COMPETITIVE AND SUSTAINABLE GROWTH (GROWTH) PROGRAMME

RADIO-NAVIGATION AND LOCALISATION INNOVATIONS FOR INLAND WATERWAYS

Working Paper

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1 INTRODUCTION

1.1 Purpose and scope

Working Group 4 within the SPIN Thematic Network focuses on getting the message across. The overall objective is to increase users' awareness of available technology through information exchange and to help the implementation of RTD-applications. Public Relations, including a communication plan and lobbying activities will enhance transparency of the new technological possibilities, improve the acceptability of the available technology and speed up the innovation at user-level. This paper will specifically deal with the awareness of innovations concerning radio-navigation services and GALILEO, and in particular advantages of using Galileo for

- Inland navigation through all phases of the voyage.
- Benefits for Long Range Identification and Tracking (LRIT) (for security, management and reporting) If adopted.
- Potential for SMS Messaging within LRIT and interoperability with maritime users.

Issues related to the proposed programme of monitoring of VHF AIS from space on a global basis.

1.2 References

European Radio-navigation Plan
GPS technical documentation.
Galileo Joint Undertaking documentation
European Maritime Radio-navigation Forum papers

1.3 European Radionavigation Plan Study of Helios Tech - Inland waterways.

Quoted text related to Inland Navigation:- "*Historically, inland waterways applications have not been considered explicitly. These requirements, and associated services, are generally governed by local or regional authorities (e.g. Central Commission for Navigation on the Rhine, the Danube Commission), which may or may not adopt IMO recommendations. In the absence of alternative material, it has been assumed that the IMO requirements are representative. Augmented GPS systems are used to support inland navigation, which is safety critical, along with visual aids.*"

For the past few years, experts representing members states, professional institutions or users, have been meeting on a regular basis to determine a "European Radio Navigation Plan" that would cover all user process, Technology and Policy issues. The European radionavigation planning process has also been attended by representatives from The Russia Federation, and United States of America.

It is evident now that the process is complete, that Road, leisure and Inland navigation requirements have not been fully covered. In respect of Inland waterways (Inland Navigation), they have not been addressed at all. This document tries to set out all aspects that are relevant to Inland navigation so to provide a base platform to stimulate discussion on radionavigation planning needs of Inland Waterways.

2 EMERGING RADIO-NAVIGATION SYSTEMS & THOSE AVAILABLE TODAY

These Inlcude.

Satellite services

- GPS, and future GPS2 & 3
- Future GALILEO
- GLONAS

Terrestrial services

- LORAN / Chayka (possibility of convergence) (possible use for maritime community)

These and other emerging base line services will be supplemented by technological solutions (Psuedolites for example) to increase their integrity and accuracy enabling a number of safety critical and high accuracy / integrity applications.

2.1 Approximate Accuracies for positions for existing & emerging services.

Service / technology	Accuracy (m)
GNSS	20 (4 in future)
DGNSS	1-2
LORAN	20 (enhanced) to <500
Pseudolites	0.001
RTK	0.1-0.2

The paper considers both existing and emerging Radionavigation services and techniques within the Inland waterway networks of Europe (including the Danube via Rumania, Bulgaria and Turkey to the Black Sea). This inevitably will include many satellite and terrestrial services were waterways fall within their area of coverage. The following inventory of available and emerging services should be considered in light of other sectors such as the port and maritime sector where equality of position information may be important.

2.2 GNSS

2.2.1 GPS

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

2.2.1.1 Signal Vulnerability

The US has evaluated the vulnerability of GPS and indeed therfore GNSS, to interference in the Volpe Report 87 .
It found:

- GPS service is susceptible to unintentional interruptions from ionospheric effects, blockage from buildings, and interference from narrow and wideband sources. Some natural phenomena such as ionospheric distortions and scintillation can be predicted.
- The GPS signal is subject to degradation and loss through attacks by hostile interests. Potential attacks cover the range from jamming and spoofing of GPS signals to disruption of GPS ground stations and satellites. However, though the Volpe report concentrated on GPS, it is true to say that all GNSS and terrestrial radionavigation services could find themselves vulnerable.
- As with any radio navigation system, the vulnerability of the transportation system to unintentional and intentional GPS disruption can be reduced, but not eliminated.

There is a growing awareness within the transportation community that the safety and economic risks associated with loss or degradation of the GPS signals have been underestimated.

