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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

1 Scope

1.1 General

The European Commission requires a feasibility study for a European standard related to the capability of VDL (Very high frequency Data Link) Mode 4 to serve as an element to support services to be provided by the Galileo local component.

The GALILEO system is comprised of a number of major architectural components. The Local Component is included in the overall architecture to allow a range of enhanced services to be provided to a specific groups of users who require more demanding performance and whose areas of operation are limited to a given locality. Potential application areas that are envisaged to benefit from such a Local Component include precision approaches in aviation, the maritime Automatic Identification System (AIS) and a wide range of applications in the wider transport market, including applications where VDL Mode 4 might provide a suitable local component.

The Commission is currently funding work (project GALILEI) to investigate the business models for Galileo including the role of the Local Component. The funded work includes derivation a system definition for the Local Component and specific investigation of a number of promising application areas including:

- Aviation.
- Network assisted positioning.
- In-door positioning.
- Automated driver assistance.
- Professional RTK/TCAR applications.
- Unmanned vehicle navigation.
- Marine and Harbour Docking.
- GNSS train control.

The GALILEI project will take a generic view of the Local Component. The purpose of this study is to assess the suitability of VDL Mode 4 to provide elements of this local component and to recommend appropriate standardization measures. The work will study the wider applicability of VDL Mode 4 to other Local Component applications, and will need to be carried out in close cooperation with the GALILEI project team.

The European Commission has issued a Mandate Number M/318 to the European Telecommunication Standards Institute (ETSI) to carry out the study. In turn, ETSI has established Special Task Force (STF) 240 (STF240) to carry out the work. STF240 consists of representatives from two companies: Helios Technology Ltd and Swedavia AB.

The present document is the final report of the study.

1.2 Background

The"classic" local component comprises a Data Generation Mechanism (DGM) and a Data Delivery Mechanism (DDM) (see figure 1.1).

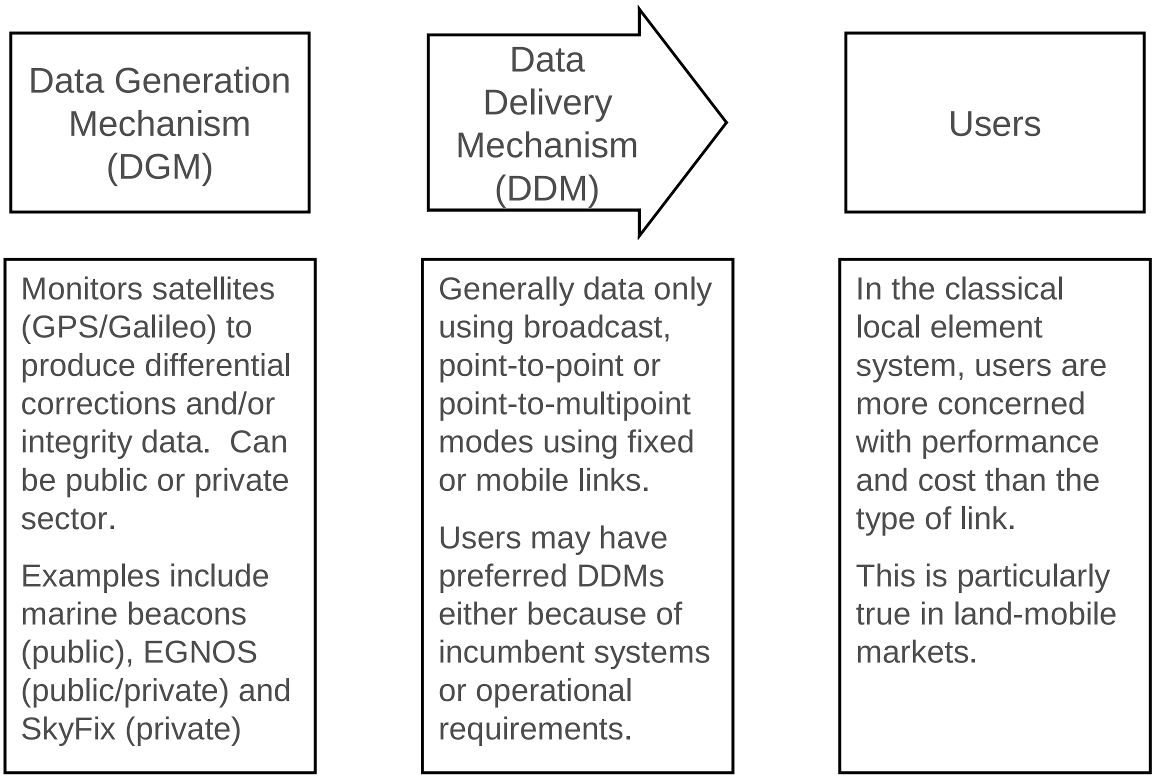

Figure 1.1: Context for the local component

VDL 4 is much more, providing a self-organising Data Exchange Mechanism (DEM) with a two-way data capability (see figure 1.2).

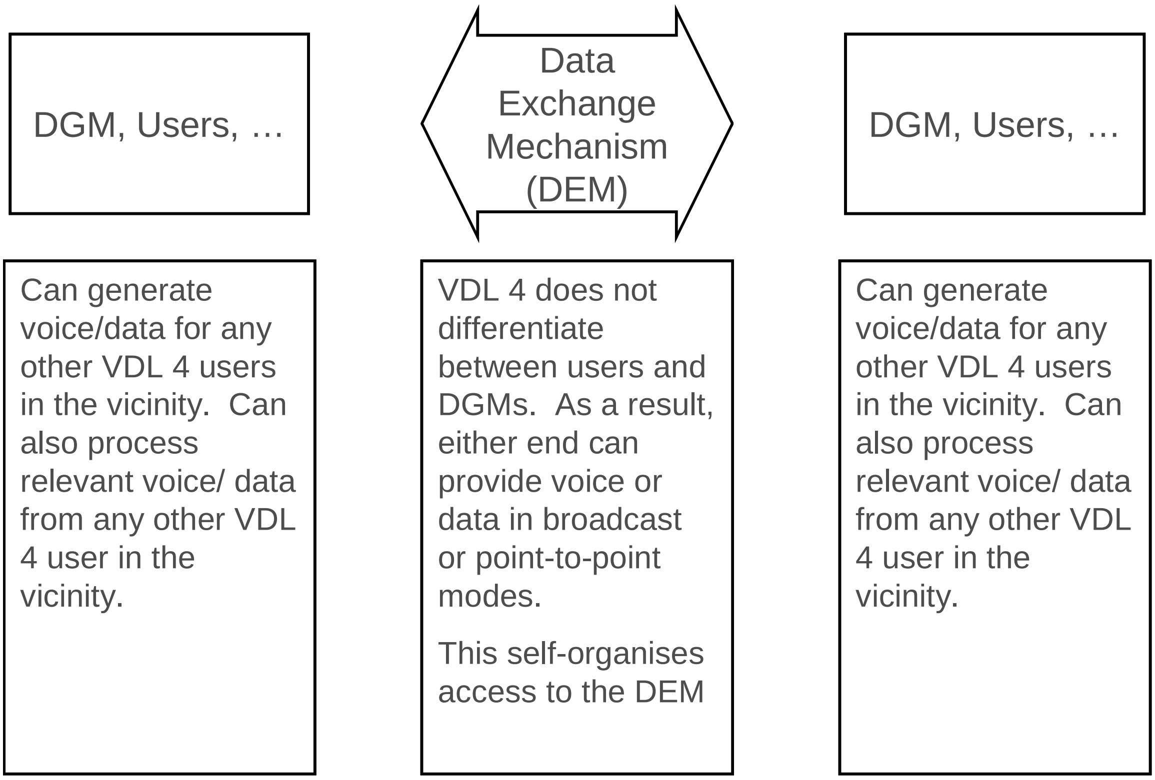

Figure 1.2: Interpretation of local component relevant to VDL Mode 4

Hence, our approach is driven by link performance and its impact on service delivery. "Classical" local component studies that focus solely on navigation performance are inappropriate and inadequate for VDL 4 and this study.

The important parameters here are those that describe the DEM. Our approach considers the DGMs and Users as independent external entities. Provided that there is sufficient bandwidth, the type of data transmitted and its impact at the other end of the link is irrelevant for this study.

1.3 Methodology

The approach taken by the team is illustrated in figure 1.3.

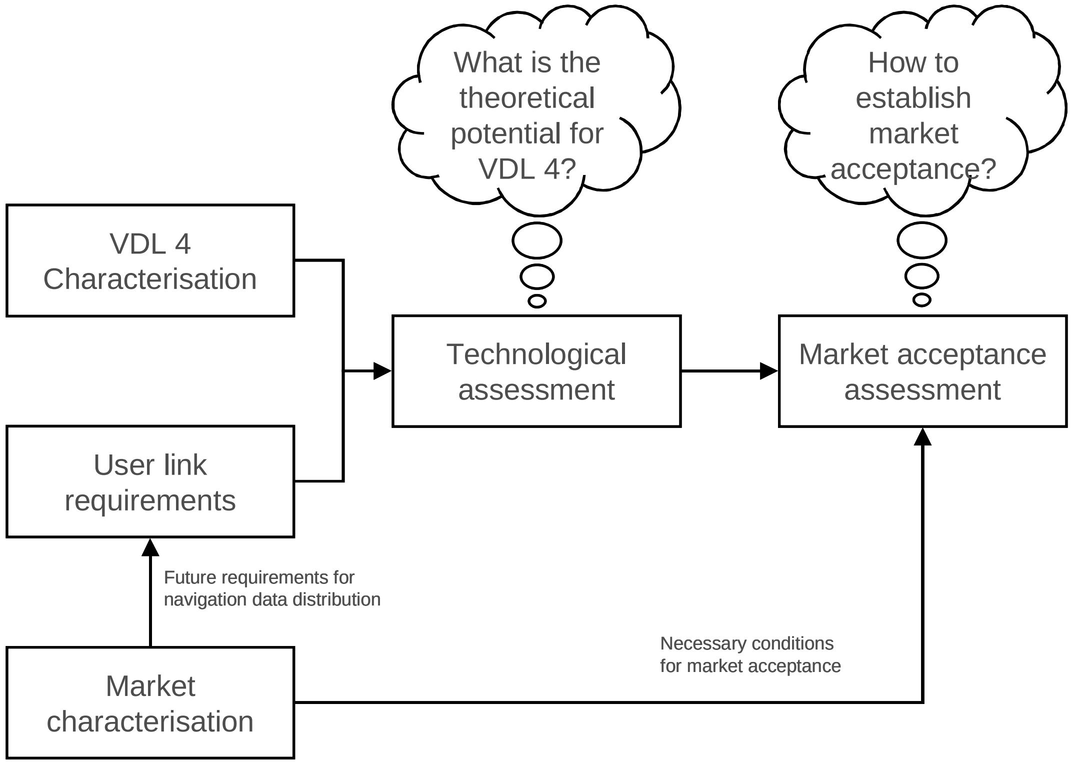

Figure 1.3: Approach

The technological assessment will identify the extent to which VDL 4 meets the link requirements of a number of applications. It is anticipated that there will be a large number of applications for which VDL 4 has appropriate characteristics. However, this is different to market acceptance but is a good first filter.

But many other aspects drive market acceptance:

- Institutional/political acceptance.
- Spectrum availability.
- Competition.
- Cost of replacement (incumbent systems).
- Availability of suitably priced user terminals.
- Operational requirements.
- Standards.
- Integration with other platforms and technologies.

1.4 Selection of candidate markets and applications

Our proposed candidate markets for this analysis are:

- Aviation, focussing on the civil Air Traffic Management (ATM) segment of the market.
- Maritime.
- Rail.
- Fleet and asset management (e.g. public safety, utilities, transport terminals).
- High-integrity road transport (e.g. road tolling).

These markets have been specifically selected on their general suitability for VDL Mode 4 as a data carrier within a Galileo local element. These markets therefore satisfy all (or most) of the following criteria:

- Safety or operationally critical applications.
- Multiple user population with two way data requirements.
- Transport synergies with aviation.
- Likely users of remotely distributed navigation data (i.e. not via SIS (Signal In Space)).

Other applications such as those in the mass market and other professional markets have been deemed unlikely candidates for VDL Mode 4 and (as agreed with ETSI) have been specifically excluded from this analysis.

The inherent VDL Mode 4 flexibility allows the Users to work together in new ways - "Classical" local elements merely enhance performance at the user. VDL 4 allows surveillance, position and other parameter reporting, situational awareness, situation awareness (e.g. floating car data), authentication, revenue collection.

This allows us to consider some novel applications. For example:

- Road-tolling and law enforcement.
- Position reporting from GPS (Global Positioning System).
- High-power local VHF is hard to spoof/jam.
- Two-way communication gives authentication.
- Asset management at the Olympics.
- Private spectrum gives higher availability.
- Voice and data enables surveillance and fleet management.

Within the study, VDL Mode 4 has been characterized in terms of its link performance and service delivery:

- Resistance to anti-jamming and anti-spoofing.
- Time-to connect/disconnect.
- Available bandwidth.
- Encryption.
- Broadcast and point-to-point modes.
- Data (and potential to support voice).
- Coverage and power.
- Indoors/urban.

- Certified.

Information has been gathered from the Galilei, Geminus and GALA studies as well as previous Helios assignments.

The study has carried out:

- Analysis of market acceptance of VDL Mode 4 as a local component.
- Identification of appropriate standardization measures.

1.5 Structure of the present document

Clause 4 characterizes each of the candidate markets and thereby identifies potential drivers for the uptake of Galileo services and the opportunities for navigation data distribution to mobile users. clause 4 also highlights specific market issues that will affect market acceptance (see clause 6).

Clause 5 quantifies the performance of VDL Mode 4 as a navigation data distribution channel and assesses this against each of the link requirements arising from clause 4. The output of clause 5 is therefore a list of potential markets for VDL Mode 4 that appear, on first sight, to satisfy the minimum technical requirements.

Clause 6 considers each of the potential markets/applications and considers what criteria must also be satisfied for market acceptance of VDL Mode 4. This assessment results in a set of actions for each market that should be addressed in order that VDL Mode 4 is progressed further as a navigation data distribution channel.

Clause 7 sets out recommended standardization measures.

2 References

For the purposes of this Technical Report (TR) the following references apply:

[1] Current Market Outlook 2002, Boeing Commercial Airplanes, Marketing, July 2002.

[2] General Aviation Statistical Databook 2002, General Aviation Manufacturers Association, http://www.gama.aero.

[3] Eurocontrol ADS-B cost benefit analysis based on CARE-ASAS "Package 1" applications, Eurocontrol, June 2003.

[4] Aeroports magazine, "Trafic Aeroportuaire 2000, Le Palmares Mondial", Aeroport de Paris, May 2001.

[5] Eurocontrol ADS Programme High-Density 2015 European Traffic Distributions for Simulation, Eurocontrol, Edition 1.2, Eurocontrol, 24 March 2000.

