satellite, Local Radio Network, Marine Radio Beacons, Radio LW, FM and the internet.

A positioning system for this application is mission critical, in light of its importance for cost-efficient application of chemicals, a source of the highest cost input on farms and its importance in adhering to European guidelines.

I.7.3.2 Service Delivery

Service delivery is as for yield monitoring (See H.7.2.2 for diagram), except that the internet (mobile telephony) is not used as a means of data delivery.

Performance Requirements			
Chemical Spraying	**Accuracy (95%)**	**Availability**	**Continuity**
Navigation Requirements	>1m	99%	10^{-5}

Chemical Spraying	Accuracy	Integrity requirements	Availability	Continuity requirements
Timing Requirements	>1ms Absolute	99%	99%	99%

Chemical spraying is carried out across large areas of farmland, requiring regional uniform coverage across the region. The receiver needs to be small, robust, waterproof and able to withstand long periods of vibration, humidity and dust.

The positioning system should be fully supported by voice and data communications, support bi-directional high speed data and be able to receive weather data. The receiver combines the GPS and differential correction signals to calculate position, which is passed to a logging device and to a control interface, where it is displayed on a tracking display. Flow rate data from flow rate sensors is also sent to the control interface, which sends it on to the logging device, to be recorded with the position information, and simultaneously displayed on the tracking display.

Not all sprayers have GPS fitted (it is optional) and there is a retro fit market for bolt-on systems such as RDS, LH AGRO, Ag-Leader, Mico-Tac and Mid-tech.

I.7.3.3 Service Availability

[TBD]

I.7.3.4 Service Charges

Service providers such as Fugro OmniSTAR and Racal provide a satellite differential service by subscription. Revenue is collected through a licence fee at 3 month, 1, 2 and 3 year rates via the service provider. Some satellite differential service providers offer farm licences that provide a differential service within a set radius of a base station at reduced rates. Marine radio beacon services are free although these suffer from radio wave propagation and range problems and electrical interference. EGNOS is expected to provide a free service.

I.7.4 Weed and Pest Control

I.7.4.1 Overview

This application monitors weed and pests by constantly logging the position of the crop walker using DGPS. The crop walker searches for weed or pest infestation within the field. The position of these infestations is recorded and plotted on to the farm map. This information is then loaded into the spray control machine. DGPS now gives guidance to the infestation patch. Once located, the spray machine can automatically switch on and apply the correct chemical flow rate. Position, time and chemical flow rate data is logged for future reference and complete audit trail.

Current systems used include GPS and DGPS, with differential corrections delivered by GSM, L-band satellite, Local Radio Network, Marine Radio Beacons, Radio LW and FM.

A positioning system for this application is mission critical, in light of its importance for improving the identification of pest and weed infested areas and for the appropriate application of pesticides, thereby minimising both costs and reduction in yield.

I.7.4.2 Service Delivery

Service delivery is as for yield monitoring (See H.7.2.2 for diagram), except that the internet (mobile telephony) is not used as a means of data delivery.

Performance Requirements			
Weed and Pest Control	**Accuracy (95%)**	**Availability**	**Continuity**
Navigation Requirements	>1m	99%	10^{-5}

Weed and Pest Control	**Accuracy**	**Availability**
Timing Requirements	>1ms Absolute	99%

Weed and pest control is used across large areas of crops, requiring regional uniform coverage across the region. The receiver, which is carried in backpack by the crop walker, needs to be small, robust, waterproof, lightweight and with its own power supply.

The positioning system should be fully supported by voice and data communications, support bi-directional high speed data and be able to receive weather data. The receiver combines the GPS and differential correction signals to calculate position, which is passed to a logging device when the crop walker has located weeds or pests in the crop. Both position and the source of the infestation are logged and the data is used to generate a map of the problem area, which is then used by the spraying machine.

I.7.4.3 Service Availability

[TBD]

I.7.4.4 Service Charges

Service providers such as Fugro OmniSTAR and Racal provide a satellite differential service by subscription. Revenue is collected through a licence fee at 3 month, 1, 2 and 3 year rates via the service provider. Some satellite differential service providers offer farm licences that provide a differential service within a set radius of a base station at reduced rates. Marine radio beacon services are free although these suffer from radio wave propagation and range problems and electrical interference. EGNOS is expected to provide a free service.

I.7.5 Soil Sampling

I.7.5.1 Overview

A whole field is divided into 1m square grids and within a set area, usually an acre, 16 points are determined and soil samples taken. The DGPS position is attached to each sample and all the data logged. Samples are then sent away for analysis to determine the soil structure nutrient levels etc. A prescription is then written for the specific field and loaded into the software. The software prescription is then loaded into a fertiliser spreading apparatus. DGPS will now position and guide the spray machine to affected areas and automatically apply correct flow rate.

Current systems used include GPS and DGPS, with differential corrections delivered by GSM, Local Radio Network, Marine Radio Beacons, Radio LW and FM.

I.7.5.2 Service Delivery

Service delivery is as for yield monitoring (See H.7.2.2 for diagram), except that the internet (mobile telephony) is not used as a means of data delivery.

Performance Requirements			
Soil Sampling	**Accuracy (95%)**	**Availability**	**Continuity**
Navigation Requirements	>1m	99%	10^{-5}

Soil Sampling	**Accuracy**	**Integrity requirements**	**Availability**	**Continuity requirements**
Timing Requirements	>1ms Absolute	100%	99%	100%

Soil samples can be taken from anywhere across large areas of farmland, requiring regional uniform coverage across the region. The receiver needs to be small, robust, waterproof and able to withstand long periods of vibration, humidity and dust.