Backups for positioning and precision timing are necessary for all GPS applications involving the potential for life threatening situations or major economic or environmental impacts. The backups involve some combination of terrestrial or space-based navigation and precision timing systems; on-board vessel systems; and operating procedures.

2.2.1.2 GPS Modernisation

GPS is undergoing a process of continuous improvement with the aim of transitioning to GPS III. From a civil perspective the most important developments are the availability of two new civil signals. The new civil signals for GPS II will become available on satellites to be launched in 2004. An Initial Operational Capability (IOC) is expected in 2009 and a Full Operational Capability is expected in 2012. Further new civil signals often referred to GPS III will become available from satellites to be launched in 2006, Initial Operational Capability is expected in 2011 and Full Operational Capability FOC is expected in 2015.

2.2.1.3 Service provision

There has been much debate regarding what the US policy is regarding provision of service to Non Us interests. A Policy Statement was made by the US regarding GPS availability, March 21, 2003. It recognized that GPS plays a key role around the world as part of the global information infrastructure and as such the US takes seriously the responsibility to provide the best possible service to civil and commercial users worldwide. This would be as true in times of conflict as it is in times of peace.

2.2.1.4 Accuracy

Today selective availbility is switched off. The global average predictable positioning accuracy is therfore of 13 meters (95 percent) horizontally and 22 meters (95 percent) vertically. Decisions to change operational modes of GPS to include degrading GPS accuracy provided to civil users, (eg by switching selective availbility back on) will be made by the US National Command Authority.

2.2.1.5 Availability

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

2.2.1.6 Coverage

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

2.2.1.7 Reliability

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

2.2.1.8 Fix Rate

The fix rate is essentially continuous, but the need for receiver processing to retrieve the spread-spectrum signal from the noise results in an effective user fix rate of 1-20 per second.

2.2.1.9 Integrity

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

2.2.1.10 Dependencies

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

2.2.2 GLONASS

GLONASS (Global'naya Navigatsionnaya Sputnikovaya Sistema or Global Navigation Satellite System) consists (like other GNSS) of the ground segment, space segment and user receivers (user segment).

The space-based positioning and navigation system provides worldwide, all weather, passive, three-dimensional position, velocity, and time data. The GNSS user community has grown exponentially in recent years and that growth is expected to continue. Though the Russian Global Navigation Satellite System (GLONASS) share the same principles with GPS, because GLONASS constellation until recently consisted of only 11 **active** of 24 satellites, it has been virtually impossible to use this system stand alone, nevertheless receivers able to decode both GPS and GLONASS signals can take advantage over basic GPS receivers positioning particularly in the urban environment, exploiting the increased number of satellites available. High end users also use GLONASS for Real Time Kinematic positioning wihtin Rotterdam port area.

The GLONASS Ground Segment track the GLONASS satellites in view and accumulate ranging data and telemetry from the satellites signals. The nominal space segment consists of a constellation comprises of 24 satellites in an inclined medium earth orbits (MEO).

GLONASS satellites as of February 2004 transmit two types of signal: the Standard Precision (SP) and High Precision (HP) signals, each having their own independent fequency. For the next generation of satellites called GLONASS-M the frequency and transmission power will differ from today. The follow-up generation of satellites called GLONASS-K will provide additional features beyond the GLONASS-M capabilities, the main innovations of this generation will be the extension of lifetime to 10 years, reduction in weight and, importamntly, the inclusion of a Search and Rescue (SAR) payload that will work with GALILEO and GPS 3 SAR missions.

2.2.2.1 Institutional

A Russian Federation Government Resolution of Mearch 1995, offered GLONASS services for civil use to ICAO and IMO for a long-term period. Several directive documents have been approved by the Russian President and Government aimed at unconditional maintenance and development of the GLONASS system. Probably the most important, for users in Europe is the federal dedicated and mission-oriented program "Global Navigation System." Approved by the Government of the Russian Federation on 20 August 2001 (by the Government Decision N 587) the program's duration is scheduled from 2002 to 2011. The main goals of the program are:

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

The most important task will be the fulfilment of international commitments of Russia in the field of satellite navigation including:-

- Development of international co-operation
- Participation in international projects
- Development and manufacturing of competitive user equipment to be provided for both the Russian and international markets.