3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AIS	Automatic Identification System
ADS-B	Automatic Dependant Surveillance - Broadcast
ADS-C	Automatic Dependant Surveillance - Contract
APV	APproach with Vertical guidance
A-SMGCS	Advanced Surface Movement Guidance and Control System
AT	Air Transport
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
AVOL	Aerodrome Visibility Operational Level
B-RNAV	Basic RNAV

CAT	[approach] CATegory [I, II, III]
CFIT	Controlled Flight Into Terrain
CNS	Communication Navigation and Surveillance
CPDLC	Controller - Pilot Data Link Communication
D/U	Desired/Undesired
DDM	Data Delivery Mechanism
DEM	Data Exchange Mechanism
DGM	Data Generation Mechanism
DGNSS	Differential GNSS
DGPS	Differential GPS
DME	Distance Measurement Equipment
ECAC	European Civil Aviation Conference
ECDIS	Electronic Chart Display Information System
EFC	Electronic Fee Collection
EGNOS	European Geostationary Navigation Overlay System
EGPWS	Enhanced GPWS
EMRF	European Maritime Radio-navigation Forum
ETCS	European Train Control System
ETCS-LC	ETCS - Low Cost
ETSI	European Telecommunications Standards Institute
FAA	Federal Aviation Administration
FANS	Future Air Navigation System (ICAO special committee)
GA	General Aviation
GBAS	Ground Based Augmentation System
GIS	Geographic Information System
GLS	GNSS Landing System
GNSS	Global Navigation Satellite System
GNSSP	GNSS Panel
GPRS	General Packet Radio Service
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
GRAS	GNSS Regional Augmentation System
GSM-R	GSM - Railways
HAL	Horizontal Alert System
IALA	International Association of Lighthouse Authority
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
IMO	International Marine Organization
INS	Inertial Navigation System
IRS	Inertial Reference System
JAA	Joint Aviation Authority
LAAS	Local Area Augmentation System
LF	Low Frequency
MASPS	Minimum Aircraft System Performance Specifications
METARS	Aviation routine weather report
MF	Medium Frequency
MLS	Microwave Landing System
NPA	Non-Precision Approach
PMR	Private Mobile Radio
P-RNAV	Precision RNAV
RAIM	Receiver Autonomous Integrity Monitoring
RNAV	Area navigation
RNP	Required Navigation Performance
RTCA	Requirements and Technical Concepts for Aviation
SA	Selective Availability
SARPs	Standards And Recommended Practices
SBAS	Satellite Based Augmentation System
SIDs	Standard Instrument Departures
SIS	Signal In Space
SoL	Safety of Life
SOLAS	Safety Of Life At Sea

SRS	System Requirements Specifications
STARs	Standard Terminal Arrival Routes
STDMA	Self-organising TDMA
STF	Special Task Force
TAF	Aerodrome forecast
TAWS	Terrain Awareness Warning System
TDMA	Time Division Multiple Access
TOC	Train Operating Companies
TRS	Time Reference System
TU	Traction Unit
UAT	Universal Access Transceiver
UHF	Ultra High Frequency
UIC	International Union of Railways
UMTS	Universal Mobile Telecommunications System
VAL	Vertical Alert System
VDL 4	VHF Data Link Mode 4
VHF	Very High Frequency
WAN	Wide Area Network

4 Market characterization

4.1 General

This clause characterizes each of the candidate markets and thereby identifies potential drivers for the uptake of Galileo services and the opportunities for navigation data distribution to mobile users. clause 4 also highlights specific market issues that will affect market acceptance (to be investigated later in the study).

The specific areas addressed within this clause are:

- Organizational context.
- Market segmentation.
- Applications and requirements.
- Current and planned use of GNSS.
- Drivers for uptake of new services (i.e. DGNSS, EGNOS or Galileo).

The clause focuses primarily upon VDL Mode 4's role as a channel for navigation data within a local or regional augmentation. This clause also identifies any other supplementary two-way data applications that may also be exploited by VDL Mode 4 in the event that it qualifies as a potential channel for navigation data.

4.2 Aviation

4.2.1 Organizational context

This clause focuses on the ATM segment of the Aviation market. This market has a complex organizational structure due to the global and safety critical nature of the industry. Key stakeholders in the market are:

- Airlines and commercial aircraft operators.
- General aviation aircraft operators.
- Military and state aircraft operators.
- Civil and military air traffic service providers.
- Airport operators.

- Airframe and avionics manufacturers.
- Support organizations, e.g. meteorological service providers.

Whilst the market is highly regulated, there is also a trend for increased commercialization or even privatization amongst government-owned stakeholders. This is bringing increased commercial pressures to the market, which can conflict against traditional regulation processes.

Global and regional organizations are established to define and help introduce new systems and procedures. The key organizations in this way are:

- ICAO, the International Civil Aviation Organization responsible for agreeing global standards and treaties.
- JAA, the Joint Aviation Authorities, responsible for harmonising regulations in Europe.
- Eurocontrol, the European Organization for the Safety of Air Navigation.
- FAA, the Federal Aviation Administration responsible for service provision.
- European Telecommunications Standards Institute (ETSI).
- EUROCAE.
- National regulators and services providers.

4.2.2 Market segmentation

The airborne market can be subdivided into three segments:

- Air Transport (AT) - aircraft operated for the transportation of passengers or cargo, either scheduled or charter.
- General Aviation (GA) - all other commercial or leisure aircraft, including the following applications: leisure, business aviation, police, air ambulance, flying training, aerial photography and survey, pipeline and electricity cable.
- Military/State Aircraft - aircraft owned and/or operated by the military or other state organizations. This market is not considered here further.

The following clauses give estimates of the market sizes for a VDL Mode 4 local component for AT and GA aircraft, as well as European market sizes for ground stations.

AT market

They are based on the assumptions that every year, VDL Mode 4 airborne equipment would be required for:

- New aircraft that are replacing retiring aircraft. We have assumed annual retirement rates of 3 %, i.e. an average aircraft lifetime of just over 30 years.
- New aircraft introduced because the market is growing. The growth rates are taken from Boeing estimates [2]. The initial airframe numbers are also taken from Boeing.
- Aircraft that are upgrading their avionics. We have assumed this happens once in the lifetime of an AT aircraft, i.e. to 3 % of the fleet of aircraft each year, and when they do they install VDL Mode 4 equipment.

Table 4.1: Estimated AT aircraft market (2008, 2015 and 2020)

	2008	2015	2020	Total 2008-2020
European AT aircraft requiring new GNSS receivers	623	740	823	9 398
Global AT aircraft requiring new GNSS receivers	2 139	2 501	2 759	31 840

Note that the Boeing figures include all jet aircraft from single aisle aircraft up to 747s.

GA Market

The GA aircraft market has been estimated using data from the General Aviation Manufacturers Association [2]. A similar approach to estimating the market size has been used, but in this case, the growth in airframe numbers is estimated at 3 %, and the number of aircraft upgrading avionics is estimated at 1,5 % (GA aircraft upgrade at a slower rate than AT aircraft).

Table 4.2: Estimated GA aircraft market (2008, 2015 and 2020)

	2008	2015	2020	Total 2008-2020
European GA aircraft requiring new GNSS receivers	4 048	4 978	5 771	63 215
Global GA aircraft requiring new GNSS receivers	29 000	35 700	41 400	453 000

Ground station market

In this clause we estimate the market for VDL Mode 4 local component ground stations. This estimate is comprized of 2 components: the number of ground stations required for GRAS/ADS-B coverage and the number required for GBAS (Ground Based Augmentation System) coverage.

Eurocontrol [4] has already estimated the number of ground stations required to achieve ADS - B (Automatic Dependant Surveillance - Broadcast) coverage in the ECAC area as 525. This assumes ground station range of 60 NM, which is a conservative figure to ensure low-altitude coverage. It is expected that these ground stations can also be used for uplinking GRAS (GNSS Regional Augmentation System) augmentation signals.

GBAS ground stations would be located at airports that require precision approach capability. We have assumed that airports with over 500 000 annual passenger movements may require CAT II/III capability and those with 100 000 to 500 000 movements may require CAT I capability. This assumption holds for a sample of European airports, but it not precise since the actual requirements of an airport will also depend on other factors such as the local weather.

The number of airports corresponding to the CAT I or CAT II/III categories defined above have been derived from global passenger statistics [4]. The comparison shows that about 267 airports in Europe could require CAT I systems, and a further 70 could require CAT II/III.

The results of the ground station analysis are given in table 4.3. These figures are the total market size over the system life, i.e. around 15 years. The annual market will be a fraction of the total.

Table 4.3: Summary of European ground station market estimate

ADS-B/GRAS ground stations	525
CAT I airports	267
CAT II/III airports	70
Total (assuming no dual-use systems)	862

4.2.3 Applications and requirements

This clause gives the requirements on a navigation source for aviation applications. These requirements would have to be met by Galileo with a VDL Mode 4 local component (other navigation systems may also be used).

Tables 4.4 to 4.7 define GNSS requirements for different applications extracted from the ICAO GNSS SARPs, LAAS MASPS and the Eurocontrol RNAV standard.

Table 4.4: Aviation operational performance requirements

Operation	Accuracy (95 %)		Integrity	Alert limit	
	Horizontal	Vertical		Horizontal	Vertical
Oceanic	12,4 nm	-	$1\text{-}10^{-7}$ per hour	12,4 nm	-
En-route	2,0 nm	-	$1\text{-}10^{-7}$ per hour	2,0 nm	-
Terminal	0,4 nm	-	$1\text{-}10^{-7}$ per hour	1,0 nm	-
NPA	220 m	-	$1\text{-}10^{-7}$ per hour	555 m	-
APV I	220 m	20 m	$1\text{-}2 \times 10^{-7}$ per approach	556 m	50 m
APV II	16 m	8 m	$1\text{-}2 \times 10^{-7}$ per approach	40 m	20 m
CAT I	16 m	4 m to 6 m	$1\text{-}2 \times 10^{-7}$ per approach	40 m	10 m 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

Table 4.5: Aviation operational performance requirements (continued)

Operation	RNP value	Time to alert	Continuity	Availability
Oceanic	< 20	2 min	$1\text{-}10^{-5}$ per hour	0,99 to 0.99999
En-route	4	1 min	$1\text{-}10^{-5}$ per hour	0,99 to 0.99999
Terminal	1	30 sec	$1\text{-}10^{-5}$ per hour	0,99 to 0.99999
NPA	0,3	10 sec	$1\text{-}10^{-5}$ per hour	0,99 to 0.99999
APV I	0,3/125	10 sec	$1\text{-}8 \times 10^{-6}$ per 15 s	0,99 to 0.99999
APV II	0,03/50	6 sec	$1\text{-}8 \times 10^{-6}$ per 15 s	0,99 to 0.99999
CAT I	0,02/40	6 sec	$1\text{-}8 \times 10^{-6}$ per 15 s	0,99 to 0.99999
CAT II	0,01/15	1 sec	$1\text{-}4 \times 10^{-6}$ in any 15 sec	0,99 to 0.99999
CAT III	0,003/z	1 sec	$1\text{-}4 \times 10^{-6}$ in any 15 sec (lateral) $1\text{-}4 \times 10^{-6}$ in any 15 sec (vertical)	0,99 to 0.99999

Table 4.6 defines the accuracy requirements for ADS-B reports defined in RTCA MASPS. Again, Galileo could support this application with a VDL Mode 4 local component.

Table 4.6: ADS-B accuracy requirements

Parameter	Aircraft location	
	Airborne	Surface
Horizontal position	20 m	2,5 m
Horizontal velocity	0,25 m/sec	0,25 m/sec
Vertical position	30 ft	N/A
Vertical velocity	1 ft/sec	N/A

Table 4.7 defines the navigation sensor requirements for airport surface applications as presently determined by RTCA.

Table 4.7: Navigation sensor requirements for airport surface applications

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	$1\text{-}4 \times 10^{-4}$ per hour	$1\text{-}3 \times 10^{-3}$ per hour
Alert limit	8 m	6 m	TBD
Time to alert	10 sec	2 sec	2 sec
Availability	0,95	0,999	0,999

4.2.4 Current and planned use of GNSS

This clause describes the current and planned use of GNSS in aviation. It includes all the aviation applications that may apply to Galileo with VDL Mode 4 local component.

Oceanic and remote airspace

GNSS (and presently GPS specifically) has a significant role in oceanic/remote operations. The UK allows GPS use "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.

GPS can also be used for "sole means" navigation in oceanic airspace under FAA Notice 8110.60. In Australia, several en-route operational approvals are in place, including GPS "primary means" in oceanic and remote areas.

En-route airspace

In Europe, aircraft in upper airspace must meet B-RNAV requirements. GPS with RAIM (Receiver Autonomous Integrity Monitoring) is approved as a navigation source for B-RNAV. However, an alternative terrestrial navigation source is always required. Most navigation systems take multiple navigation sources, usually GPS, DME/DME and/or Inertial Reference Systems (IRS).

For example, within Europe, the ECAC Navigation strategy includes the long-term use of DME/DME as a back up to GPS. The introduction of Galileo (possibly with a suitable local component) might enable decommissioning of DMEs but considerable investigations validation would be required before GNSS becomes the sole means navigation system for aviation.

Terminal airspace

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 longer-term P-RNAV procedures 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.

As with en-route airspace, the introduction of Galileo (possibly with a suitable local component) might enable a move to GNSS sole means navigation.

NPA and APV

Non-Precision Approaches (NPA) based on GPS are becoming increasingly popular because they are easier and potentially safer to fly than conventional approaches.

ICAO has recently defined a new sort of approach; APproach with Vertical guidance (APV). This is designed to be supported by GPS augmented with a local component (currently defined as 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 50 m 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 40 m HAL and 20 m VAL with a 6 second time to alert. APV II is designed to be supported using SBAS.

For SBAS, the European SBAS system EGNOS is expected to support APV I and II by 2005.

Precision approach and landing

GNSS Landing Systems (GLS) are under development as a replacement for Instrument Landing System (ILS). Standards are already available for GLS CAT I, which make use of a non-VDL Mode 4 local component. 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 (Galileo, etc) and local component (such as VDL Mode 4) requirements.

Surface movement

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 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 7,5m".

GNSS will probably have a major role to support A-SMGCS, particularly as an accurate navigation source and as data source for ADS-B surveillance (see below).

Surveillance

Within surveillance, 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 standardized:

- Contract (ADS-C) in which information is transferred on a point-to-point addressed communications (usually a satellite) to a ground system.

- 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. The Future Air Navigation System (FANS)-1/A ADS-C implementation is widely deployed on long-haul aircraft. GNSS is not a necessary source for FANS-1/A although it is generally used.

ADS-B will support both airborne and ground surveillance and is the key enabler of airborne separation assistance system (ASAS) applications. At present, ADS-B is under development and trials are underway using the ADS-B capabilities of VDL Mode 4. 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).

Some of the long-term applications proposed for ADS-B will place very high integrity and availability requirements on the GNSS position. This could lead to a strong role for a local component to augment Galileo.

Communications

GNSS can provide time synchronization 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 time stamping of data messages.

Air-to-ground datalink applications currently being deployed in Europe and the US (known as controller-pilot datalink communications, CPDLC) require time stamping 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 synchronization of Air Traffic Control (ATC) facilities. Eurocontrol has developed Functional and Technical Specifications for Time Reference Systems (TRS), which include synchronization to GPS time. The specification is not mandatory.

Ground Proximity Warning

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 technology 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 and earlier terrain warnings.

EGPWS is referred 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 between 5 700 kg and 15 000 kg, or between 9 and 30 passengers, must be fitted with an 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.

4.2.5 Drivers for uptake of new services

The main drivers for change in the aviation industry are:

- Increasing capacity and reducing delays, particularly in high-density, congested areas.
- Increasing flight efficiency.
- Minimising the environmental impact of air transport.
- Maintaining or increasing safety as traffic increases.
- Reducing costs of service provision and infrastructure.

Local component services will have a greater attractiveness if they can deliver these benefits.

In addition, some specific areas where there could be drivers in the navigation domain are:

The development of new application(s) for GNSS

The obvious area to introduce a new application is in the approach phase (in the same way that APV has been designed for use with SBAS), but there are already many different types of approaches defined. Alternatively, surface movement navigation and surveillance is an area where new procedures could bring significant benefits.

Enabling present applications more cheaply

An example of this class of application is GBAS, since GBAS ground stations are expected to be cheaper than ILS or microwave landing system (MLS) ground stations. However, cost savings will also have to be demonstrated on the airborne side to make a convincing argument.

Enable increased reliance on GNSS

An aim of one segment of the aviation community is to develop GNSS as a "sole means" system, sufficient for all aviation requirements globally. IATA Europe has stated this as an appropriate solution, subject to it being shown to be technically feasible and financially beneficial.

Some of the technical challenges to be overcome here include:

- Meeting some of the high-accuracy requirements for precision approach and surface movement applications. The availability of Galileo possibly with a VDL Mode 4 local component might overcome these issues.
- Convincing the community of the prudence of relying on one navigation system. The main arguments against sole-means GNSS today are lack of international control and vulnerability (including interference resistance and failure mode analysis). Galileo with a VDL Mode 4 local component could be one way that these concerns are addressed.

4.2.6 Implementation challenges

This clause describes some of the main implementation challenges facing VDL Mode 4 as a local component for Galileo:

Avionics integration

VDL Mode 4 as a local component and also as a communication/surveillance system needs to be integrated on a range of aircraft with different architectures for different applications. This will require avionics development.