The positioning system should be fully supported by voice and data communications, support bi-directional high speed data and be able to receive weather data. The system is used with specialised software and vehicles/equipment. The receiver combines the GPS and differential correction signals to calculate position, which is passed to a logging device wherever a soil sample is taken.

I.7.5.3 Service Availability

[TBD]

I.7.5.4 Service Charges

Service providers such as Fugro OmniSTAR and Racal provide a satellite differential service by subscription. Revenue is collected through a licence fee at 3 month, 1, 2 and 3 year rates via the service provider. Some satellite differential service providers offer farm licences that provide a differential service within a set radius of a base station at reduced rates. Marine radio beacon services are free although these suffer from radio wave propagation and range problems and electrical interference. EGNOS is expected to provide a free service.

I.7.6 Crop Dusting

I.7.6.1 Overview

By using GPS / DGPS, the fixed or rotor wing aircraft can be positioned in the correct field to be sprayed or seeded. Crop dusting aircraft are fitted with a computer logging system, rolling map display and a visual steering indicator all linked to the DGPS. The system determines the area and application rate, possibly using historic data from a previous soil sample, crop walking or crop yield data. Controlled lines of flying and the automatic flow rate of chemicals are generated from the onboard computer mapping system. The position and chemical flow rate along with other data is constantly recorded. This data generates mapping for historic reference and audit trail.

Current systems used include GPS and DGPS, with differential corrections delivered by Local Radio Network, Marine Radio Beacons, Radio LW and FM.

A positioning system for this application is mission critical, in light of its importance for the accurate application of pesticides over crop areas and minimising incorrect application over environmentally sensitive and populated areas.

I.7.6.2 Service Delivery

Service delivery is as for yield monitoring (See H.7.2.2 for diagram), except that GSM and the internet (mobile telephony) are not used as a means of data delivery.

Performance Requirements			
Crop Dusting by Aircraft	**Accuracy (95%)**	**Availability**	**Continuity**
Navigation Requirements	>1m	99%	10^{-5}

Crop Dusting by Aircraft	**Accuracy**	**Availability**
Timing Requirements	>1ms Absolute	99%

The application is used across large areas of farmland, requiring regional uniform coverage across the region. The receiver needs to be small, robust, waterproof and able to withstand long periods of vibration, humidity and dust.

The positioning system should be fully supported by voice and data communications and support bi-directional high speed data. The receiver is connected to a computer logging system, map display and a visual steering indicator on the aircraft.

Crop dusters are now being fitted with DGPS system as standard in most cases. Examples of receivers include the Del Norte Flying Flagman.

I.7.6.3 Service Availability

[TBD]

I.7.6.4 Service Charges

Service providers such as Fugro OmniSTAR and Racal provide a satellite differential service by subscription. Revenue is collected through a licence fee at 3 month, 1, 2 and 3 year rates via the service provider. Some satellite differential service providers offer farm licences that provide a differential service within a set radius of a base station at reduced rates. Marine radio beacon services are free although these suffer from radio wave propagation and range problems and electrical interference. EGNOS is expected to provide a free service.

I.7.7 CAP fraud monitoring

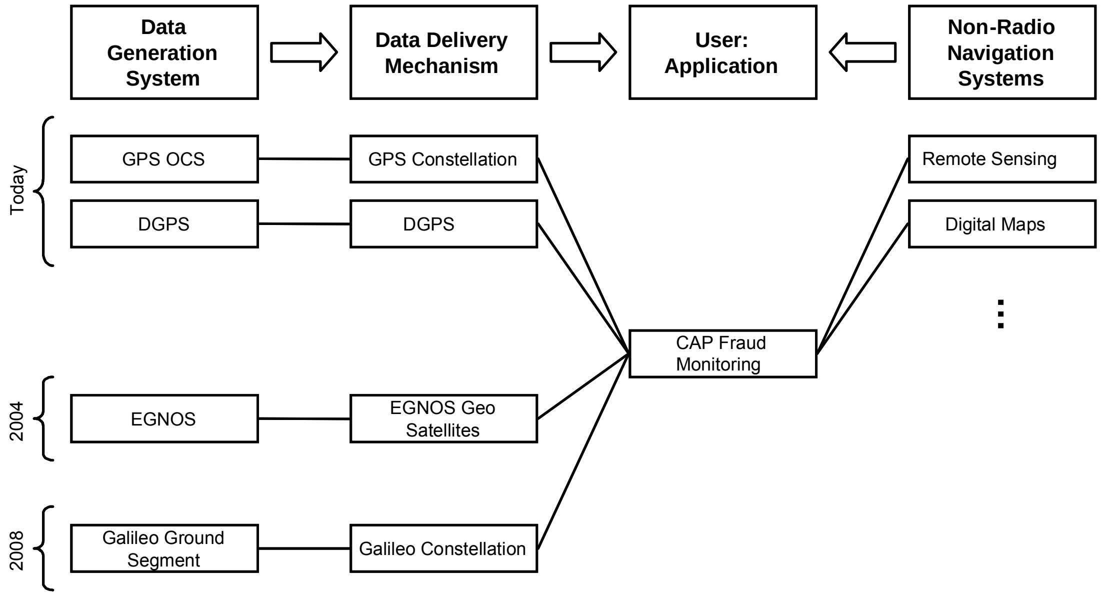
I.7.7.1 Overview

This application involves carrying out on-the-spot-checks of agricultural areas (parcels) that have been declared for EC CAP funding, in order to verify their compliance with the terms under which aid has been granted. An independent inspection is required to verify agricultural parcel boundaries and to verify eligibility for CAP funding.