The GLONASS system has two types of navigation signal; a standard signal (SP) and a high precision signal (HP). The SP service is available to all GLONASS civil users on a continuous worldwide basis and provide the capability to obtain horizontal position accuracy within 57- 70 meters (99.7% probability , vertical positioning accuracy within 70 meters (99.7 probability). Although the service is provided free of direct user charges, it is presently poorly maintained and there is no liability regime. GLONASS is an independent system

2.2.3 GALILEO

Over the next few years Europe will be commissioning its own GALILEO service which will operate along with GPS 2 available from 2007, GPS 3 in 2015 and GLONASS. The first element of GNSS modernisation will enable Civil GPS 2 users to correct for ionospheric errors using a second frequency in addition to the current signal. These corrections, when combined with switching off Selective Availability (SA)(Now done), will enable user equipment that meets benchmark standards to achieve horizontal accuracies of about 4 meters. In addition, there will be a third civil signal for safety-of-life applications. It is proposed that GALILEO should also be operational by 2008 (deferred to 2010) and therefore must now be recognised as a service for provision of position information that will provide levels of accuracy better than GPS 2. GALILEO will provide for an independent, global, European-controlled satellite based navigation system. The system will provide a number of services to users equipped with GALILEO receivers. It has been proposed that GALILEO will offer differing levels of service to suite differing needs.

The proposed GALILEO navigation performance is described in the following table.

		Open	Safety Of Life	Public regulated
Coverage		Global	Global	Global
Accuracy (95%)	Horizontal (m)	4	4	6.5
	Vertical (m)	8	8	12
Integrity	Alarm limit	Not Any	H 12 / V20	H 12 / V20
	Time to Alarm		6	10

		Open	Safety Of Life	Public regulated
	Integrity Risk		1.5x 10-7/150s	3.5x 10-7/150s
Continuaty		8x10-5 /15 s	8x10-5 /15 s	8x10-5 /15 s
Timing accuracy		50ηs	50ηs	100ηs
Certification /Liability		No	Yes	TBC
Availablilty		99.5%	99.8%	99-99.9%

2.2.4 GNSS Interference reduced with GALILEO

2.2.4.1 Multipath Interference

Re-radiation or reflection of GPS signals is common in the vicinity of large steel structures or communication antenna. Ports, berths, locks and roadstead's are therefore danger areas for signal interference. Galileo will improve the situation and suppress multipath interference due to additional satellites that may average out the interference. If both proposed signals (E5A and E5B) are used together as a super-wideband signal, the multipath interference can suppressed.

2.2.4.2 Ionospheric Interference

GPS alone delivers a signal signal to the receiver and it is not possible to calculate the ionospheric interference from this information alone. EGNOS it able to map the ionospheric path of each satellites signal, therefore the difference psuedo range and actual range difference can be calculated enabling a map to be produced of the electron content of the atmosphere. This information supplied as a correction for ionospheric error. GPS 2 and GALILEO will by providing more than one signal to a receiver will be able to provide its own ionospheric corrections

2.2.4.3 Integrity authenticity and reliability

GPS does not provide Integrity or authenticity information. The addition of EGNOS will improve this, but EGNOS will only be of use for the satellites that it monitors. EGNOS will not monitor all GPS satellites of the horizon of the user when the user horizon is only partially within EGNOS coverage, and when outside coverage, may still receive EGNOS corrections for GPS satellites within coverage EGNOS coverage that are visible to the user. Only partial integrity is therefore available on the Signal in Space. GALILEO will have a positive effect by providing both authenticity and Integrity information.

By addition of 3 more signals in space, EGNOS will improve the predictability, availability, accuracy and continuity, Galileo will further improve. With more satellites the calculated position will improve in accuracy and reliability. The information will be more trustworthy, with EGNOS and even more with GALILEO.

2.2.4.4 SBAS V GALILEO & GPS 3

EGNOS at present (Spring 2005) does not give a consistent accuracy throughout mainland Europe, and therefore cannot be relied on today to deliver the accuracy needed for close quarter navigation. Improvements to the service should though eradicate this problem in time.

2.3 Augmentation and Hybrid GNSS solutions

2.3.1 Wide Area Augmentation

The European EGNOS is safety-critical systems consisting of the equipment and software that augments GPS. They are satellite and ground based system that augment the existing satellite services for those users who are suitably equipped. The European EGNOS service will originally provide augmentation over the European area, and there are plans to expand coverage. EGNOS is one of a number of Satellite Based Augmentation Systems (SBAS) being developed to augment the US Global Positioning System (GPS) and Russian Federation GLONASS system. Each SBAS broadcasts a GPS look-alike signal modulated with Wide Area Differential (WAD) corrections and integrity data from dedicated geostationary satellites that provide dual coverage over the SBAS region. The additional GPS look-alike signals improve availability, the WAD corrections improve accuracy and the integrity messages improve integrity (safety or quality of service).