User acceptability

Whilst the aviation community is highly aware of GNSS, some quarters remain sceptical as to the value of additional integrity and/or interference protection. Some also question the prudence of relying on a single navigation system. The main arguments today against sole-means GNSS are lack of international control and vulnerability (including interference resistance and failure mode analysis). These may be overcome by GALILEO deployment.

4.3 Maritime transport

4.3.1 Organizational context

4.3.1.1 General

The worldwide fleet has been growing for the last two decades (about 1 % a year) and this tendency is expected to continue. Automation of ship operation (one man machine rooms, one man wheelhouses, etc) is important current issues and, because of this system facilitating navigation and communication, is becoming more and more important.

The market is driven on the one hand by vessel owners, wanting to optimize vessel operation, and on the other hand by regulating authorities, wanting safe navigation without loss of life and with a minimal risk for the environment. GNSS navigation can be a major aid in achieving both goals, and because of this, GNSS systems have already gained wide acceptance in the maritime sector.

Purchasers of vessel navigation systems and harbour docking systems will be ship owners and fleet owners. The user (platform) for navigation systems is an individual vessel. Purchasers for equipment for dredge positioning will be the dredging contractors (private companies) and port and waterways authorities (public bodies).

4.3.1.2 Political and regulatory issues

The International Maritime Organization (IMO), a United Nations Agency, regulates safety matters. Most countries (157 in total) are members of the IMO and Member states engage themselves to adopt the IMO resolutions as a part of their local legislation. IMO covers about 98 % of the world's merchant fleet tonnage.

IMO has recognized the importance of satellite navigation systems and of satellite communication and is using these technologies to improve global navigation safety. Recent regulations have set performance standards for GNSS, electronic navigation charts, electronic chart display systems, distress calling, vessel surveillance, etc.

The establishment of the shore based AIS is the greatest current challenge and is considered by many to be essential to the enhancement of safety at sea. This has been mandated for all vessels by IMO and is due to be introduced over the next two (in the USA) to four years (in the rest of the world). AIS, which has the same technical basis as VDL Mode 4, will effectively support existing navigation and operations functions by enabling situational awareness within each vessel.

AIS utilizes a very similar to the Self-organising TDMA (STDMA) protocol to VDL Mode 4, and is a prime example of how the characteristics of VDL Mode 4 may be transferred to another market. The main differences are the bit rate and some of the message contents.

4.3.2 Market segmentation

Table 4.8 illustrates the different categories of user in the maritime market and the estimated global market size by year. This market size represents the maximum number of potential users and does not represent the actual number of GNSS or Galileo users. Global figures are shown (as opposed to Europe) since regulation and standards apply globally and therefore VDL Mode 4 should not be applied within Europe alone.

Table 4.8: Market segmentation and size (Maritime)

User Group	2005	2010	2015	2020
Fishing vessels	60 000	60 000	60 000	60 000
Inland waterway users	2 300	4 100	6 017	8 200
Navigation - regulated coastal and port vessels	14 700	15 400	16 240	17 100
Marine Leisure Vessels (millions)	5.5	6.2	7.0	7.7
Oceanographic and Cryospheric Mapping for Environmental studies	2 413	2 665	2 942	3 248

Based upon figures for regulated vessels from the EC GALA study, it is estimated that Europe represents approximately 25 % of the global market, most of which relates to Western Europe.

4.3.3 Applications and requirements

4.3.3.1 General

Applications in the maritime market may be broadly categorized as follows:

- Safety-related applications.
- Professional applications
- Consumer applications.

The user requirements for these different market sectors are presented in table 4.9 and are based on the draft revision of A860A860 prepared by the European Maritime Radio navigation Forum (EMRF) and submitted by France, Finland, the Netherlands, Sweden and the United Kingdom to the IMO's Sub-Committee on Safety of Navigation.

Table 4.9: Performance requirements (Maritime)

Application		Accuracy		Integrity		Availability	Coverage
		Horiz (m)	Vert (m) (if app.)	Time to alarm (sec)	Integrity risk (per hour)	(%) per 30 days	Local (L) Regional (R) Global (G)
Safety							
1	Ocean navigation	10		10	10^{-7}	99,8	G
2	Coastal, port approach & restricted	10		10	10^{-7}	99,8	G/R
3	Inland Waterways	10		10	10^{-7}	99,8	R
4	Operations	1-10		10	10^{-7}	99,8	G
5	Search & Rescue	10		10	10^{-7}	99,8	G
6	Traffic Management	10		10	10^{-7}	99,8	G/R
7	Casualty Analysis	10		10	10^{-7}	99,8	R
Professional							
8	Fisheries Operations	10		10	10^{-7}	99,8	G
9	Fisheries Monitoring	10		10	10^{-7}	99,8	G
10	Traffic Management	10		10	10^{-7}	99,8	G
11	Oceanography	10	10	10	10^{-7}	99,8	G
Consumer							
12	Recreation & Leisure	10-100		10	10^{-7}	99,8	R

Local, regional or global coverage indicates the area over which operations pertaining to each application may take place. For example, a regulated vessel may make a port approach in any port in the world and therefore global standards and regulations are required.

4.3.3.2 Safety market

The safety market comprises:

- **Ocean navigation** where the ship operator is the customer.
- **Coastal, port approach and restricted waters navigation where the marine navigation** service provider is the customer.
- **Inland waterways** where the inland waterways authority is the customer.
- **Operations** including track control and automatic collision avoidance, where the ship operator is the customer.
- **Search and rescue** where the search and rescue authority, e.g. coastguard, is the customer.
- **Traffic management** where the vessel traffic services operator is the customer.
- **Casualty analysis** where the incident/accident investigator uses recorded navigation data. This is a special market that may make use of the services provided under other navigation applications.

4.3.3.3 Professional market

The professional market comprises:

- **Fisheries operations** where the customer is the operator of the fishing vessel, either on a fleet or an individual basis.
- **Fisheries monitoring** where the customer/retailer is the agency responsible for fisheries monitoring. This agency might also act as the intermediate service provider for, say, the integrating positioning system, the communications link and the surveillance display necessary for the monitoring function.
- **Traffic management** in support of port operations where the customer and intermediate service provider is the port operator and the end-user is the ship operator.
- **Oceanography** where the customer is the institution involved in the oceanography.

4.3.3.4 Consumer market

The consumer market in the maritime sector comprises:

- **Recreation and leisure** where the customer is the operator of the leisure craft.

4.3.4 Current/planned use of GNSS

4.3.4.1 Existing DGPS infrastructure

With the exception of the consumer market, stand-alone GPS cannot meet the requirements of the maritime market on its inability to meet integrity requirements. This provides a clear potential driver for investment in improved systems or services.

Currently there are between 60 and 80 differential GPS (DGPS) stations in Europe operating in the frequency band 283,5 kHz to 315 kHz. They are located mainly in the Baltic, North, Barents and Irish seas as well as Icelandic waters and along the Atlantic coastlines. Most European coastal waters are covered by DGPS, with the exception of the Eastern parts of the Mediterranean. When the network is complete, a total of 126 stations will be operational, which, in addition to providing overlapping coverage in most areas, will cover the Canary Islands and the Western and Central parts of the Mediterranean sea. To the best of our knowledge, the funding for the extension of coverage into the Eastern Mediterranean has not yet been approved.

Whilst the removal of Selective Availability (SA) has caused many users to question the need for existing DGPS infrastructures, these are likely to remain due to:

- IMO requirements for accuracy better than 10 m at harbour navigation and in coastal waters with dense traffic. (IMO Resolution A.815).
- Integrity Monitoring (i.e. the possibility to warn users in case of failures concerning the transmitted navigation signals or the transmission is unmonitored).
- Implementation of ECDIS (Electronic Chart Display Information System) and AIS has resulted in great demands of accurate positioning.

4.3.4.2 Safety market

Requirements for ocean navigation are currently met by a combination of systems within Europe (including GPS with RAIM, local area DGPS, radar, visual aids, celestial navigation, etc). Current systems and procedures have also been developed and implemented to meet local accuracy and integrity requirements for coastal, port approach, restricted waters and inland waterways navigation.

The capability of current DGPS is almost sufficient to meet the current requirements associated with the majority of operations applications. Any deficiencies in performance are currently resolved using specialized terrestrial systems. DGPS will also meet current requirements for track control but will be extended to the limit of its capabilities to meet future track control and automatic collision avoidance requirements.

With regard to SBAS (including EGNOS), IALA have stated: "Once they are fully deployed and approved for safety of navigation, it is likely that these systems could find some level of application in the maritime navigation mode. However, it is anticipated that the current terrain-penetrating MF/LF radio beacon DGPS system, which is optimized for surface applications, will continue to be the primary system for maritime navigation" (GNSS2002, Copenhagen, May 2002).

4.3.4.3 Professional market

When applications are limited to existing DGPS coverage, then requirements may be met. However, the global nature of these applications means that requirements cannot be wholly met by DGNSS or EGNOS. Galileo will however provide substantial coverage improvements.

4.3.4.4 Consumer market

GPS is capable of broadly satisfying the existing requirement based upon an absolute accuracy in the range of 10 m to 100 m. With GNSS Augmentation this can be improved to 1 m to 3 m.

4.3.5 Drivers for uptake of new services

The potential drivers for introducing EGNOS or Galileo in the maritime market are to:

- Supplement existing DGPS systems on the basis of improved performance (i.e. accuracy, integrity and coverage).
- Replace existing DGPS and other terrestrial systems on the basis of lower overall costs.
- Provide a cheaper alternative to DGPS where coverage does not yet exist.
- Enable new applications that could not otherwise be supported by existing radio navigation means, such as those that may require a form of institutional or legal accountability.

Performance drivers: The documented performance of the Galileo Safety Of Life (SOL) service should be capable of meeting the majority of maritime transport applications, excluding extreme local applications such as harbour docking. Whilst there is little in the way of improved accuracy to tempt a shift towards Galileo, its global coverage will be more uniform than that provided by DGPS because of the regional rather than local nature of the former system.

DGPS currently provides the user with integrity information within its coverage area. However, because of the method of determining integrity, the information provided by Galileo (either globally or via EGNOS as a regional component) is likely to be more robust than that provided by DGPS. That said, today's systems meet user expectations within the specified coverage area.

Cost and process drivers: The feasibility of Galileo - either wholly or partially - replacing existing DGPS schemes depends upon the rationalizetion of existing ground infrastructure. However, the cost of purchasing an on-board GPS/Galileo receiver remains the primary financial implication that must be overcome.

Application drivers: Some users have expressed the view that the biggest differentiation between Galileo and existing legacy systems is its institutional basis and the potential legal accountability that this may imply. The way in which such a framework could operate in a maritime environment has yet to be specified. However, if such accountability were established then the maritime sector may be prepared to increase its dependency upon Galileo as its primary means of positioning.

4.4 Rail transport

4.4.1 Organizational context

4.4.1.1 Economic factors

The tendency towards liberalization in the transport world means that in future the railways are going to have to compete even more intensively with other modes of transport. The European Train Control System (ETCS) of the future, therefore, is intended not only to improve operating efficiency, but also to seize every opportunity to reduce acquisition and maintenance costs.

Unfortunately, the national railway administrations of the EU have historically developed their own different and incompatible signalling systems, which do not use traditional radio navigation. This has made operating trains between countries difficult since locomotives may have to be changed at the border or, in the case of the Eurostar service between London, Paris and Brussels; the locomotives carry equipment for three different signalling systems, thereby increasing complexity and cost.

The adoption of harmonized systems at a European level will result in cost reductions, as system development and maintenance can be carried out in a uniform manner. Furthermore, the fact that all the railways will be using the same system means that the system components can be produced in larger quantities.

4.4.1.2 Business needs

All railways have the same business needs: to be able to provide market-oriented, reliable, safe and cost-effective train transportation for both passengers and freight. One of the prerequisites for this is to have an appropriate system for train control and protection, which consists of fixed installations and of equipment installed on board the trains themselves. Obviously, such equipment will only function if the traction units of a particular system run on appropriately equipped lines.

One consequence of the absence of a standardized European system is that each railway company is currently following its own programme for the development of system components, both fixed and on the trains. The business aims are equally disparate: in certain countries, the idea is to enhance the safety of train traffic, by equipping lines with systems that are not equipped at all or by replacing or supplementing outdated equipment. A second aim applies above all to parts of networks with high traffic densities: to increase the carrying capacity of the line by taking speed and headway to the limits of the physically possible.

4.4.1.3 European Train Control System (ETCS)

To combat this problem, particularly for high-speed trains, the International Union of Railways (UIC), on behalf of the European Commission, has developed the three level ETCS standard. This lays out the standards for development of new signalling systems that are becoming affordable with the development of new technologies to enable trains, in the future, to move freely from country to country.

The ETCS system description includes a number of related initiatives that will provide hardware and software modules or "subsystems". These include:

- **Euroradio:** data transmission via the future digital train radio in the 900 MHz frequency range.
- **Eurobalise:** transponders fixed to the track which send data to a train when activated by the train passing overhead.
- **Eurocab:** train borne equipment that will interface with existing signalling systems for train protection and control and provide data transmission between track and train.

The ETCS Systems Requirements Specification (SRS) is fundamentally based upon track-based techniques as the core method of determining train location. This is then supplemented by other on-board means such as odometry to determine speed and relative position.

4.4.1.4 Cab-based positioning

ETCS level 3 specifies that the train should be able to determine its position independently of the ground infrastructure, thus raising a potential application for GNSS. Furthermore, such higher levels assume the reduction and (ultimately) the removal of all trackside signals that also potentially raise specific local applications for GNSS. GNSS therefore has a potential role both as a fallback means and complementary means of determining train location.

Transmission based train control, using radio communication from train to trackside, is widely accepted as a next technology step. ETCS Level 3 will lower installation and maintenance costs and also reduce the need for trackside equipment. This is of particular importance where the risk of damage or vandalism is prevalent.

For rural areas however and for other regions which do not necessarily have the necessary ground infrastructure to support accurate positioning of trains, the role of satellite positioning may play a more dominant role. Such a system based largely upon non-terrestrial infrastructure is widely termed as 'low cost signalling' or ETCS-LC.

ETCS will inevitably require several years' development before it is available for use with passenger trains. Notwithstanding this development, ETCS is likely to be operational in many European countries before Galileo, although higher applications levels (including Level 3) will not follow until a later date.

If included into the ETCS architecture, radio navigation systems under development will also be able to supply real time passenger and management information to both stations and trains. This is in addition to a host of other personal location based value added services that could be provided to passengers on the back of an integrated GNSS solution.

4.4.2 Market segmentation

Table 4.10 illustrates the different categories of user in the rail transport market and the estimated market size (according to year). This market size represents the maximum number of potential users and does not represent the actual number of GNSS users.

Table 4.10: Market segmentation and size (Rail)

User Group	2005	2010	2015	2020
Passenger trains	17 500	17 500	17 500	17 500
Traction Units (for the purposes of management information)	25 500	25 500	25 500	25 500
Trains equipped to necessary level of ETCS	1 515	7 500	28 000	38 500
Track surveyors	354	343	334	323

The number of passenger trains is defined as the total number of Traction Units (TUs) that are normally operated by train operating companies as passenger trains. The second row meanwhile shows the *total* number of TUs, including passenger and non-passenger functions. The third row illustrates the total estimated number of trains that are equipped to the necessary level of ETCS and are therefore deemed capable of integrating GNSS. This could either correspond to ETCS Level 3 (i.e. track-independent signalling) or lower levels in which GNSS is designed to support lower cost signalling.

4.4.3 Applications and requirements

4.4.3.1 Safety critical applications

Train control: Signalling on high traffic lines using based upon GNSS is envisaged as an evolution of ETCS (see clause 4.4.1). This is likely to take place between 2005 to 2015. ETCS is being developed by European industry and will offer benefits of low cost signalling systems and reduced maintenance costs.

Train supervision: Complete installation of signalling equipment on all lines is not economically feasible. However, with the increase in traffic levels, railway operators require a supervision system that provides the locomotive driver and the control centre with additional and more detailed information to monitor operations.