The check consists of two parts – a preliminary verification of all declared agricultural parcels against map data, and a physical inspection of a sample of at least half the total areas to verify the crops, their quality and the precise size of the parcels. Non-eligible areas such as roads, ditches, buildings, woodland and permanent crops are excluded from the measurements.

Radio navigation systems such as GPS, DGPS and single and dual frequency GPS systems are used for this mission critical application. EGNOS and Galileo are expected to improve accuracy and reliability.

I.7.7.2 Service Delivery



Technical tolerance margins are applied to land measurement systems. For GPS systems, the tolerance is set as a buffer at 1.25m times the perimeter of the agricultural parcel. For single and dual frequency GPS systems the tolerance is either set at no greater than 2% of the area of the parcel or a buffer of 0.35m times the perimeter.

The application environment is carried out across large areas of farmland, requiring regional uniform coverage.

GPS stand-alone systems are either broad-public GPS equipment, developed principally for navigation purposes but including a function for area-calculation, or alternatively dedicated packages developed for agricultural applications on a palm or pocket-PC environment.

Examples of GPS stand-alone equipment are:

- ARCPAD on PC - this system from ESRI has the ability to use different projection systems in real time and the possibility to overlay compressed imagery)
- ISAGRI - this company proposes a dedicated application for parcel measurement based on Pocket PC
- D3E Electronique
- GARMIN Etrex
- GARMIN GPS12
- METERGRAPH D & F System
- Palm area SATCON – this company proposes dedicated applications for agriculture: Positioning field observation or soil-sample, recording farming practices with date and co-ordinates, area measurements. Palm Area is also used by regional Administrations (FR, DE) for IACS on-the-spot controls
- PRESTILEM - French dealer of SATCON, but proposes also an antenna
- SOKKIA Imap software

I.7.7.3 Service Availability

[TBD]

I.7.7.4 Service Charges

[TBD]

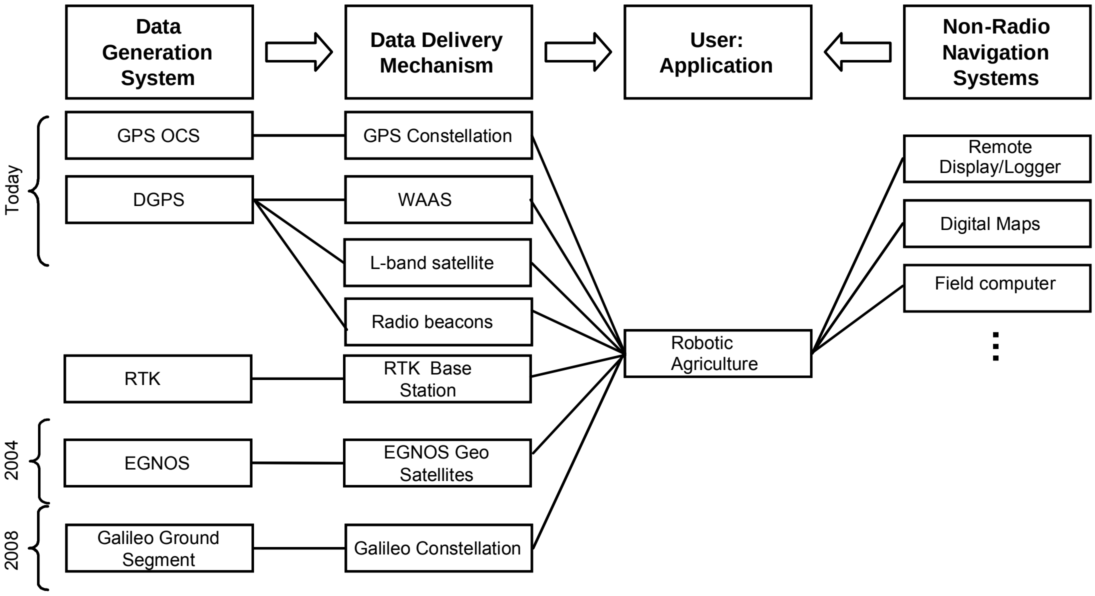
I.7.8 Robotic Agriculture

I.7.8.1 Overview

This involves the full or partial automisation of agricultural machinery such as tractors. The fully automated tractor will carry out rotary tillage, seeding, harvesting, spraying without the need for an operator. Partial automation is where the tractor is controlled automatically in a straight line with the operator controlling the turns only.

Systems currently used include GPS with DGPS via WAAS, L-band satellite and/or beacon for partially and fully automated machinery and RTK systems for fully automated machinery, where greater accuracy is achieved. The application is both mission and safety critical in that control of the machine has been transferred from a human operator to an automated system.

I.7.8.2 Service Delivery



Navigation Performance Requirements		
Robotic agriculture	RTK	DGPS
Accuracy (95%)	2.5cm	15 - 25cm

The application environment is carried out across large areas of farmland, requiring regional uniform coverage. The communications functionality required for RTK demands high bandwidth and data flow rates on permanently open links. A typical radio link required for RTK is in the UHF, VHF, or spread spectrum radio band. Radios operate best within line of sight or with a repeater.

GPS receivers can be used in conjunction with visual guidance systems such as a light bar to assist the operator in cases of partial automation of machinery. The receivers are integrated with a navigation controller and data radio for communications for fully automated systems, with interfacing display and logging systems, field computer and/or maps. Examples of receivers are Trimble, AgSystems and Rinex.