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

EGNOS has been designed to meet the demanding performance requirements:-

- Accuracy is improved (relative to GPS or GLONASS) to about 2-3 m vertical and 1-2 m horizontal through the broadcast of WAD corrections;
- Integrity is improved both through the high degree of redundancy in the system and by alerting users within 6 seconds if something goes wrong with EGNOS, GPS or GLONASS
- Availablilty is improved by broadcasting GPS look-alike signals from three geostationary satellites.

Within the EGNOS Core Coverage Area, the accuracy is expected to be around 1 metre. However this is still not enough for some applications.

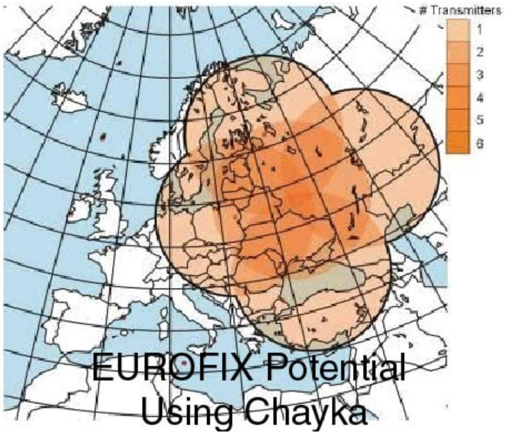
The EGNOS Programme is exploring, through a set of inter-regional partners, the feasibility of extending Core Coverage to other regions. The following illustration shows the extensions currently being investigated in the Caribbean and South America, Africa and the Middle East. However, the degree of augmentation and, hence, accuracy in the regions of extension is not yet defined and will depend on the number and density of reference stations that are implemented.

2.3.1.1 SISNeT

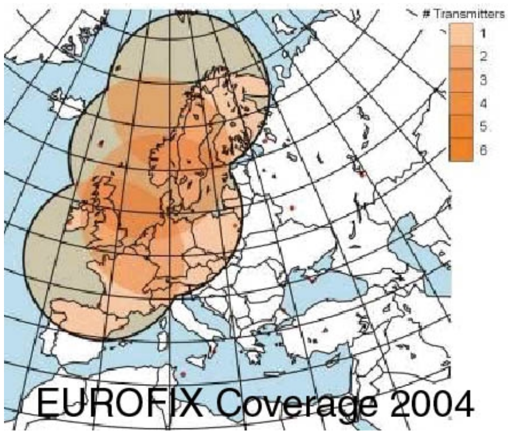
The European Space Agency (ESA) has been assessing the use of complementary transmission links to optimise EGNOS service delivery. SISNeT is an EGNOS internet service that aims to provide access to the EGNOS messages over the Internet. Among the benefits are that an EGNOS receiver is no longer necessary to obtain the EGNOS WAD and integrity messages – only a connection to the internet is required; and the EGNOS signal is available even if GEOs are not visible.

2.3.2 EUROFIX

The EUROFIX system in use within Europe today requires the LORAN infrastructure. EUROFIX within Europe requires a political decision as to the whether funding can be provided to keep the NELS LORAN service commissioned beyond 2004. Eurofix is an integrated radionavigation and communication system which is proposed and developed by Delft University of Technology. Loran-C or Chayka stations are upgraded to broadcast low-speed data reliable over ranges up to 1,500 km. The normal navigation operational mode of Loran-C and Chayka respectively is preserved which gives the Eurofix user, next to accurate DGPS positions, improved navigation reliability. As the Loran-C and Chayka infrastructure are already available, the upgrading to Eurofix is a minor and low-cost operation. Eurofix is operated by NELS. The service is free of charge for all users.



The coverage of Eurofix is estimated to be at least 1000 km from each equipped Loran-C transmitter. Fully implemented an absolute accuracy of better than 5 m and an availability of better than 99,9996% per month is achievable in most areas. At the moment four Loran-C stations broadcast Eurofix data:



The Eurofix coverage area could be extended by implementing Eurofix to all NELS stations and to Russian Chayka stations.

The coverage diagrams show clearly that EUROFIX using NELS alone only has limited use for Inland navigation. However with the inclusion of CHAYKA, would give full coverage of the Danube corridor.