4.4.3.2 Management applications

Energy optimized driving style manager: Train timetables have an additional buffer margin of time incorporated into them to ensure that trains are able to arrive on time, even if starting with a delay. The energy optimized driving style manager application will use the permitted speed profile, the train's position and the predicted arrival time to provide the driver with a suggested speed which enables the train to arrive at the destination on time whilst minimising energy consumption. This application is already beginning to be adopted in some European countries (e.g. Germany), but has yet to gather widespread support as a concept.

Fleet management: Rail network operation can be achieved more efficiently if the availability and location of locomotive, train sets and other rolling stock is known. Furthermore, tracking of vehicles can assist in the co-ordination of rolling stock maintenance by giving advance notification of required maintenance and monitoring the operational hours and distance travelled. The use of positioning information can also assist in route pricing in deregulated networks.

Track survey: Provision of positioning information provides benefits to track survey by improving or adding geographic data to the survey information.

4.4.3.3 Passenger applications

Passenger information: Two categories of information can be identified - information prior to boarding the train and information provided to passengers whilst on the train. Prior to boarding the train, use of positioning information can enhance the quality of information provided to passengers. On-board information can include next station, estimated arrival times and details of connecting services.

Table 4.11: Performance requirements (Rail)

Application		Accuracy		Integrity		Availability	Coverage
		Horiz. (m 95 %)	Vertical (m 95 %) (if appl.)	Time to alarm (sec)	Integrity risk	(%)	Local, Regional or Global
1	Train control	1		1	10^{-9}	99,99	R
2	Train supervision	7		1	5×10^{-6}	99,98	R
3	Energy optimized driving	20		10	10^{-5}	99,9	R
4	Rail fleet management	50		30	5×10^{-4}	99,9	R
5	Track survey	0,005		15	10^{-4}	99,95	L/R
6	Passenger information service	100		30	5×10^{-4}	99,5	R

4.4.4 Current/Planned use of GNSS

4.4.4.1 Current Train Location Systems

Train operation requires the safe separation of trains while travelling on the same track and safe separation at junctions. Any failure of the system must result in a safe situation, usually with trains being brought to a stop. This is traditionally achieved by track circuits detecting the presence of a train through conduction of an electric current through the wheels and axles. This requires a significant amount of trackside equipment; but the train needs no on-board signalling equipment. The driver sees trackside signals and reacts accordingly.

To ease the problems of seeing signals, for example at high speed or in fog, cab signalling has been introduced in some areas. With this, the signal is transmitted to the cabin for display to the driver. As the train is moving, the signal must be related to the train location. To achieve this, a control centre is needed which is continuously updated with the location, speed, identity and direction of each train in its area.

The primary systems already in use within the rail market are:

- Ground systems:
  - Track circuits.
  - Balises.
  - Manual token passing systems.
- On-board systems:
  - Odometry.
  - Rail maps/books.
  - Driver/controller knowledge.
  - Satellite based systems (GPS).

4.4.4.2 Future use of GNSS

The use of GNSS for non-safety critical applications remains limited to a minority of Train Operating Companies (TOCs). Despite the fact that GPS has been available for some time and meets the necessary user requirements, it appears that TOCs are, as yet, unable to justify the necessary investment on the basis of saved fleet costs or satisfied customers. If the method of positioning may be effectively shared with safety critical applications, then the business case becomes clear.

Given the stringent requirements of accuracy (1 m) and integrity TTA (1 second), neither Galileo nor any regional augmentation will be able to satisfy such requirements and it is therefore highly likely that existing ground based systems will remain as the operational standard and primary method of train location until higher levels of ETCS are implemented. However, such ground systems may be implemented at a reduced level in some areas if safety and cost considerations allow.

GNSS may provide additional accuracy and redundancy where required as a complement to ground based systems. Furthermore, for rural lines where the density of traffic is lower and particularly where there are single-track clauses and little trackside equipment, GNSS based train control may be proven sufficient for a lower level of requirement.

4.4.5 Drivers for uptake of new services

Given the relatively low level of use of GPS, the most critical issue for the railways is whether GNSS (as a whole) can be accepted by the railway community, as opposed to EGNOS or Galileo specifically:

The take-up of GNSS based services is only likely to occur where:

- In regions with developing railway infrastructure (e.g. Eastern Europe), Galileo offers a cost effective means of improving safety relative to more expensive ground based solutions.
- In regions with a developed infrastructure (e.g. Western Europe), Galileo offers a means of reducing global costs whilst at least maintaining safety levels. (This is becoming increasingly valid for those clauses of railway suffering from damage and vandalism).

The primary drawbacks of GPS to the railway industry are as follows:

- Low signal availability, which presents particular problems for rail users in cuttings and tunnels.
- Lack of signal integrity information (required for all applications, although its applicability to passenger information is debatable and could be overcome with DGPS).
- Lack of commercial accountability with regard to performance (i.e. service guarantees).

Signal availability: The additional ranging sources provided by GPS/Galileo will provide an improvement in terms of signal availability. However, in extreme visibility conditions, it is considered unlikely that it will be sufficient on its own, thereby necessitating additional local/regional augmentation. For example, a combination of EGNOS and other on-board instrumentation (e.g. odometry) has been shown in recent trials undertaken by the Czech Railways to deliver the necessary continuity of service through extreme conditions such as tunnels and cuttings.

Integrity: The requirement for integrity for safety critical applications represents the most stringent of all markets, in terms of both integrity risk and time to alarm. If however, the industry moves towards a mix of systems including GNSS, then the integrity information provided by Galileo and/or regional augmentations will be highly valuable. (EGNOS has never been needed!!).

The delivery of Galileo/EGNOS data (including integrity) might also be best delivered via existing PMR/GSM-R radio links as opposed to the SIS, thus maximising service availability in extreme visibility conditions. The functionality and complexity of the receiver could also be simplified, thus also reducing on-board costs.

Service guarantees: Depending upon the mix of positioning systems deployed and the level of dependency upon GNSS, a commercial service guarantee may be highly valuable in demonstrating a suitable safety case. However, the necessary legal and institutional frameworks are currently far from being implemented and such a value proposition therefore carries some risk.

4.5 Fleet and asset management

4.5.1 Organizational context

This clause addresses corporate users or organizations responsible for managing and/or co-ordinating a fleet of vehicles, personnel or assets as part of an operational business. For the purposes of this analysis, the clause only addresses those markets that are deemed to have an operationally critical requirement, and may therefore be willing to support a non-consumer based technology platform such as VDL Mode 4. These include:

- Emergency services.
- Asset and cargo management (including inter-modal operation).
- Transport of highly valuable/dangerous goods.

This clause does not address the wider less critical market for fleet management incorporating general commercial vehicles and public transport that are not deemed to represent likely markets for VDL Mode 4. However, it is vital to note that this market will be heavily influenced by the availability of inexpensive products and services in the consumer market.

Despite the wide group of users within this clause, there are a number of common characteristics. Unlike, previous clauses, this market occur at a more local level. Decisions with regard to technology deployment will normally be made by individual organizations on the basis of operational benefit. The only exception to this is emergency services, where there may be some degree of national co-ordination or funding.

To this end, the number of potential end users is vast and the competition amongst system manufacturers, system integrators and different technology platforms is fierce. The market for telematics services, vehicle tracking applications and GPS receivers is mature despite the fact that its use cannot yet be considered widespread, and is often therefore driven by cost as the main differentiator.

By its very definition, there are no regulatory requirements placed upon this market that could influence the introduction of navigation services. All regulatory drivers are covered under clause 4.6.

4.5.2 Market segmentation

Table 4.12 illustrates the different categories of user in the road transport market and the estimated market size (according to year) in Europe. This market size represents the maximum number of potential users and does not represent the actual number of GNSS or Galileo users.

Table 4.12: Market segmentation and size (Fleet/asset management)

User Group	2005	2010	2015	2020
Emergency service vehicles	749 976	857 201	982 982	1 125 250
Public safety officers on foot (millions)	3,756	4,333	4,999	5,768
Commercial asset tracking (millions)	2,68	3,09	3,62	4,30
Valuable/secure goods vehicles	8 750	10 150	11 774	13 658
Inter-modal cargo transportation	4 320	4 990	5 840	6 930

4.5.3 Applications and requirements

4.5.3.1 Emergency services

Those applications relevant to emergency services are as follows:

- **Vehicle tracking:** where a fleet of emergency vehicles are tracked for the purposes of managing incident response and allocating resource to urgent calls. These applications already exist, typically deploying local area GPS or regional LF radio navigation schemes and using existing PMR (Private Mobile Radio) or TETRA (TErrestrial TRunked RAdio) data communications to transfer location data to a control centre.

- **Route guidance:** where emergency vehicles are guided to specific incidents and require a higher performance than the equivalent consumer application.

- **Officer-on-foot tracking:** where foot patrol officers are tracked, typically during a major incident where multiple agencies are operating in a co-ordinated fashion.

4.5.3.2 Commercial operations

Fleet management and logistics: A significant proportion of commercial fleet operators, emergency services and public utilities already operate position based fleet management applications. Many of these applications are based upon GPS or terrestrial based positional systems. The transmission of geographical position is often combined with other telemetry applications such as:

- Vehicle identity and status.
- Fuel management.
- Cargo monitoring.
- Driver identity and shift status.
- Maintenance checks.

Intermodal cargo operations: The management of fleet and goods vehicles within a major transport terminal raises specific requirements in addition to those relating to general fleet management. Within a major terminal, such as an airport or harbour, it is possible that multiple modes of transport will be integrated together through a large number of freight movements and a single operating authority will be responsible for the smooth operational running of that terminal.

Whilst the requirements for accuracy and integrity are similar to those of fleet management, the additional requirements that are raised are:

- Interoperability and/or consistency between multiple modes of transport and different commercial operating companies and policing authorities.

- High concentration of traffic within a single area, with a consequential effect on communications and capacity.

- Ability to support many other telematics applications such as electronic goods transactions.

- Safety critical implications of road vehicles interacting with high speed transport such as aircraft at a major airport terminal.

- Potentially more stringent line-of-sight constraints comparable to a heavy urban environment.

Asset management: The monitoring of cargo or assets is of primary interest to wholesale companies, major goods suppliers and supermarkets, as well as individuals (e.g. parcel delivery). The monitoring of specific items of cargo raises specific requirements that differ from those which apply to the monitoring and tracking of vehicles. The major differences are as follows:

- The organization which has the greatest vested interest in tracking the cargo location (e.g. supermarket) is not necessarily the carrying freight operator.
- The cargo itself may be transported over large distances involving one or more freight operators and/or modes of transport.

Specific examples of assets or cargo that impose additional security and/or safety requirements are those concerned with valuable goods and nuclear waste.

Table 4.13: Performance requirements (Fleet/asset mgmt)

Application		Accuracy		Integrity		Availability	Coverage
		Horz. (m 95 %)	Vertical (m 95 %) (if appl.)	Time to alarm (sec)	Integrity risk	(%)	Local, Regional or Global
Emergency services							
1	Vehicle tracking	5		20	10^{-5}	99,5	R
2	Route guidance	3		6	10^{-5}	99,5	R
3	Officer tracking	10		20	10^{-5}	99	L/R
Commercial operations							
4	Tracking of valuable or dangerous goods	10		30	10^{-5}	99,9	R
5	Intermodal cargo Ops	1-3	2-6	60	10^{-3}	95	R
6	Asset Tracking	10-30	10-30	60	10^{-3}	95	R

4.5.4 Current/planned use of GNSS

4.5.4.1 Existing use of GNSS

The primary systems already in use (or emerging) within the road transport market are as follows:

- Satellite based systems:
  - Global Positioning System (GPS).
  - Proprietary commercial D-GPS services.
- Terrestrial based systems:
  - Digital cellular systems (GSM/UMTS).
  - RDS broadcast.
  - Beacons or RF networks.
- On-board systems:
  - Odometry.
  - GIS and map matching.
  - Driver/controller knowledge.

Whilst GPS is already established as the primary choice of radio navigation system, its use is still not widespread across many sectors. Regardless of system performance, it would appear that many users are unable to justify the business case for implementing such systems on the basis of operational savings.

4.5.4.2 Shortfalls of GPS

GPS is already well established as the primary means of satellite navigation either as "sole means" or via additional wide/local area augmentation to provide a D-GPS service. The primary drawbacks of GPS are:

- Lack of signal **integrity**.
- Lack of commercial basis and **service guarantees**.
- Low signal **availability** in urban areas.
- Not true!!

In addition to the drawbacks outlined above, many existing applications require relatively high levels of positional accuracy at a sufficient level of availability. Such requirements could only currently be met by D-GPS, thereby unnecessarily increasing infrastructure costs and system complexity. An example of such an application is the tracking of law enforcement or intelligence foot patrol officers at a major incident.

In parallel with GPS, other methods (both terrestrial and vehicle based) will continue to be available for the foreseeable future. These systems should therefore be considered as a given context into which Galileo services must be directed. This is particularly relevant to systems such as odometers that are now relatively inexpensive and easy to integrate into a standard vehicle chassis.

4.5.5 Drivers for uptake of new services

4.5.5.1 Drivers for GNSS

Given that existing users of GPS are unlikely to "switch" to EGNOS/Galileo and replace existing receivers for what appears to be marginal benefit, EGNOS and Galileo must focus upon three objectives, namely:

- Provide a more cost effective alternative to D-GPS that will result in a more favourable business case.
- Complement existing GPS with EGNOS/Galileo data provided via a fixed data gateway to control centre (or equivalent).
- Enable new applications whose requirements cannot be met by existing positioning services (i.e. those valuing high integrity or service guarantees).

The first of these three objectives will be difficult to achieve and unlikely to result in significant numbers of increased users since it is unlikely that new technology solutions will remove financial or market specific obstacles. It is therefore considered that those users that already deploy GPS will be more likely to consider further improvements in performance.

There would appear to be a clear case for the provision of EGNOS data in order to provide a cost effective improvement in integrity and accuracy. For those users that would be able to justify such an upgrade, the market is best suited to indirect data distribution due to:

- The need to avoid receiver replacement.
- The potential LOS constraints in urban environments.

4.5.5.2 Specific Galileo capabilities

The benefits to users of providing an integrated GPS/Galileo capability are:

- Provision of additional **availability** in urban areas that could not otherwise be provided by GPS/DGPS. This is particularly valid for the target markets described in this clause.
- Provision of **integrity** information to those users that could justify its use. (This is already included in VDL Mode 4 systems already deployed, and has been since 1991).

A more detailed discussion of the needs for navigation data distribution is provided in clause 5.3.4.

4.6 Regulated road transport

4.6.1 Organizational context

4.6.1.1 Primary organizations and stakeholders

This market has so far been led by the private marketplace, with the provision of commercial traffic congestion information to in-vehicle terminals, and the use by commercial operators of beacon and GPS based systems to track vehicles. In both cases the systems tend to operate with a high volume of low cost end user systems.

The expanding government requirements will need to build on this commercial infrastructure with additional services. In particular, there is a developing governmental interest in road pricing and city access pricing.

The relationship between "users" and "customers" and the identification of decision makers is complex in this application. The use of a particular system for road pricing (both city access and inter-urban) and traffic monitoring will be decision made by a governmental or quasi-governmental authority. In some areas, such as Europe, for reasons of commonality it is likely to involve co-operation between governments.

This authority is the decision-maker in that it mandates the use of a particular system and (for charging) insists that all affected vehicles be fitted with the appropriate equipment. It may be that the authority pays for the equipment but it is more likely that each vehicle owner will be expected to equip the vehicle as a condition of accessing the affected areas. The owner may have a choice of suppliers of compliant equipment.

4.6.1.2 Market evolution

The commercial market appears to be expanding rapidly. Most systems rely on GPS, except for some in-city Public Service vehicle systems that use roadside beacons. Increasing road traffic is likely to increase congestion, and governments are reluctant to increase road capacity - therefore there will be pressure to make better use of available space.