I.7.8.3 Service Availability

[TBD]

I.7.8.4 Service Charges

Service providers such as Fugro OmniSTAR and Racal provide a satellite differential service by subscription. Revenue is collected through a licence fee at 3 month, 1, 2 and 3 year rates via the service provider. Some satellite differential service providers offer farm licences that provide a differential service within a set radius of a base station at reduced rates. Marine radio beacon services are free although these suffer from radio wave propagation and range problems and electrical interference. EGNOS is expected to provide a free service.

I.8 Scientific

I.8.1 Market Specific

I.8.1.1 Institutional Environment

Guidance

- *indicate the institutional environment for each market sector*
- *consider the global, regional and national regulatory regimes as required.*

Use the “normal” style

I.8.1.2 Application Summary

Application	Current Status		Critical	
	Existing	Radionav	Safety	Mission
Land surveying and GIS	Yes	Yes		Yes

Table 27 – Scientific, time and frequency application summary

I.8.2 Land surveying and GIS mapping

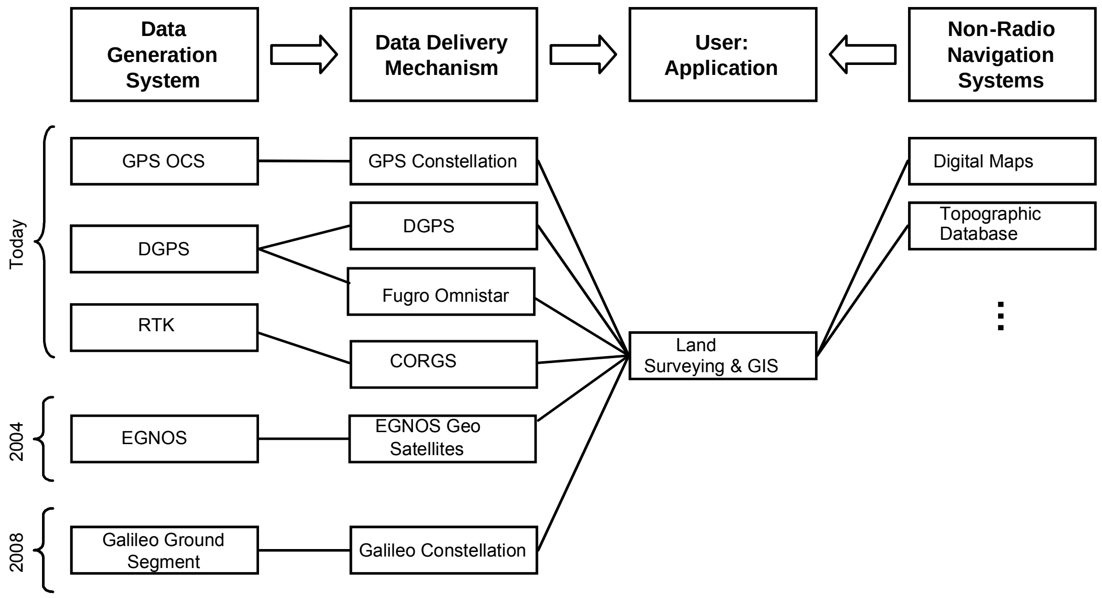
I.8.2.1 Overview

Land surveyors at a national level use positioning systems for survey control and the capture of topographic detail for the creation of mapping and local site detail. Data collectors for the geographical information industry (GIS) use positioning systems to record the physical location of assets. It can also offer an efficient quality assured method of deriving accurate positions of topographic detail in real time.

Currently, GPS with ground-based augmentation, via a network of reference stations (CORGS) and Real Time Kinematic (RTK) systems is being used to capture detail. GPS has been used in land surveying at a national level over the last 10 years and in selective environments for GIS mapping. Other technologies currently used are satellite based augmentation systems such as Fugro Omnistar and other low cost ground based augmentation systems. GSM cannot meet the 10cm accuracy required for this application.

The positioning for land surveying is mission critical.

I.8.2.2 Service Delivery



Performance Requirements			
Land Surveying and GIS mapping	**Accuracy (95%)**	**Availability**	**Continuity**
Navigation Requirements	10cm	99%	10^{-7}

Land Surveying and GIS mapping	**Accuracy**	**Integrity requirements**	**Availability**	**Continuity requirements**
Timing Requirements	<1ms Absolute	<3s TTA	99%	10^{-7}

The application environment requires global uniform coverage. The receiver needs to be simple to use, lightweight, have low power requirements and provide co-ordinates which are compatible with GPS and traditional reference systems.

The communications functionality required in precise positioning of assets demand high bandwidth and data flow rates on permanently open links. A typical radio link required for RTK is in the UHF, VHF, or spread spectrum radio band. Radios operate best within line of sight or with a repeater.

I.8.2.3 Service Availability

[TBD]

I.8.2.4 Service Charges

Revenue for code with an accuracy of 10cm may be on account, payable by any means, including through contracts or Service Level Agreements. Service providers such as Fugro OmniSTAR and Racal provide a satellite differential service by subscription. Revenue is collected through a licence fee at 3 month, 1, 2 and 3 year rates via the service provider. EGNOS is expected to provide free services.

I.9 Time and Frequency

I.9.1 Market Specific

I.9.1.1 Institutional Environment

Accurate time and frequency may be disseminated via radionavigation sources, or simply via radio sources. GPS is a radionavigation source that may also be used to provide accurate UTC time. MSF is a radio time signal transmitted from a ground-based transmitter which may be used to calibrate both time and frequency. DCF77 and TDF are additional radio time signals provided in Germany and France respectively. Whilst GPS is provided world-wide, the radio time sources all have a range between 1000 and 2000 km, and are consequently providing only a regional service.

The time signal provided by these sources currently has a number of applications, which are discussed in the following sections.

I.9.1.2 Application Summary

The time and frequency applications which will be described are summarised in the table below. The table also indicates, for each application, whether the application currently exists, whether radionavigation systems are currently used (in this case a radio time dissemination system), and whether it is safety or mission critical.

Application	Current Status		Critical	
	Existing	Radionavigation system (or radio time dissemination system)	Safety	Mission
TV and Radio Broadcasting	Yes	Yes		Yes
Telecommunications	Yes	Yes		Yes
Electricity supply	Yes	Yes		Yes
Metrology / clocks	Yes	Yes		Yes
Time tagging	Yes	Yes		Yes

Table 28 – Scientific, time and frequency application summary

I.9.2 TV and Radio Broadcasting

I.9.2.1 Overview

TV Broadcasting

Time sources are used in TV broadcasting to synchronise the different elements of a broadcasting system. For example, a TV studio will often have a central time source, such as a receiver of MSF, DCF77, or GPS signals. Feeds from this central time source are connected to all the TV cameras in the studio and to the central unit that records the TV programme.

The time is encoded in every frame of a TV, film or video picture as a 'time code'. This is used to synchronise individual picture frames, and allows versatile editing of TV, video and film.

In television studio operations, the time code is generated by a studio master sync generator, and distributed from a central point. The time generators usually derive their timing from an atomic clock, which may be calibrated using radio time signals. Studios usually maintain two or three clocks, and automatically switch over if one fails.

Digital TV broadcasting will also require an accurate source of time, which may be obtained from a radio time signal or a radionavigation signal, even though the time disseminated by digital TV is known to suffer from delays due to digital signal processing.

Radio broadcasting

Time sources are currently used in analogue radio broadcasting to provide time checks to indicate the first UTC second of each UTC hour. These time signals are more commonly know as the time 'pips'. The time source is also used to assist in programme scheduling.

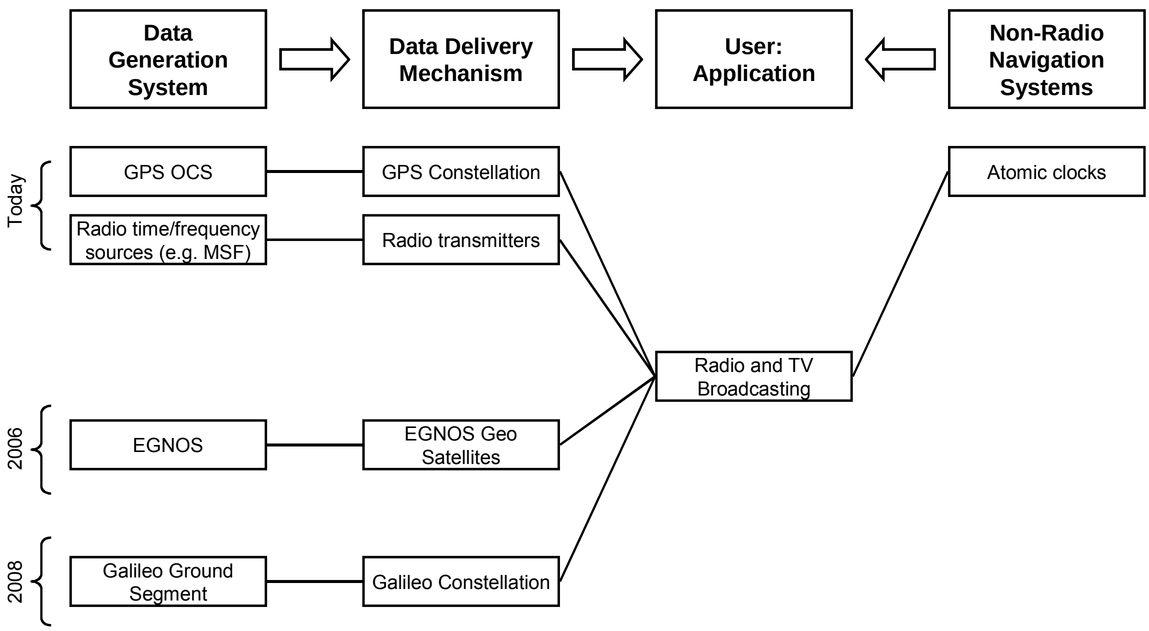
In the radio broadcasting system known as Radio Data System (RDS), data is transmitted along with the FM radio signal. The time is encoded as part of the data that is transmitted in the RDS message sets. The source of this time can be a radio time signal or a radionavigation signal.

Digital radio broadcasting will also require an accurate source of time. Again the time disseminated by digital radio may suffer from delays due to digital processing.

I.9.2.2 Service Delivery

Service delivery flow diagram

The mechanism for service delivery is as shown in the diagram below.



Performance requirements

The performance requirements are estimated in the table below.

Application	UTC Time Accuracy	Availability

Radio studio synchronisation	< 20 ms	0.95
Radio time checks	< 10 ms	0.99
RDS Data	< 10 ms	0.99
TV studio time synchronisation	< 5 ms	0.999

I.9.2.3 Service Availability

The following table assesses the potential for service disruption to a radio time signal source of time.

Threat	Risk	Consequences	Mitigation difficulty/cost
System failure	M	M	L
Power supply failure	L	M	L
Receiver/antenna failure	L	M	L
Onboard Interference	L	M	L
External Interference	H	M	L
Ionospheric	H	M	L
Jamming	L	M	L
Spoofing	L	M	L

The following table assesses the potential for service disruption to a radionavigation source of time such as GPS.