In particular, it is worth noting:

- There is an existing market for road pricing using mainly roadside infrastructure, and some use of existing GPS systems (usually installed for fleet management purposes) to provide "tracker" vehicles for road surveillance.
- The market is growing in the advanced world. By 2008 the developing world may have reached a similar position and be looking at similar solutions.
- The development of GPS based navigation systems and cellphone/UMTS information systems in vehicles will have developed further, and there will be a tend to integrate the in-vehicle systems.
- Development is likely to be in large steps rather than smooth, as a whole country (or group of countries) adopts a particular system.
- Such decisions are likely to be bureaucratic and slow, but not necessarily particularly conservative in choice of service.

4.6.1.3 Regulatory Issues

The prime regulatory requirement is the need for all vehicles to be equipped with equipment and for this to be tamper proof. For vehicles to operate across a region, or even worldwide, the technical specifications and performance requirements need to be harmonized. Furthermore, if the equipment is also used as part of other, commercial services, there will be need to resolve the conflict between the anti-tamper requirements of governments and the serviceability requirement of commercial service providers.

A number of ISO Standards are existing (or under development) related to EFC (Electronic Fee Collection) and for associated short-range communication, in a transport environment. While not specifically related to road tolling they could have an influence on system architectures, particularly where it is necessary to interface with other systems.

4.6.2 Market segmentation

Table 4.14 illustrates the different categories of user in the road transport market and the estimated market size (according to year) in Europe. This market size represents the maximum number of potential users and does not represent the actual number of GNSS or Galileo users.

Table 4.14: Market segmentation and size (regulated road transport)

User Group (millions)	2005	2010	2015	2020
Road user charging/tolling	20,0	80,0	90,0	110,0
Road surveillance and enforcement	2,6	4,7	12,9	28,0
Commercial fleet vehicles, including both goods vehicles and public transport	7 355	7 983	8 810	9 519

4.6.3 Applications and requirements

4.6.3.1 Traffic surveillance and enforcement

In order to ensure that vehicles adhere to local traffic laws, positional information can be used as the basis of enforcing such laws. Such information could be applied to a wide variety of legislation including:

- Speed restrictions.
- Limited access.
- Bus lanes.
- Parking restrictions.
- Dangerous driving/overtaking.

4.6.3.2 Road user charging/tolling

Many major highways, bridges or tunnels across Europe are subject to specific tolls, which are levied against all vehicles passing across a designated boundary. The amount levied against each vehicle may be dependent upon the type of vehicle and in order to determine that a vehicle is subject to such a levy (i.e. is not exempt for some reason), that vehicle must physically stop or slow down.

In order to transfer the necessary payment, a vehicle must stop or slow down, transferring physical toll to an attendant or automatic collecting machine. These requirements necessitate significant and expensive ground infrastructure with all of the subsequent effects such as lack of access and environmental considerations.

Positional information is one of many items of electronic information that can be used to support automatic tolling, and thereby avoid traffic delays, reduce terrestrial infrastructure and reduce staffing costs. The indirect benefit of such schemes is that those areas in which such a significant investment in terrestrial infrastructure would not be possible or appropriate (e.g. town centres, areas of beauty), can now be subject to charging, thus increasing fairness of road use.

A major procurement is already underway within Germany to implement such a scheme nationwide, initially for heavy goods vehicles. The system proposed used GPS in association with complementary short-range passive devices that provide both a location and user authentication function. Helios understands that other countries including the UK are on the verge of embarking upon similar initiatives for nationwide schemes.

In support of these initiatives, the EC is developing a European-wide standard for a road user charging system architecture based upon GNSS and other complementary technologies. These standards are intended to cover all aspects of the schemes and not purely positioning (i.e. user authentication, security, financial transactions and vehicle upgrade/fitment).

4.6.4 Current/planned use of GNSS

4.6.4.1 Existing use of GNSS

The primary systems already in use (or emerging) within the road transport market are as follows:

- Satellite based systems:
  - Global Positioning System (GPS).
  - Proprietary commercial D-GPS services.
- Terrestrial based systems:
  - Digital cellular systems (GSM/UMTS).
  - Beacons or RF networks.
- On-board systems:
  - Odometry.
  - GIS and map matching.
  - Driver/controller knowledge.

GNSS is not yet deployed for the purposes of road tolling or road surveillance and monitoring, although a number of states and local authorities have indicated plans to do so over the next five to ten years (e.g. Germany, UK, and the Netherlands).

4.6.4.2 Shortfalls of GPS

GPS is already well established as the primary means of satellite navigation either as "sole means" or via additional wide/local area augmentation to provide a D-GPS service. The primary drawbacks of GPS within this market are:

- Lack of signal **integrity**.
- Lack of commercial basis and **service guarantees**.
- Low signal **availability** in urban areas.

With the exception of signal availability, many users do not perceive the other two shortfalls. The addition of signal integrity and service guarantees will, in general, enable new applications that cannot currently be readily supported by GPS. That said a combination of GPS with complementary on-board systems is perceived to already address many of these shortfalls.

In parallel with GPS, other methods (both terrestrial and vehicle based) will continue to be available for the foreseeable future. These systems should therefore be considered as a given context into which EGNOS/Galileo services must be directed. This is particularly relevant to systems such as odometers that are now relatively inexpensive and easy to integrate into a standard vehicle chassis.

4.6.5 Drivers for uptake of new services

The traffic surveillance and enforcement applications rely upon a greater degree of integrity in order to enable legal or financial transactions. This integrity is required in order to accurately position each vehicle plus provide authentication of vehicle identification and therefore the means for charging.

It is important to therefore realize that whilst GPS cannot satisfy these requirements alone, it could be integrated with other non-positioning systems (e.g. ANPR) to provide the necessary authentication. Alternatively, such a solution may need to include two independent means of positioning in order to provide a sound legal basis.

There are a number of alternative solutions to GNSS; however the need for wide area and regional coverage provides a compelling argument for GPS/Galileo. It is therefore expected that considerable political pressure may be applied in order to provide a sound market for GPS/Galileo in Europe.

It is also worth noting that this market and its applications are "centralised" in the sense that the recipient of location information is not the end-user but a central processing facility. This operational mode would tend towards the provision of navigation data via a fixed data link and not via a SIS or mobile data link. This method of delivery is even more applicable in dense urban regions where road user charging remains applicable.

5 Technical assessment

5.1 Introduction

This clause discusses the performance characteristics of VDL Mode 4 and compares these to the application requirements for the market sectors analysed in clause 2.

5.2 VDL Mode 4 performance

The key features of VDL Mode 4 are:

- Communication services supported:
  - Mobile/ground point to point.
  - Mobile/mobile point to point.
  - Ground to mobile, mobile to ground and mobile-to-mobile broadcast.
  - Mobile-to-mobile services operate without the need for ground infrastructure.
- Channel access:
  - TDMA structure with a self-organising access protocol (STDMA).
  - The reservation protocols allows pre-reservation of a slot for transmission, facilitating control of quality of service.
  - access protocol provides for efficient re-use of slots. The efficiency depends on the physical layer Desired/Undesired (D/U) signal level - 10 dB is typical in current system (giving a re-use range ratio of 3:1)
- Physical layer characteristics:
  - Modulation rate: 19,2kbps.
  - Operates in 25 kHz channels.
  - For aviation, operates in the range 112 000 MHz to 136 975 MHz.
- Message characteristics:
  - Flexible message set supporting link control, broadcast and point-to-point services.
  - Broadcast messages contain position at course resolution sufficient for link management - extensions can be added in same message to provide greater resolution.
  - Messages occupy one or more slots.
  - Final part in a message contains a guard band, of length equal to the maximum operational range time of flight. For aviation, this is equal to 205 nautical miles.
  - For broadcast services update periods can range from 1 second to 60 seconds.

- Quality of service characteristics:
  - Supports 15 priority levels.
  - Point to point service provides for pre-emption of long messages with higher priority short messages.
  - Point to point protocol provides message fragmentation and simple transmit/acknowledge.
  - Reservation protocols enable deterministic treatment of acknowledgements (i.e. both transmitter and receiver know when an acknowledgement is due and hence can retransmit the original message quickly). Therefore the system is well suited to the support of real time data exchange.
  - 16 bit CRC provides burst checking and hence integrity of message.
  - Position information contained in VDL Mode 4 bursts enables location of transmitter to be known to recipient, supporting security applications.
  - Aeronautical Telecommunications Network (ATN) compliant security applications run over Mode 4.
- Maximum time to connect/Entry and connection:
  - Two modes provided for a new station entering the network: standard in which connection time is nominally 1 minute, rapid in which entry time is less than 10 seconds.
  - Once a station is known in the network, two modes are provided for connection for point to point communication: ZOCOP in which connection time is less than 1 second; NSCOP - connection time a few seconds but more secure.

Throughput performance depends on the load on the channel and the scenario in which VDL Mode 4 is being used. Note that re-use characteristics of VDL Mode 4 enable total channel loads significantly greater than 100 % across a region.

Table 5.1 summarizes the performance of VDL Mode 4 for the purposes of this assessment.

Table 5.1: Current technical performance (VDL Mode 4)

Parameter	Performance	Assumptions and notes
Communication services		
Point to point mode	Ground/mobile Mobile/ground Mobile/mobile	
Broadcast mode	Ground/mobile Mobile/ ground Mobile/mobile	
Ground (base) station available to support mobile to mobile services	Not required	
Message characteristics		
Typical message size (bits)	Ranges 168 (1 slot) to 2 472 (10 slots)	This is the message size across the link. Note that, for point to point communication, there is no upper limit because VDL Mode 4 is able to fragment long messages
Minimum update period (secs)	1 sec (mobile transmissions) 0,0133 sec (ground stations)	
Maximum traffic density (per sqkm)	No limit in receive-only mode. For mobile transmissions, maximum depends on configuration	
Ground station density (per sqkm)	No limit in receive-only mode. For ground station transmissions, maximum depends on configuration	
Quality of service characteristics		
Priority levels	15	Priority management for broadcast is managed by each station according to the priority of the message (i.e. high priority messages are broadcast before low priority messages) For point to point services, priority is managed by the ground station, using information contained in transmissions by mobiles
Pre-emption	yes	Applies to point-to-point services only.
Message fragmentation	yes	The impact on the user is that there is no upper limit for message size for point to point communication
Resistance to interference	Position information sent with message - supports user authentication ATN stack protocols	
Encryption	Use of ATN stack	
Message integrity	Error detection via 16 bit CRC	
User authentication	Via unique user address and user position	
Certified service	European standards exist - no format certification of services in aviation as yet	
Maximum time to connect (secs)	Net entry for transmission in less than 10 secs Point to point link established in 1 sec	Note that for uplink broadcast services provided by ground stations, time to connect is entirely set by the start up time of the mobile equipment and is not linked to delays associated with gaining knowledge of the TDMA slot map. Hence it is implementation dependent

Parameter	Performance	Assumptions and notes
Communication services		
Coverage		
Maximum range	200 nautical miles (en-route aircraft) 100 nautical miles (ground stations and low lying aircraft)	Maximum range limited by rf link characteristics for high aircraft For low lying aircraft, range limited by line of sight considerations
Typical ground station operating range	150 nautical miles (en-route aircraft) 100 nautical miles (ground stations and low lying aircraft)	Note that the range is dependent on channel load and coordination with other ground stations. For example, if the application is for short range, high load, then this can be achieved with more ground stations at close spacing
Typical ground station height above ground (m)	10 to 100 m	
Total capacity (kbits/sec sqkm)	Application dependent	Not relevant for uplink broadcast

5.3 Definition of market requirements

5.3.1 Air transport

5.3.1.1 Need for navigation data distribution

There is a critical need for navigation data distribution in the air transport market. This will be largely met by EGNOS and GALILEO, but there are occasions where this may not be sufficient:

- High latitude areas may not achieve EGNOS coverage.
- Busy airports, where a pseudo-urban environment exists close to terminal buildings, may lack good EGNOS and GALILEO coverage.
- During some low-altitude high-banking manoeuvres it is conceivable that EGNOS reception will not be possible.

In all these cases, VDL Mode 4 is one way that navigation data distribution could be supplemented.

5.3.1.2 Supplementary data requirements

Supplementary data that could be useful to air transport include meteorological information, METARS, TAFs and ATIS messages. Terrain information could also be valuable to those without necessary databases already on-board.

Distribution of these data is well suited to transmission by a ground-to-air broadcast datalink such as VDL Mode 4.

5.3.1.3 Link requirements

Table 5.2 provides a summary of the typical link requirements for the air transport market. The figures within the table are based upon typical operations. The figure for data capacity is based purely upon the requirement for navigation data distribution, although other supplementary applications have been taken into account when specifying non-quantitative requirements.

Table 5.2: Navigation link requirements (Air transport)

Parameter	Requirement	Assumptions and notes	VDL Mode 4 Compliance (uplink broadcast)
Communication services			
Point to point mode	None		Not required
Broadcast mode	Ground/mobile Mobile/ ground Mobile/mobile	Ground/mobile for GNSS augmentation distribution. Other modes used for ADS-B.	Compliant
Ground (base) station available to support mobile to mobile services	Not required		Not required
Message characteristics			
Typical message size (bits)	1 or 2 slots	2 slots for 8-satellite GNSS augmentation message based on GBAS SARPs. 1 slot for ADS-B message.	Compliant
Minimum update period (secs)	1 sec (mobile transmissions) 0,5 sec (ground stations)	Mobile update rate for ADS-B application. Ground station rate based on GLS CAT I application.	Compliant
Maximum traffic density (per sqNM)	For ADS-B: Core en-route: 0,00554 Core inner TMA: 0,0641 Core outer TMA: 0,0131 Non-core en-route 0,00277 Non-core TMA: 0,000955 Ground entire scenario: $8,85 \times 10^{-5}$ Ground core TMA: 0,318 + AIRPORT	Densities taken from Eurocontrol [5]. Units in sqNM. Note, no limit specified for GNSS augmentation which is a broadcast application.	Compliant (expected to meet GNSS uplink requirements on one channel) Detailed assessment would be needed to validate this. If assertion not true, more than one channel would be required.
Ground station numbers	For GNSS augmentation: ADS-B/GRAS ground stations: 525 CAT I airports: 267 CAT II/III airports: 70	Figures taken from clause 4.2. Units are number of ground stations in Europe. (Not density)	Compliant (see comments in previous row)
Quality of service characteristics			
Priority levels	2	One each for GNSS augmentation and ADS-B	Compliant
Pre-emption	No	Not required for uplink broadcast	Not required
Message fragmentation	No		Not required

Parameter	Requirement	Assumptions and notes	VDL Mode 4 Compliance (uplink broadcast)
Resistance to interference	Position information sent with message - supports user authentication ATN stack protocols		Compliancy not established (VDL4 provides a range of measures - detailed analysis of application requirements will be necessary)
Encryption	Use of ATN stack	But not required for uplink broadcast	Not required
Message integrity	16 bit CRC		Compliant
User authentication	Via unique user address and user position		Compliant
Certified service	European standards exist - no formal certification of services in aviation as yet		Will be compliant when certification processes are complete
Maximum time to connect (secs)	Net entry in less than 10 secs Point to point link established in 1 sec		Compliant Note that for uplink broadcast services provided by ground stations, time to connect is entirely set by the start up time of the mobile equipment and is not linked to delays associated with gaining knowledge of the TDMA slot map. Hence it is implementation dependent
Coverage			
Maximum range	200 nautical miles		Compliant
Typical ground station operating range	100 nautical miles (ground stations and low lying aircraft) 150 nautical miles (en-route aircraft)		Compliant
Typical ground station height above ground (m)	10 m to 100m		Compliant
Total capacity (kbits/sec sqkm)	Application dependent		Not relevant for uplink broadcast

5.3.2 Maritime transport

5.3.2.1 Need for navigation data distribution

Given the existing DGPS infrastructure, there is not yet a clear case for the introduction of EGNOS or Galileo. That said, both systems offer potential performance enhancements and must therefore be seen a highly likely candidates in a future radio navigation system mix.

With the exception of a minority of in-land operations and port movements, the delivery of navigation data via a SIS does not pose any limitations in availability since there are few line of sight constraints. However, in order to receive such data, a vessel will be required to upgrade its existing GPS receiver equipment to EGNOS/Galileo compatible devices.

In order to overcome such constraints, there is an opportunity for EGNOS/Galileo to provide additional navigation data to vessels via a parallel communications channel. This data can then be used to augment the GPS pseudo-range information onboard the vessel to provide an improved navigation performance.