Threat	Risk	Consequences	Mitigation difficulty/cost
System failure	L	H	M
Power supply failure	L	H	M
Receiver/antenna failure	L	H	M
Onboard Interference	L	H	M
External Interference	L	H	M
Ionospheric	M	M	M
Jamming	M	H	M
Spoofing	M	H	M

Impact of service disruption

A number of TV and radio broadcasting systems use a radio time source or a radionavigation time source as the default source of UTC time. Each of these systems will normally have a backup atomic clock which will maintain time even in the absence of a radio time signal or GPS signal.

Radio time equipment requirements

Radio time signal receivers are relatively cheap and simple devices. GPS receivers are slightly more complex and slightly more expensive

Radio time dissemination coverage requirements

Coverage needs to extend only in the region that it is used. This means that regional coverage is required.

Responsibility for current radio time signal services

MSF is funded by the UK Department of Trade and Industry and Operated by the National Physical Laboratory. DCF77 is the responsibility of the German Physikalisch-Technische Bundesanstalt (PTB). TDF is the responsibility of French Government. The GPS service is the responsibility of the US Government.

I.9.2.4 Service Charges

Currently the MSF, DCF77 and TDF radio time signals are provided free of charge to all users. GPS is also provided free of charge.

I.9.3 Telecommunications

I.9.3.1 Overview

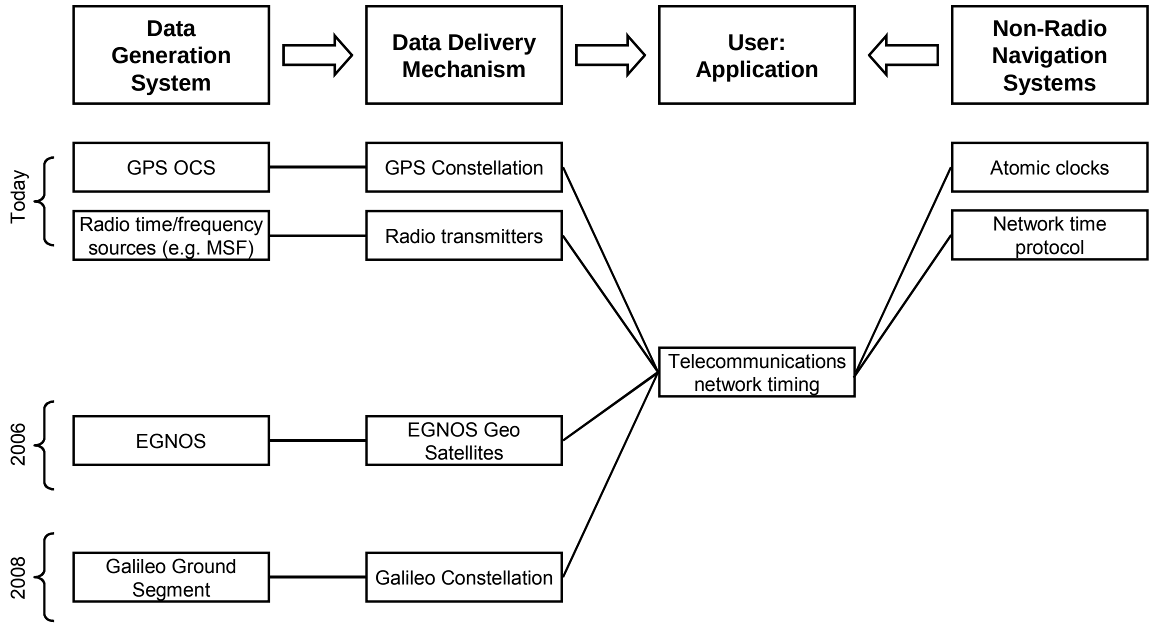
Telecommunications networks operating nationally or internationally require time synchronisation, so that different parts of a network can communicate efficiently with each other. Atomic clocks may be used to maintain a local time standard for a particular part of the telecommunications network, with the atomic clocks being periodically updated with GPS or radio time signal sources.

Modern telecommunications networks also employ time-division multiple access (TDMA) techniques in which access to the network is organised into specific time slots. Networks of this type must be synchronised to a common time source such at UTC in order to operate efficiently.

I.9.3.2 Service Delivery

Service delivery flow diagram

The mechanism for service delivery is as shown in the diagram below.



Performance requirements

The performance requirements are estimated in the table below.

Application	UTC Time Accuracy	Availability
Synchronizing telecommunications networks	1 ms	0.999

I.9.3.3 Service Availability

The following table assesses the potential for service disruption to a radionavigation source of time.

Impact of service disruption

The potential for service disruption to a radio time signal or a radionavigation source of time was described in the tables in Section H.8.2.3.

Responsibility for current radio time signal services

The responsibility of the MSF, DCF77, TDF and GPS services was discussed in Section H.8.2.3.

I.9.3.4 Service Charges

Currently the MSF, DCF77 and TDF radio time signals are provided free of charge to all users. GPS is also provided free of charge.

I.9.4 Electricity supply

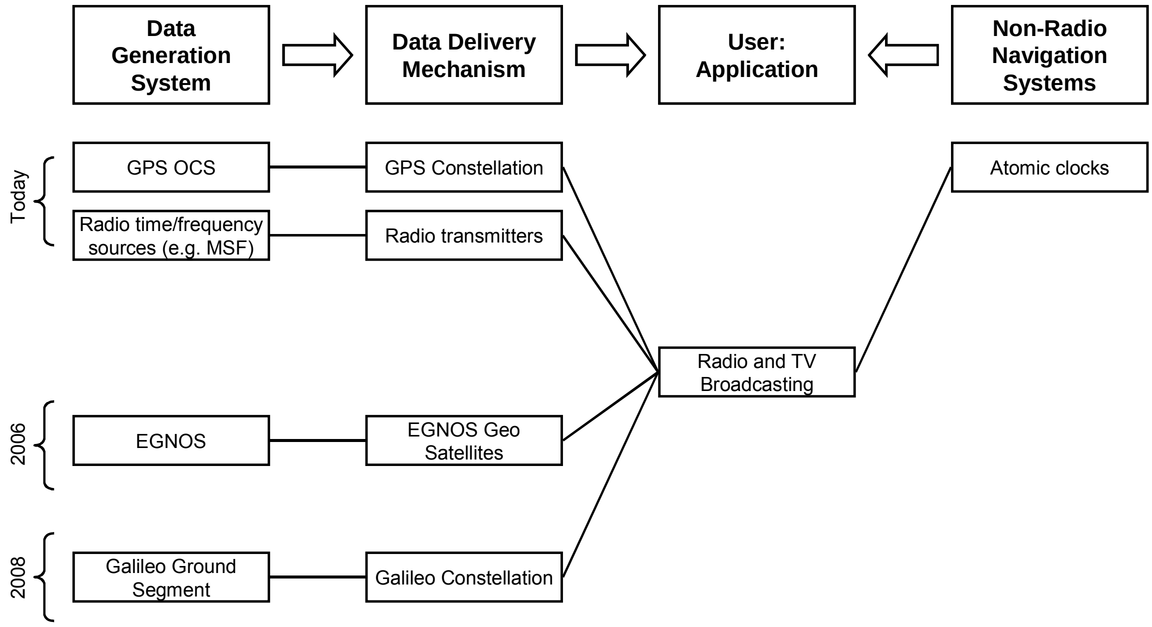
I.9.4.1 Overview

Electricity suppliers use radio time signals or radionavigation time signals as a means to calibrate frequency and coordinate electricity supplies. Electricity companies use atomic clocks to provide continuous frequency control. These may then be calibrated by systems such as MSF or GPS.

I.9.4.2 Service Delivery

Service delivery flow diagram

The mechanism for service delivery is as shown in the diagram below.



Performance requirements

The performance requirements are estimated in the table below.

Application	Accuracy	Availability
Frequency stabilisation	0.02 Hz	0.999

I.9.4.3 Service Availability

The potential for service disruption to a radio time signal or a radionavigation source of time was described in the tables in Section H.8.2.3.

Impact of service disruption

Electricity companies use atomic clocks to provide frequency control. Short-term loss of GPS or of a radio frequency standard such as MSF will therefore not have an immediate impact on the electricity distribution system. Long-term loss of GPS and/or MSF may prevent calibration of the electricity network and lead to drifts in frequency or to phase differences between different networks.

Responsibility for current radio time signal services

The responsibility of the MSF, DCF77, TDF and GPS services was discussed in Section H.8.2.3.

I.9.4.4 Service Charges

Currently the MSF, DCF77 and TDF radio time signals are provided free of charge to all users. GPS is also provided free of charge.

I.9.5 Metrology / clocks

I.9.5.1 Overview

Radio time signals, such as MSF, and radionavigation systems, such as GPS, are used to provide accurate time for industrial and private clocks, and to provide time and/or frequency comparison for scientific measurement. Examples of applications are:

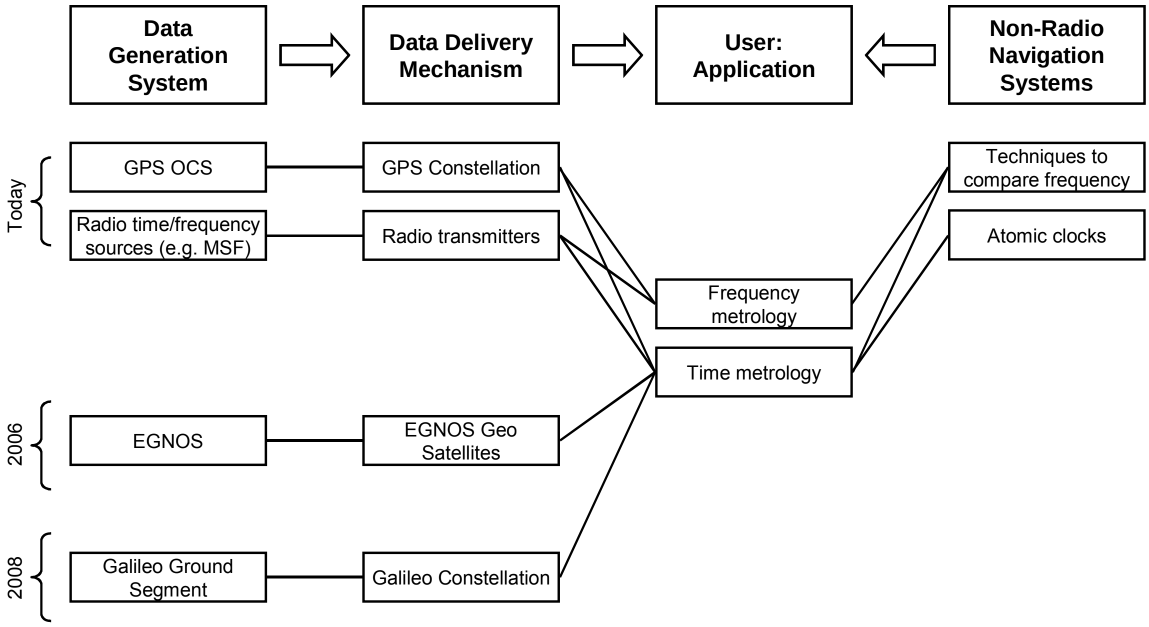
- Personal alarm clocks
- Commercial wall or building mounted clocks
- Railway station clocks
- Scientific measurement

Scientific measurement requires a higher accuracy for time or frequency measurement than many other applications. In the case of scientific measurement, there are a number of non-radionavigation techniques that can be used to provide time or frequency transfer.