The primary candidate for such communication would appear to be the STDMA AIS links between shore and vessels. However, the work undertaken as part of the GALILEI local elements study has also proposed the use of GSM/UMTS in coastal regions.

It should also be noted that for applications such as port security and traffic management, the final recipient of vessel location information is the port authority and not the vessel itself (see clause 4.3.4). This "centralized" application architecture lends itself extremely well to the remote delivery of navigation data. Such a channel does not however depend upon a mobile capability and can be handled via a fixed communications gateway over the Internet or Wide Area Network (WAN).

5.3.2.2 Supplementary data requirements

AIS support increased situational awareness both shore to vessel and vessel to vessel. In addition, it provides a means of broadcasting a host of other data services to vessels such as meteorological information, heading, wind speed, tidal information, etc. Such requirements are well suited to an STDMA scheme such as that already supported by the mandated maritime AIS.

5.3.2.3 Link requirements

Table 5.3 provides a summary of the typical link requirements for the maritime transport market. The figures within the table are based upon typical operations in a coastal or harbour region with dense traffic requirements. The figure for data capacity is based purely upon the requirement for navigation data distribution, although other supplementary applications have been taken into account when specifying non-quantitative requirements.

Table 5.3: Navigation link requirements (Maritime transport)

Parameter	Requirement	Assumptions and notes	VDL Mode 4 Compliance (uplink broadcast)
Communication services			
Point to point mode	None		Not required
Broadcast mode	Ground/mobile Mobile/ ground Mobile/mobile	Ground/mobile for GNSS augmentation distribution. Other modes used for navigation and position reporting.	Compliant
Ground (base) station available to support mobile to mobile services	Not required at present		Not required
Message characteristics			
Typical message size (bits)	< 250	Estimate based upon RTCA standard for GNSS augmentation data. Could be further reduced/optimized.	Compliant
Minimum update period (secs)	1 sec	Source: European Maritime Radio navigation Forum (EMRF)	Compliant
Maximum traffic density (per sqNM)	50	Estimate based upon harbour operations	Compliant NOTE: High density compared with air transport. This will probably require a greater number of ground stations or channels to accommodate load - detailed analysis out of scope.
Ground station numbers	136	Estimate of European total of DGPS stations, based upon future known plans.	Compliant

Parameter	Requirement	Assumptions and notes	VDL Mode 4 Compliance (uplink broadcast)
Quality of service characteristics			
Priority levels	2	Regulated/non-regulated navigation services. No formal requirement currently.	Compliant
Pre-emption	No		Not required
Message fragmentation	No		Not required
Resistance to interference	High	Safety critical application	Compliancy not established (VDL4 provides a range of measures - detailed analysis of application requirements will be necessary)
Encryption	No	Note user authentication below.	Not required
Message integrity	Not known		TBD
User authentication	Via unique user address and user position	Further potential requirement to support revenue collection and user charging.	Compliant
Certified service	European standards exist - no formal certification of services in maritime transport as yet		Will be compliant when certification processes are complete
Maximum time to connect (secs)	5 secs	Estimate based upon AIS/ECDIS requirements.	Note that for uplink broadcast services provided by ground stations, time to connect is entirely set by the start up time of the mobile equipment and is not linked to delays associated with gaining knowledge of the TDMA slot map. Hence it is implementation dependent
Coverage			
Maximum range	250 nautical miles	Estimate based upon current usable range in DGPS network.	Compliant
Typical ground station operating range	100 nautical miles for navigation 2 to 5 nautical miles for harbour operations	Normal operational range.	Compliant
Typical ground station height above ground (m)	25 m to 100 m		Compliant
Total capacity (kbits/sec sqkm)	Application dependent		Not relevant for uplink broadcast

5.3.3 Rail transport

5.3.3.1 Need for navigation data distribution

There is a common belief within the industry that GNSS has a future role as an element within the radio navigation system mix for safety critical rail transport. That said, the current use of GPS is low and limited purely to management information applications. That said, much is already being done to prove the value of EGNOS in a safety critical environment.

The primary driver for GNSS is the rationalization of ground infrastructure, thereby tending towards a future on-board capability consisting of GNSS plus odometry, INS, etc. However, the severe line of sight constraints in deep cuttings, major terminals and tunnels provide a difficult environment for GNSS.

Navigation data from local or regional augmentation is therefore likely to be provided via a blend of SIS (where local conditions allow) and preferred communications bearers. The railways are already a heavy user historically of trunked analogue PMR (Private Mobile Radio) and will be expected to move almost entirely towards GSM-R by 2015.

A number of applications (e.g. management information) support a centralized mode of operation where the recipient of vehicle or asset location information is a control centre as opposed to the train itself. These applications would therefore tend towards non-mobile methods of navigation data delivery.

5.3.3.2 Supplementary data requirements

There is a considerable communications requirement within the rail transport sector, both in support of signalling and also general "track to shore" communications. These in turn, cover both essential and non-essential applications. This requirement is a mix of point-to-point communications and broadcast communications and is in general terms satisfied by existing means.

5.3.3.3 Link requirements

Table 5.4 provides a summary of the typical link requirements for the rail transport market. The figures within the table are based upon typical operations surrounding a major rail terminal with dense traffic requirements. The figure for data capacity is based purely upon the requirement for navigation data distribution, although other supplementary applications have been taken into account when specifying non-quantitative requirements.

Table 5.4: Navigation link requirements (Rail transport)

Parameter	Requirement	Assumptions and notes	VDL Mode 4 Compliance (uplink broadcast)
Communication services			
Point to point mode	Yes	Some safety critical addressable signalling functions.	Compliant
Broadcast mode	Ground/mobile Mobile/ ground Mobile/mobile	Wide variety of signalling functions plus cab/shore voice and data services.	Compliant
Ground (base) station available to support mobile to mobile services	Yes	Services are currently directly analogous to cellular systems.	Compliant
Message characteristics			
Typical message size (bits)	< 250	Estimate based upon RTCA standard for GNSS augmentation data. Could be further reduced/optimized. Note that there are non-nav applications which will use a larger message size - to be addressed during market acceptability assessment	Compliant
Minimum update period (secs)	1 sec	Source: European Rail Advisory Forum	Compliant
Maximum traffic density (per sqNM)	100	Estimate based upon major rail terminus.	Compliant NOTE: High density compared with air transport. This will probably require a greater number of ground stations or channels to accommodate load - detailed analysis out of scope.

Parameter	Requirement	Assumptions and notes	VDL Mode 4 Compliance (uplink broadcast)
Ground station numbers	Up to 10 per sq km Varies according to specific capacity and coverage requirements. Potentially large overlap and reuse.	Ground stations are currently based upon GSM/GSM-R.	Compliant (further analysis would be needed to determine number of ground stations required)
Quality of service characteristics			
Priority levels	At least 3	Consistent with existing data services.	Compliant
Pre-emption	Yes	Application specific	Compliant
Message fragmentation	Yes	Not required for uplink broadcast but would be needed for other applications	Compliant
Resistance to interference	High	Safety critical application	Compliancy not established (VDL4 provides a range of measures - detailed analysis of application requirements will be necessary)
Encryption	No	Note user authentication below.	Compliant
Message integrity	Not known		TBD
User authentication	Via unique user address, user position and mixed status	Further potential requirement to support revenue collection and user charging.	Compliant
Certified service	Yes	Safety cases for new services are developed at a national level.	Will potentially be compliant when certification processes are complete
Maximum time to connect (secs)	2,5 sec	Based upon current performance of GSM-R.	Compliant (for uplink broadcast)
Coverage			
Maximum range	50 miles 20 miles	Extreme of legacy VHF PMR Typical range of GSM-R.	Compliant
Typical ground station operating range	10 miles	Normal operational range.	Compliant - note that short typical operating range means that it is possible to re-use channel - this is standard operating practice for GSM
Typical ground station height above ground (m)	5 m to 25 m		Compliant
Total capacity (kbits/sec sqkm)	Application dependent		Not relevant for uplink broadcast

5.3.4 Fleet and asset management

5.3.4.1 Need for navigation data distribution

Both EGNOS and Galileo offer potential benefits to this sector, in terms of signal availability in urban environments, positional integrity and (potentially) commercial service guarantees. There are a number of factors that lead to a significant need for navigation data distribution:

- The urban environment does not necessarily support high availability from SIS.
- The users in this market are heavy users of mobile telecommunications.
- This market is a source of service revenues for service providers who would wish to control access to navigation data.

Despite the apparent requirement for data distribution, it must also be noted that:

- A large number of the applications are centralized and require location information to be transmitted to a control centre via a fixed channel (e.g. Internet);
- There are a significant number of existing mobile communication channels and would effectively act as competitors to VDL Mode 4 (see clause 4).

5.3.4.2 Supplementary data requirements

There is a considerable two-way communications requirement within the fleet/asset management market. This is predominantly point-to-point communications between a mobile resource and a control centre (e.g. telematics, data dispatch, status monitoring, etc). These in turn, cover both essential and non-essential applications. There is also a smaller requirement for broadcast communications (e.g. traffic information).

5.3.4.3 Link requirements

Table 5.5 provides a summary of the typical link requirements for the fleet/asset management market. The figures within the table are based upon a number of co-operational and simultaneous users within an urban region (e.g. major incident/event). This does not account for the potential number of simultaneous users that are undertaking un-related operations.

The figure for data capacity is based purely upon the requirement for navigation data distribution, although other supplementary applications have been taken into account when specifying non-quantitative requirements.

Table 5.5: Navigation link requirements (Fleet/asset management)

Parameter	Requirement	Assumptions and notes	VDL Mode 4 Compliance (uplink broadcast)
Communication services			
Point to point mode	No	Rarely used	Not required
Broadcast mode	Ground/mobile Mobile/ ground Mobile/mobile	Yes Yes No	Compliant
Ground (base) station available to support mobile to mobile services	No	Operated as uplink broadcast only	Not required
Message characteristics			
Typical message size (bits)	< 250	Estimate based upon RTCA standard for GNSS augmentation data. Could be further reduced/optimized.	Compliant
Minimum update period (secs)	5 secs to 10 secs	Source: European GNSS Road Advisory Forum	Compliant
Maximum traffic density (per sqNM)	200 1 000	Busy urban area Estimate based upon major event or multi-agency emergency incident.	Compliant NOTE: Very high density compared with air transport. This will probably require a greater number of ground stations or channels to accommodate load - detailed analysis out of scope.

Parameter	Requirement	Assumptions and notes	VDL Mode 4 Compliance (uplink broadcast)
Ground station numbers	Up to 10 per sq km Varies according to specific capacity and coverage requirements. Potentially large overlap and reuse.	Maximum density based upon deployment of GSM/UMTS microcells.	Compliant (further analysis would be needed to determine number of ground stations required)
Quality of service characteristics			
Priority levels	1-3	Normally only one level of operational priority. Could be higher for emergency services.	Compliant
Pre-emption	Yes	In event of emergency call. Not applicable to GNSS data broadcast.	Not required
Message fragmentation	No		Not required
Resistance to interference	Medium	Operationally critical application	Compliant Expect VDL Mode 4 measures to be appropriate for this medium criticality application
Encryption	Yes	Required for emergency services and high value asset management.	Not compliant unless provided by higher layers
Message integrity	Yes	See encryption.	Not compliant unless provided by higher layers
User authentication	Via unique user address		Compliant
Certified service	No		Not required
Maximum time to connect (secs)	5 secs	Estimate of average requirement and existing systems.	Compliant (for uplink broadcast and most other applications)
Coverage			
Maximum range	20 miles	Typical range of GSM in rural regions	Compliant - note that physical layer would require modification to provide reduced guard range
Typical ground station operating range	200 m	Normal operational range in heavy urban region	Compliant - see comment in row above
Typical ground station height above ground (m)	5 m to 20 m	Estimate based upon existing microcells	Compliant
Total capacity (kbits/sec sqkm)	Application dependent		Not relevant for uplink broadcast

5.3.5 Regulated road transport

5.3.5.1 Link requirements

Table 5.6 provides a summary of the typical link requirements for the regulated road transport market. The figures within the table are based upon a road user charging environment along a busy motorway. The figure for data capacity is based purely upon the requirement for navigation data distribution, although other supplementary applications have been taken into account when specifying non-quantitative requirements.

Table 5.6: Navigation link requirements (Regulated road transport)

Parameter	Requirement	Assumptions and notes	VDL Mode 4 Compliance (uplink broadcast)
Communication services			
Point to point mode	No	Rarely used	Not required
Broadcast mode	Ground/mobile Mobile/ ground Mobile/mobile	Yes Yes No	Compliant
Ground (base) station available to support mobile to mobile services	No	Operated as broadcast only	Not required
Message characteristics			
Typical message size (bits)	< 250	Estimate based upon RTCA standard for GNSS augmentation data. Could be further reduced/optimized.	Compliant
Minimum update period (secs)	5 secs	Source: European GNSS Road Advisory Forum	Compliant (OK for uplink broadcast)
Maximum traffic density (per sqNM)	1 500	Estimate based upon extreme conditions in road user charging scheme	NOTE: Very high density compared with air transport. This will probably require a greater number of ground stations or channels to accommodate load - detailed analysis out of scope.
Ground station numbers	Up to 10 per sq km Varies according to specific capacity and coverage requirements. Potentially large overlap and reuse.	Maximum density based upon deployment of GSM/UMTS microcells.	Compliant (further analysis would be needed to determine number of ground stations required)
Quality of service characteristics			
Priority levels	2	Estimate based upon likely priority needs	Compliant
Pre-emption	No		Not required
Message fragmentation	No		Not required
Resistance to interference	High	Services are financially critical and therefore highly susceptible to intentional jamming or interference.	Compliancy not established (VDL4 provides a range of measures - detailed analysis of application requirements will be necessary)
Encryption	Yes	See above	Not compliant unless provided by higher layers
Message integrity	Yes	See encryption.	Compliant - CRC probably good enough
User authentication	Via unique user address	Yes, to support financial transaction and legal basis for law enforcement	Compliant
Certified service	Yes	See above	Will potentially be compliant when certification processes are complete
Maximum time to connect (secs)	5 secs	Estimate of average requirement.	Compliant
Coverage			
Maximum range	20 miles	Typical range of GSM in rural regions	Compliant - note that physical layer would require modification to provide reduced guard range
Typical ground station operating range	200 m	Normal operational range in heavy urban region	Compliant - see comment in row above

Parameter	Requirement	Assumptions and notes	VDL Mode 4 Compliance (uplink broadcast)
Typical ground station height above ground (m)	5 m to 20m	Estimate based upon existing microcells	Compliant
Total capacity (kbits/sec sqkm)	Application dependent		Not relevant for uplink broadcast

5.4 Conclusions

5.4.1 Communication services

VDL Mode 4 can support all identified requirements. Note that the emphasis of the assessment has been on the uplink broadcast of navigation data. VDL Mode 4 provides a far wider range of communication services and the potential for use of these services in related applications will be assessed during the market acceptance work.

5.4.2 Message characteristics

Since applications are uplink broadcast only then generally the uplink load is not a problem to sustain. One issue, which would be a subject for detailed assessment of applications, arises where long range is required (i.e. aviation and maritime) and capacity could be provided through controlled re-use slots re-use needs or though additional VHF channels.

The opposite extreme applies to short-range high-density applications (particularly in land applications). The general message rates are relatively low and hence there are unlikely to be capacity issues. However, optimization of the link characteristics may be required to tailor the slot times and guard ranges for use at short range.

Capacity of the link is more of an issue where other communication services are required. This issue will be investigated when a clearer picture of other desirable applications has been derived.

5.4.3 Quality of service characteristics

VDL Mode 4 provides good support for priority and meets all requirements.

User authentication: since VDL Mode 4 provides identity and position of the user (assuming that mobiles receiving an uplink broadcast service also transmit) it is well adapted to services requiring user authentication and, in particular, services were charging may be an issue.

The general topic of resistance to interference and encryption is a difficult area to assess. VDL Mode 4 provides a package of measures, which can provide a level of immunity to interference. Detailed investigation is required to evaluate if these are sufficient for particular applications. This will be carried out as part of the evaluation of the need for further standardization measures.

Time to connect is no issue for the uplink of information from ground stations and limited simply by the time taken for a mobile to power up. Time to connect becomes an issue if other types of communication services are required although VDL Mode 4 can meet most requirements

5.4.4 Coverage

There is a wide variation in maximum range and ground station operating range for the applications considered. This indicates that significant adaptation of link might be required (i.e. reduce guard range). This will be considered further when investigating the need for further standardization.

5.4.5 Summary

VDL 4 can support most uplink broadcast requirements but might need additional standardization measures as follows:

- Adaptation of link characteristics (physical layer and MAC layer).
- Adaptation of message set.
- Addition of encryption, authentication etc. services.

6 Market suitability assessment

6.1 Introduction

This clause provides an assessment of the wider market suitability of introducing VDL Mode 4 in each of the target markets. clause 3 has already determined the technical feasibility of utilising VDL Mode 4 for the uplink broadcast of navigation data and other applications. This clause therefore builds upon the output from clause 3 to determine what other issues and obstacles would need to be tackled for VDL Mode 4 to be considered as a candidate data link.

The assessment is structured according to a set of acceptance criteria. These are:

- **Functional suitability:** As stated in clause 3, VDL Mode 4 provides a far wider range of communication services and the degree to which these other functions are required will dictate the suitability and effective cost of VDL Mode 4.
- **Institutional/organizational acceptance:** Acceptance by international bodies, governments and other relevant institutions. This is highly applicable to safety critical transport and less relevant to de-regulated land mobile markets.
- **Standards:** The availability of suitable standards in order to enable the introduction of VDL Mode 4. These may be required at both the application level and system level.
- **Competition:** The range of alternative data link technologies available to each market will dramatically affect the likelihood of VDL Mode 4 gaining widespread acceptance. The availability of multiple, low cost legacy systems will effectively prohibit VDL Mode 4's introduction.
- **Cost:** Depending upon the degree of replacement of legacy systems, the cost of introducing a new data link technology may be prohibitive for some markets. The key issue here is the relative cost of VDL Mode 4 against competition.
- **Terminal availability:** Linked to the cost of infrastructure, it is essential that users have access to low cost terminals that adhere to all relevant standards.
- **Spectrum availability:** Many of the markets already utilize spectrum in the VHF range and may be adapted to take account of VDL Mode 4 capability. Other markets may require new spectrum allocations or the adaptation of VDL Mode 4 to other spectrum ranges.

Each of these criteria is assessed for each market in the following clauses. At the end of each market, a table is presented summarising the degree of suitability in qualitative terms (i.e. high, low or medium). This will enable a simple comparison of markets at the end of this clause and the clear identification of future actions including standards.

Table 6.1 provides an indicative guide to the terms used in the qualitative assessment.

Table 6.1: Qualitative assessment guide

Market suitability criteria	Qualitative assessment		
	Low	Medium	High
Functional suitability	Low match of service needs with VDL Mode 4 capabilities. Typically confined to broadcast services.	Relatively high degree of synergy between needs and capability. Potential to expand in the future.	High match of service needs with VDL Mode 4 including broadcast and point to point applications
Institutional/organizational acceptance	Highly unlikely to gain the necessary support due to cost, competition or other key factors.	Possible to gain the necessary support but some major obstacles remain.	Some institutional acceptance already established. Further work is still required.
Standards	Highly unlikely that sufficient support can be gathered in order to develop the required standards. Dictated largely by institutional acceptance.	No standards currently exist - likely to represent new application. Potential for standards to be developed.	Standards already exist either at a technical or app. level. Further work may be required to adapt and optimize.
Competition	High degree of competition with numerous existing competitors. Very difficult to justify new data link solution.	Some degree of competition and multiple existing solutions. Potential for new services and applications.	VDL mode 4 or similar systems are prime candidate for data link applications. Other competitors still exist.
Cost	Very high cost of introduction relative to alternative solutions. Normally requires replacement of legacy systems.	Cost of introduction is comparable to alternative data link solutions. Cost of implementation will be dictated by value of new applications.	Low cost of introduction due to existing use of similar ground infrastructure or user platforms.
Terminal availability	Highly unlikely that user terminals will reach widespread availability due to reasons of cost, competition, etc.	Possible that new terminals may be available in the future following development of standards, etc.	Existing terminals exist that may be adapted to support new data link applications.
Spectrum availability	Little or no prospect of VHF spectrum utilization. VDL Mode 4 may require adaptation to new spectrum band and justify price of additional spectrum.	Some existing utilization of VHF spectrum. Future availability may however be uncertain.	Expected use of VHF spectrum band in the future. Opportunity to maximize value of spectrum with further data link applications.

6.2 Aviation

6.2.1 Functional suitability

VDL Mode 4 has good functional suitability for providing DGPS data distribution and the distribution of other information such as meteorological information.

There will be a need in the future for a point-to-point data link that is compliant with the ATN and that can support the transfer of time-critical messages. VDL Mode 4 has been designed to meet these requirements.

6.2.2 Institutional/organizational acceptance

The institutional acceptance of any new aviation technology is absolutely key to its deployment, particularly for global use where adoption by ICAO and support from global aviation industries (such as Airbus and Boeing) is critical.

VDL Mode 4 has been adopted by ICAO, but has not yet been adopted by global aviation industries.

6.2.3 Standards

Development of VDL Mode 4 surveillance and communication standards is underway by the main institutions at this stage: ICAO has developed SARPs, ETSI is developing aviation ground standards and Eurocae is developing MOPS for airborne equipment.

ICAO GNSSP has developed standards for distribution of GNSS Navigation data for approach and landing (GBAS) and is also working on standards for regional distribution of DGNSS data (GRAS).

6.2.4 Competition

Competition for new data links already exists. Several new systems, which have some overlapping capabilities with VDL Mode 4, have been developed and in some cases implemented. These include Universal Access Transceiver (UAT), Mode S extended squitter and VDL Mode 2. However, none of those have the same multi function capabilities as VDL Mode 4. There is still potential for new services based on VDL Mode 4, and in particular for the integrated and more cost effective solutions that VDL Mode 4 can provide.

6.2.5 Cost

VDL Mode 4 is expected to have a relatively low cost because of the ability to provide multiple services (e.g. navigation data distribution, point-to-point communications) using a single equipment. This means that the cost of the equipment can be shared amongst several services or applications. However, in large air transport, costs are often dominated not by data transmission/reception equipment but other factors such as integration onto the flight deck and pilot training.

From a total systems perspective VDL Mode 4 offers significant cost savings mainly due to its multifunctional capability, the cost of ground stations is approximately 15 % to 20 % of a radar network and it introduces the possibility for each country to provide air-ground communications services independently.

6.2.6 Terminal availability

Terminal availability is expected to be good, since at least one manufacturer is already developing systems that meet the necessary aviation requirements.

For international aviation users, a global support network is also required and this is not yet available. However, it should be easily achievable if manufacturers with an existing global support network adopt VDL Mode 4.

6.2.7 Spectrum availability

VHF spectrum is scarce for aviation communication and navigation applications. There is a considerable shortage of assignable 25 kHz VHF channels and other systems also compete for these resources. Since VDL Mode 4 is more spectrum efficient than any of the competing systems it should be possible to assign sufficient channels for all the services that it is capable of providing.

6.2.8 Summary

Table 6.2 presents a summary of the key issues affecting market suitability. The level of suitability is represented by "high", "medium" or "low" accompanied by supporting notes where applicable.

Table 6.2: Market suitability (Aviation)

Market suitability criteria	Suitability assessment	Notes
Functional suitability	High	Wide range of broadcast services valuable to aviation. A point-to-point link capable of support time-critical applications will be important in the future.
Institutional/organizational acceptance	Medium	ICAO has adopted VDL Mode 4, but global aviation industries have not yet adopted VDL Mode 4.
Standards	High (Sur and Com) TBD (Nav)	Surveillance and communication standards are under development and near completion. Information on navigation standard is to be completed.
Competition	Medium	A number of competitors exist, but there is still potential for new services.
Cost	High	Smaller aircraft and ground infrastructure providers will see the largest differential in cost.
Terminal availability	High	Development of aviation-compatible terminals is underway.
Spectrum availability	Medium	VHF channels are in short supply for new aviation applications but increased understanding of VDL Mode 4 efficiencies should help in willingness to assign spectrum.

6.3 Maritime transport

6.3.1 Functional suitability

The maritime sector utilizes a wide range of safety critical broadcast services and it is expected that the list of applications will increase in the future. With respect to navigation data, DGPS corrections are already broadcast to vessels throughout much of Europe via existing coastal DGPS stations and MF/LF. However, there is on-going work to use the AIS ground infrastructure to provide DGNSS data as well.

In addition to the navigation infrastructure (supported by DGPS), the maritime community is making increased use of AIS and ECDIS (see clause 4.3). These services utilize a VDL Mode 4 - like system to transmit position information via dedicated VHF stations in order to provide a greater level of situational awareness amongst vessels. This is becoming particularly popular in busy ports, coastal regions and for reasons of port security.

There are few, if any, recognized point-to-point requirements for data communications in today's operations.

Functional requirements are similar for any safety critical application. The need for user authentication, high resistance to interference and certification is met by the VDL Mode 4-type of AIS system and is mandated in e.g. USA with implementation targeted for end of 2004 (see clause 5.3).

6.3.2 Institutional/organizational acceptance

Gaining the necessary institutional acceptance will be vital to the introduction of new services and/or data link technologies. The primary route for acceptance is via IMO (see clause 4.3), in which the dominant players and influencers are the General Lighthouse Authorities (GLAs) who are responsible for the operation of maritime infrastructure.

The existing use of the VDL Mode 4-like data links for the purposes of the mandatory AIS (globally for so-called SOLAS ships and in the USA for all boats with a length exceeding 8 meters) should serve as a good basis for the delivery of additional services and data via the same data links. In turn, gaining the necessary institutional acceptance should be feasible.

Gaining the necessary acceptance will depend upon the delivery of operational/safety benefits at a cost that is acceptable to the wide community. Once having gained this acceptance, then resources should be forthcoming both from GLAs and industry for the development of standards and other associated material.

The introduction of new data link applications is unlikely to be justified on the basis of replacing existing infrastructure. The DGPS network is less than 7 years old and might be expected to last for 15 years. However, these same stations will need to be upgraded to take account of future GPS enhancements and Galileo. Space capacity exists on existing MF/LF links in order to carry future applications such as the broadcast of navigation data but has the disadvantages of higher costs for the extra receiver that is required.

Extending the use of AIS for the broadcast and distribution of correction data already has support amongst many players, including receiver manufacturers and service providers. Extending the functionality of existing AIS services will inevitably have opponents within the industry but supported by others.

6.3.3 Standards

In order to gain acceptance for additional applications (such as the broadcast of navigation data) over the existing mandatory AIS service, standards for data formats will need to be developed. A number of relevant standards already exist, namely:

- ITU/RTCM standards for the distribution of DGPS corrections.
- RTCM specifications for the distribution of DGPS corrections.
- RTCA specifications for the distribution of EGNOS/WAAS data.
- IMO standards for the transfer of location data via AIS.

These together could all form the starting point for revised standard for the broadcast of navigation data using existing AIS VHF SOTDMA bearers. Significant benefit will be accrued if such as data format is consistent with the existing DGPS broadcast standard, thus also effectively acting as a back-up.

6.3.4 Competition

As outlined above, there are two primary alternatives for the broadcast of navigation data, namely MF/LF and VHF AIS. Both of these solutions have spare data capacity that could be utilized for this purpose. It may already exist in some manufacturers AIS systems.

It is understood that the work undertaken by the EC GALILEI project has also identified GSM/UMTS as a potential solution for coastal waters. This will be further investigated during reviews and discussions with the relevant parties. Other potential solutions include satellite communications and LF/Loran-C.

6.3.5 Cost

As outlined earlier in clause 6.3.2, gaining support and acceptance for the increased use of VHF AIS will depend upon new services offering clear cost benefit case in the context of alternative solutions and competition. The development of new bespoke VHF data links in addition to AIS and MF beacons to support the broadcast of navigation data is therefore unlikely to get support for cost reasons (see clause 6.3.5).

Demonstrating an acceptable cost to the community is likely to depend upon:

- The "inexpensive" upgrade of existing vessel-borne AIS terminals and costal VHF base stations (if required).

NOTE: Specifications already exist through RTCM!!

- Demonstrating a cost effective solution, either as an alternative to existing DGPS solutions over MF or even as an effective fallback or redundant solution.

6.3.6 Terminal availability

See discussion in clauses 6.3.2, 6.3.3 and 6.3.5.

6.3.7 Spectrum availability

The existing use of VHF for AIS means that spectrum is already available for the broadcast of navigation data. The implementation of a modified VHF data link may however require an additional allocation during a transition period.

6.3.8 Summary

Table 6.3 presents a summary of the key issues affecting market suitability. The level of suitability is represented by "high", "medium" or "low" accompanied by supporting notes where applicable.

Table 6.3: Market suitability (Maritime)

Market suitability criteria	Suitability assessment	Notes
Functional suitability	Medium	Wide range of broadcast services and increased use of "situational awareness" through AIS. Some direct parallels with aviation, but no current requirement for point-to-point mode.
Institutional/organizational acceptance	High	Existing use of "VDL Mode 4"-like services for AIS. Adoption of further features likely to gain some support.
Standards	High	The existing AIS service is a global standard. Specific standards for navigation data broadcast exist for the maritime community.
Competition	Medium	AIS is prime data link candidate for distribution of navigation data. Other competitors include GSM/UMTS, MF and satellite communications.
Cost	High	Mandated use of AIS should enable cost effective upgrade of existing equipment to support further applications and services.
Terminal availability	High	See "Cost" above.
Spectrum availability	High	See "Cost" above.

6.4 Rail transport

6.4.1 Functional suitability

The complexity of current voice and data communications required supporting signalling and "track to shore" communications services means that there is a very high match between the potential capability of VDL Mode 4 and the needs of the rail transport market. Such applications go far beyond navigation or positioning related services.

Ground based passive sensors currently undertake positioning of trains and therefore the use of GNSS is currently limited to non-safety critical management and passenger information services. There is therefore no current safety critical use of GNSS and no broadcast of navigation data to support train positioning.

Safety critical requirements for user authentication, high resistance to interference and certification are met by VDL Mode 4 (see clause 5.3).

6.4.2 Institutional/organizational acceptance

There is little or no awareness within the rail industry of VDL Mode 4 and no obvious operational or safety justification for seeking new data solutions. Huge amounts of time and investment have already been made across Europe in the development of GSM-R to meet the very wide and diverse requirements of this sector and there is now a need to maximize its value and usage. The justification for much of this investment is founded on the replacement of legacy trunked PMR infrastructure.

In the event that industry embraces the concept of on-board positioning based upon GNSS then this situation may change. However, the key to creating a need for a further data link solution will rely upon demonstrating that requirements may not be readily satisfied by GSM-R.

6.4.3 Standards

There is already a very large family of international standards that support GSM/GSM-R and train control systems (TCS/ERTMS). Legacy PMR systems in use within various countries are not standardized and interoperable.

The case for GNSS as an integral positioning element has yet to be proven but effort has already commenced towards the production of necessary standards. Trials have also been undertaken that begin to demonstrate the accuracy and availability performances that can be achieved with on-board positioning. There are therefore early signs of sufficient support and business justification within certain environments.

A number of parties have proposed the remote delivery of navigation correction data to a train as a more suitable method of delivering high accuracy positioning. There has however been little work to date to investigate this fully or towards the development of suitable data formats. It is not therefore clear how and from where resource could be gained for the development of such standards.

6.4.4 Competition

As outlined in clause 6.4.2, the increasing reliance upon GSM/GSM-R means that the opportunities for any new data link solution must be regarded as minimal.

6.4.5 Cost

See clause 6.4.2.

6.4.6 Terminal availability

See clause 6.4.2.

6.4.7 Spectrum availability

The existing use of legacy PMR systems provides the potential availability of VHF spectrum. However, its availability may be short term depending upon its potential use as a fallback system in the future.

6.4.8 Summary

Table 6.4 presents a summary of the key issues affecting market suitability. The level of suitability is represented by "high", "medium" or "low" accompanied by supporting notes where applicable.