I.9.5.2 Service Delivery

Service delivery flow diagram

The mechanism for service delivery is as shown in the diagram below.



Performance requirements

The performance requirements are estimated in the table below.

Application	Time Accuracy	Availability
Personal alarm clocks	10 ms	0.95
Commercial wall or building mounted clocks	5 ms	0.95
Railway station clocks	5 ms	0.99
Scientific measurement	1 ms – 1 ns	0.99

I.9.5.3 Service Availability

The potential for service disruption to a radio time signal or a radionavigation source of time was described in the tables in Section H.8.2.3.

Impact of service disruption

Service disruption to radio time/frequency signals or to radionavigation sources of time/frequency will cause inconvenience, but will not be a safety-critical issue. If a single radio time standard such as MSF is unavailable, disruption will be caused to users of systems (in general, clocks) that rely solely on MSF. For any industrial time-keeping system there will in general be at least a quartz clock backup that will keep time for a limited period while the radio time signal is unavailable, or there will be back-up systems such as GPS available.

Responsibility for current radio time signal services

The responsibility of the MSF, DCF77, TDF and GPS services was discussed in Section H.8.2.3.

I.9.5.4 Service Charges

Currently the MSF, DCF77 and TDF radio time signals are provided free of charge to all users. GPS is also provided free of charge.

I.9.6 Financial time tagging

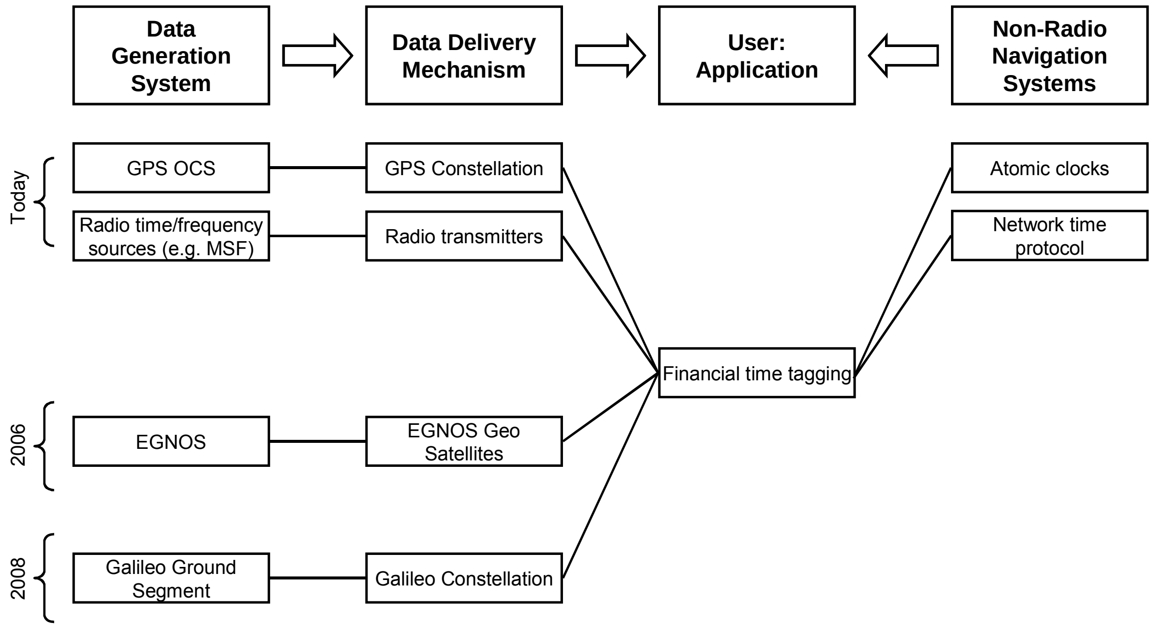
I.9.6.1 Overview

Accurate sources of time are required to monitor and process national and international financial transactions. The time at which a financial transaction is made, and the order in which they are made is important for many different types of transactions that are made, for example in equity markets. Since exchange rates and stock prices change rapidly during the day, transactions involving large amounts of money show significant value changes for relatively small differences in time.

I.9.6.2 Service Delivery

Service delivery flow diagram

The mechanism for service delivery is as shown in the diagram below.



Performance requirements

The performance requirements are estimated in the table below.

Application	UTC Time Accuracy	Availability
Time tagging	1 ms	0.99

I.9.6.3 Service Availability

The potential for service disruption to a radio time signal or a radionavigation source of time was described in the tables in Section H.8.2.3.

Impact of service disruption

A financial services network will normally include a number of clocks for redundancy, and these will provide time to the whole of the rest of the network using timing protocols such as the Network Time Protocol. The networks' clocks would be periodically calibrated using either a radio time signal or a radionavigation time signal. However, failure of a radio time signal source or of GPS is unlikely to cause significant disruption to the financial services network, as an alternative source of time will normally be available.

Responsibility for current radio time signal services

The responsibility of the MSF, DCF77, TDF and GPS services was discussed in Section H.8.2.3.

I.9.6.4 Service Charges

Currently the MSF, DCF77 and TDF radio time signals are provided free of charge to all users. GPS is also provided free of charge.

Multi-modal

WP Leader: Helios (3 days)

J Consultation Activities

Scheduled Project Meetings

Date	Location	Meeting	Attendees

Third Party Meetings/Conferences

Other