Table 6.4: Market suitability (Rail)

Market suitability criteria	Suitability assessment	Notes
Functional suitability	High	All service modes currently deployed. "Cab-based" positioning not yet widespread and limited current use of situational awareness.
Institutional/organizational acceptance	Low	Existing trunked PMR (including VHF) schemes are being replaced by GSM/GSM-R schemes. Limited opportunity for further data link solutions, although fall-back systems may be required.
Standards	Medium	Standards will be required via ETSI/UIC to support distribution of navigation data. Potential for standards exists based upon growing initiative to develop GNSS standards.
Competition	Low	Heavy incumbent GSM/GSM-R solution acts as major restriction of other data link solutions.
Cost	Low	Additional cost of supporting another data link solution is likely to be prohibitive to business case.
Terminal availability	Low	See above.
Spectrum availability	Medium	Existing use of legacy PMR systems provides potential availability of VHF spectrum. Availability may be short term depending upon its potential use as a fallback system.

6.5 Fleet and asset management

6.5.1 Functional suitability

In broad terms, the capability of VDL Mode 4 far exceeds the current and emerging requirements of this market. Whilst the requirements for navigation data broadcast may be satisfied, there are few communications modes beyond "simple" broadcast.

The requirement for user authentication arises from the need to recover revenue from the distribution of value added data, whilst the need for encryption is focused upon high value operations such as emergency services or dangerous/valuable loads. As a non-safety critical market, there is no current requirement for certified services and data.

Many of the applications in this market are "centralized" (e.g. fleet/asset tracking), thereby potentially removing the need for a mobile navigation data link and instead serving data via a fixed link or Internet.

6.5.2 Institutional/organizational acceptance

As described in clause 4.5.1, there is no single institution or decision-making organization either at a national or European level. The decision to accept new services and technologies is ultimately made by individual corporate organizations who themselves may be in control of significant fleet sizes. That said, it is important to note that this is a large market with a heavy influence from the consumer market, which means that:

- New services are likely to be enabled by common equipment and data standards.
- Available products often determine market requirements - in other words, the market is often driven by technology and not requirements.

Widespread support amongst many users would be required to justify the cost of developing new products and services plus the resources required to influence and establish the necessary standards. Within this highly competitive and cost-driven market, it is extremely difficult to see how the introduction of VDL Mode 4 would gain sufficient support and commitment from users.

Whilst the use of GPS is becoming increasingly widespread, especially since the removal of SA, the need for additional value or accuracy above and beyond "basic" GPS has yet to be proven. Whilst emerging services such as EGNOS and Galileo believe that there is a substantial long-term market for higher accuracy, integrity and service guarantees, this has yet to be confirmed by a wide community of users. It is therefore important to realize that, before accepting VDL Mode 4, the market must first recognize the need for additional navigation data.

6.5.3 Standards

Any Galileo navigation services within this market are likely to be provided in an integrated fashion with GPS. Those organizations that already provide DGPS commercial services to fleet and asset managers are therefore likely to be the greatest influencers of future standards for navigation data broadcast. Such data format standards could be readily adapted for use over VDL Mode 4 as opposed to alternative existing data links such as satellite communications and LF.

6.5.4 Competition

As stated earlier in clause 6.5.2, there is immense competition within this market that is increasingly dominated by public bearers such as GPRS/UMTS. This is due to a wide choice of inexpensive equipment and the availability of open standards and integrated service/application platforms.

The use of mobile voice and data over VHF/UHF is still widespread amongst emergency services, taxis and other fleet managers. However, existing low bit rate solutions already satisfies these requirements. Private packet data networks such as Ericsson Mobitex are already available to suit applications that require a higher level of availability than can currently be afforded from public networks.

6.5.5 Cost

See clauses 6.5.2 and 6.5.3.

6.5.6 Terminal availability

See clauses 6.5.2 and 6.5.3.

6.5.7 Spectrum availability

As stated in clause 6.5.4, there is some existing use of VHF spectrum for mobile voice and data. However, its long-term availability is uncertain.

6.5.8 Summary

Table 6.5 presents a summary of the key issues affecting market suitability. The level of suitability is represented by "high", "medium" or "low" accompanied by supporting notes where applicable.

Table 6.5: Market suitability (Fleet/asset management)

Market suitability criteria	Suitability assessment	Notes
Functional suitability	Low	Relatively simple current set of communications services. Wide uses of broadcast modes, but most services are controlled via the ground infrastructure.
Institutional/organizational acceptance	Low	Wide range of existing mobile voice and data services, ranging from low cost public networks to private high dependability networks. Increasing use of public networks through GPRS and UMTS.
Standards	Medium	Standards not mandatory for introduction - essential for mass market production. Emerging standards for navigation data distribution would require some amendment.
Competition	Low	See above.
Cost	Low	Highly cost sensitive market - further exacerbated by heavy competition.
Terminal availability	Low	See above.
Spectrum availability	High	Existing use of VHF PMR by utilities, emergency services and other high value fleet managers. Long-term availability is uncertain.

6.6 Regulated road transport

6.6.1 Functional suitability

In broad terms, the capability of VDL Mode 4 far exceeds the current and emerging requirements of this market. Whilst the requirements for navigation data broadcast may be satisfied, there are few communications modes beyond "simple" broadcast.

However, whilst the communications modes may be "straight forward", the ability to support financial transactions and (potentially) subsequent law enforcement and legal cases, gives rise to stringent requirement for certification. Such a requirement may offer a challenge to alternative public bearers.

Many of the applications in this market are "centralized" (e.g. road user charging and tolling), thereby potentially removing the need for a mobile navigation data link and instead serving data via a fixed link or Internet.

6.6.2 Institutional/organizational acceptance

This market has many similarities to the fleet/asset management market insofar as this is a very large market with a heavy influence from the consumer market, which means that:

- New services must be enabled by common equipment and data standards for reasons of commercial cost.
- Available products often determine market requirements - in other words, the market is often driven by technology and not requirements.

However, this market is concerned with regulated services provided in the public interest as a result of government policy. Organizational acceptance is therefore required primarily from:

- Government agencies and transport policy makers (at both a national and European level).
- Private sector highway operators and road tolling organizations.
- Vehicle manufacturers and associated supply chain.

Obtaining support for a new data link technology amongst such a large group of organizations represents an enormous challenge, particularly at a stage when standards are in the early stages of development (see clause 6.6.3).

The most important point to note with regard to this market is that virtually *all* of the potential applications for GNSS data within the regulated road transport sector do not currently exist and are either planned or long-term. This means that in addition to gaining support for VDL Mode 4 as a *specific* data link technology, the market must first be informed about and gain acceptance of:

- New position-enabled applications, many of which pose difficult financial, political and legal consequences.
- The use of GNSS as a source of position information.
- The need for broadcast navigation data to supplement "basic" navigation sources.

6.6.3 Standards

Standards are essential to support what is essentially a mass market for millions of users across Europe. Given the immaturity of the market (see clause 6.6.2.), these standards are required at several levels for applications such as road tolling, including:

- Application and national interoperability.
- Financial transactions, user authentication and security.
- Air interface covering positioning and mobile data links.

It is understood that work has already begun towards the development of such standards for road tolling, based upon a core technical architecture consisting of:

- GPS as the primary means of positioning.
- RF ID tags as a supplementary means of positioning and user authentication.
- GPRS as the primary means of communication.

These standards are following initial implementation of systems and services in Germany, to be followed shortly by the UK and other potential European countries. The extent to which these specific technologies will be able to satisfy the application requirements will be subject to further work, scrutiny and trials over the forthcoming years.

6.6.4 Competition

See clauses 6.6.2 and 6.6.3.

6.6.5 Cost

This market is extremely cost sensitive for a number of reasons including:

- The need to develop mass market products for several millions of vehicles.
- The sensitivity of the motor industry to increased vehicle costs and the need to minimize additional extras to consumers.

These factors would tend to favour mass-market products based upon public data link solutions.

6.6.6 Terminal availability

See clauses 6.6.2 to 6.6.5.

6.6.7 Spectrum availability

There is no existing use of VHF spectrum for such widespread consumer applications throughout Europe, and there are no prospects for this situation to alter.

6.6.8 Summary

Table 6.6 presents a summary of the key issues affecting market suitability. The level of suitability is represented by "high", "medium" or "low" accompanied by supporting notes where applicable.

Table 6.6: Market suitability (Regulated road transport)

Market suitability criteria	Qualitative assessment	Notes
Functional suitability	Low	Relatively simple current set of communications services. Wide uses of broadcast modes, but most services are controlled via the ground infrastructure.
Institutional/organizational acceptance	Low	Wide range of existing mobile voice and data services, ranging from low cost public networks to private high dependability networks. Increasing use of public networks through GPRS and UMTS.
Standards	Medium	Standards not mandatory for introduction - essential for mass market production. Emerging standards for navigation data distribution would require amendment.
Competition	Low	See above.
Cost	Low	Highly cost sensitive market - further exacerbated by heavy competition.
Terminal availability	Low	See above.
Spectrum availability	Low	No existing use of VHF within the mass market. Limited to corporate organizations in the fleet and asset management market. Re-use and long term availability is uncertain.

7 Identification of standardization measures

7.1 Lessons learnt from the market assessment

The analysis of the previous clause indicates that:

- The opportunities for systems based on VDL Mode 4 are greatest where there are already similar systems in place, enabling low cost extension of existing equipment. This particularly applies to aviation, where VDL Mode 4 is gaining acceptance in significant parts of the community, and also to Maritime where there is a similar system, AIS, which is based on similar STDMA principles to VDL Mode 4 and which is mandated for widespread equipage.

- There are significant barriers in other markets arising from the existence of rival and established systems.

- It is also true that the capabilities of VDL Mode 4 exceed current capabilities foreseen in other markets. Hence these markets could, in the future, take advantage of additional benefits provided by VDL Mode 4.

It is therefore recommended that standardization work focus on developing the system to suit applications in, or near, to the aviation and maritime markets. The aim is to provide a system that supports intermodal operations focussed on aviation and maritime uses but also supports related land applications.

The study terms of reference focused on the use of VDL Mode 4 for uplink broadcast of local component. However, it is apparent that the real opportunity for a protocol such as VDL Mode 4 is to provide a wide range of communication services supporting a wider range of applications. The driver for this is the already demonstrated efficiency of the VDL Mode 4 protocol in spectrum utilization and re-use.

The opportunities for such a system are set out in the next clause.

7.2 Market requirements for additional standardization

7.2.1 Aviation

The protocols to support a wide range of service are already in place. Key issues for extension of the system include:

- **Local component information.** Specification of messages to transfer local component information. This applies both to aircraft and ground vehicles operating at airports.
- **Support for general aviation users.** GA users require low cost transponder systems which, as well as providing position information, support the transfer of information on terrain, weather and airspace configuration (including restricted and controlled airspace). As well as improving the operational efficiency of GA users, such a system would offer potential safety benefits. The required standardization measures includes introduction of the new message types.
- **Increased communication integrity for commercial aviation users.** VDL Mode 4 does not currently include encryption. Some discussions aimed at introducing such features have been held in the aviation community.
- **Operation in other aeronautical bands.** Because of congestion in the VHF band, there is a risk to the implementation of VDL Mode 4. Suggestions have been made to move the system to alternative bands. The likelihood is that such a move would result in a dedicated band containing subbands for different VDL Mode 4 services. However, the availability of spectrum in other bands is limited and the aviation community need to reconsider the usefulness and viability of other less spectrum efficient systems.
- **Support for Ipv4 and IPv6.** VDL Mode 4 point-to-point services currently support connection to the ATN. Technical specifications have been developed based on a modified version of IPv4 that will be used in some on-going CEC sponsored projects. The aviation community is also considering IPv6 connections as an alternative. In general, IPv6 would be expected to provide a mode of connection more appropriate for other market segments and an extension of VDL Mode 4 to support this is proposed.

7.2.2 Maritime

VDL Mode 4 offers a wider range of protocols than the current AIS system particularly in relation to point-to-point services. A key issue is to transfer the additional protocols available in VDL Mode 4 and combine them with, and make them compatible with, the AIS protocols. The aim would be to enable an AIS system upgrade at low cost and with backwards compatibility.

7.2.3 Combined Aviation/Maritime

An interoperable aviation/maritime standard would facilitate:

- Search and rescue services.
- Mobile air traffic control services for offshore operations.

7.2.4 Land applications in support of aviation and maritime

An initial focus for other markets should be on serving the needs of users that operate near to current users of VDL Mode 4/AIS. Example includes:

- **Ground vehicle users at airports and ports**. This would primarily be focussed on surface logistics but would include, for example, operations close to aircraft and ships. A key issue here is to optimize the physical layer to provide optimum use of the available spectrum and to provide low power/low cost solutions that can interoperate with equipment already installed on aircraft/ships.

- **Cargo and container/pallet tracking.** Tracking cargo and containers/pallets around airports and ports is an important potential use. The tracking of vehicles transporting cargo is an extension of the ground vehicle use. Tracking of containers/pallets raises a further extension requiring the use of very low cost devices. A number of solutions are possible. For example, the use of the VDL Mode 4 sleep protocol could be tailored to provide low reporting rates, increasing when a container/pallet is in motion. This would be a means of reducing the overall power requirements. A further solution might be to develop a 'passive' transponder, which syncs to a master transponder on the transporting vehicle or in the storage area. The master would gather identity information from the passive transponder and re-transmit to base stations together with position information. This would avoid the need to connect the container/pallet transponder to a GNSS source. VDL Mode 4 protocols already include a means of synchronising to other signals.

7.3 Standardization measures

To meet the diverse requirements set out above, this clause sets out an approach to providing additional standardization. The approach is based on the following assumptions:

- A generic STDMA system will be defined intended to be implemented in a variety of radio types.
- The radio types would support, at least:
  - A mode compatible with VDL Mode 4 as currently realized in aviation.
  - A mode compatible with AIS as currently realized in maritime.
  - A low power mode optimized for surface operations.
  - A very low power mode focussed on container/pallet tracking.
- The standard would envisage that a singe multi-mode radio would support more than one of these modes dependent on application requirements.
- The STDMA system would provide a set of link layer protocols that provide the range of services supported by VDL Mode 4.
- A number of variations to the link layer protocols will be provided to enable backwards compatibility with existing VDL Mode 4 and AIS standards.
- New protocols will be provided, inter alia, to:
  - Support encryption and resistance to jamming.
  - Support passive operations with master stations.
  - Support Ipv6 data services.
- New message types will be design dependent on application requirements but including:
  - Local component information.
  - Terrain maps.
  - Weather information.

The following programme is proposed:

- **Confirm market requirements**. The aim is to obtain community support for the standardization programme and to provide a prioritized list of requirements for the standardization activities.
- **Analyse VDL Mode 4/AIS interoperability**. Since a major part of the recommended way forward is to consolidate around the aviation and maritime markets, it will be important as a first step, to analyse the differences between the VDL Mode 4 and AIS standards and propose a harmonized way forward. The output will be a list of standardization requirements to make the standards interoperable.

- **Confirm concept of operations for intermodal services**. The extension of VDL Mode 4 requires the introduction of new physical layer modes, new link layer protocols and new message types. The purpose of this task would be to produce a specification for the standardization measures based on an appreciation of the end point mode of operation. Factors included here would be the required system capacity, the range of operations and the services to be provided. A further issue to be considered is the design of a common signalling channel across all modes to enable services to be advertised in a common format.

- **Design of physical layer**. This will consist of tailoring the physical layer to support the envisage services. The work will consider the appropriate power levels, modulation scheme and guard range. The work will also provide new requirements for incorporation of error correction ad consider operation of VDL Mode 4 in other bands. It will take account of the need to provide interoperability between physical layer modes including VDL Mode 4 and AIS.

- **Design of link layer protocols**. This will review existing protocols and introduce new protocols aimed at:

    - Providing interoperability with AIS.
    - Extending the range of AIS.
    - Supporting encryption.
    - Increasing resistance to jamming.

- **Definition of new message types**. This will introduce new messages according to application requirements including:

    - Local component information.
    - A support package for general aviation including a terrain map and weather map/picture.

History

Document history		
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