2.4 Local Area Augmentation Services

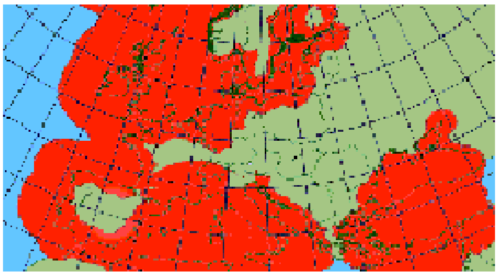
DGNSS, accuracy performance degrades as the distance between the user and the ground station increases. Close to the station the accuracy performance is likely to be much better than the 10m quoted above, whereas at extreme ranges the accuracy performance could be worse than 10m. This effect is dominated by the temporal de-correlation of the differential corrections calculated at the DGNSS reference due to signal fading and interference, especially under night-time conditions

In addition to marine coverage, work is ongoing to investigate the quality of radio-beacon DGNSS service over European land-masses, particularly in the UK and France. There are some discussions about expansing the coverage within other countries, however countries like Germany having small coastlines and large area, would have a relatively high cost to give coverage of there inland areas. Germany, Switzerland and Austria though allready have RTK coverage.

2.4.1 IALA Marine Radiobeacon DGPS

The internationally accepted method of providing DGNSS (effectively DGPS at present) corrections to maritime users is by local broadcast stations transmitting “free-to-air” corrections on frequencies within the maritime radionavigation band (283.5 to 325 kHz). The system was originally conceived to enhance the accuracy from GPS when selective availability (SA) was applied. Following the termination of SA, the DGNSS system continues to improve accuracy above that available from GPS alone but also fulfils the vital integrity monitoring and dissemination function. Other than for frequency coordination, control and monitoring, and coverage purposes, each system currently operates independently of all other systems, i.e. there is no networking.

The system provides extensive coverage within the European Maritime Area, as well as some



many inland regions. In addition to maritime users, the IALA Radiobeacon DGNSS service is available to users for other sectors and some States, have implemented inland stations to provide complete overland as well as coastal coverage. Furthermore, investigations and trials are ongoing, for example in Austria, to use aeronautical non-directional beacons (NDBs) to broadcast signals identical to those provided by the IALA Radiobeacon DGNSS service. However the small sketch shows that the coverage for the Danube corridor is very poor, and coverage of the Rhine corridor is not complete.

Correction and integrity data is generated using reference stations, usually colocated with the transmitters. The reference stations consist of survey quality, dual frequency GPS receivers at very accurately surveyed positions. These receivers are used to generate differential corrections and integrity flags for all GPS and/or GLONASS satellites in view. A typical range of a station is approximately 150 nautical miles. Service providers publish the station’s name, position transmission frequency and rate, the identification number of the reference and transmitter station, whether the station provides integrity monitoring, the status of the station e.g. operational, trial, planned, the nominal ranges of stations and the transmitted message types. IALA maintains a database of DGNSS stations including the reference and transmitter identification numbers and transmission characteristics.

Transmissions from MF beacons are subject to a variety of interference effects:

- over-the-horizon interference from other beacons operating on the same or nearby channels
- skywave fading, especially at night
- atmospheric noise
- precipitation static (not usually a problem)
- man-made noise.

These factors are taken into consideration when determining the nominal range of stations. In particular, interference from other beacons is minimised through a frequency plan coordinated by IALA through the ITU. In addition, the broadcasts could be vulnerable to intentional interference although MF transmitters are not portable and the size of the masts needed to transmit effective jamming signals may be sufficient to ensure that this threat is not significant. In theory, spoofing could be achieved by gradually increasing pseudorange corrections. However, the threat to DGNSS broadcasts is likely to be relatively low as it is much easier to jam the core GNSS system itself.

2.4.1.1 Institutional

The IALA Radiobeacon DGNSS service is provided to meet each State's obligations under the SOLAS Convention. In the majority of cases the infrastructure is owned and operated by the service provider – the marine Aids to Navigation (AtoN) provider, with the exception of some maintenance activities that are outsourced. The majority of DGNSS service providers are either unregulated or self-regulating (with specific regards to the DGNSS service) although all comply with international recommendations and guidelines.

The IALA Radiobeacon DGNSS service is standardised globally, coordinated through IALA but utilising the instruments of the competent standards bodies, particularly ITU and RTCM as appropriate. The system is not explicitly recognised as part of the World Wide Radio Navigation System (WWRNS) by the International Maritime Organisation but is noted as necessary in the Resolutions recognising both GPS and GLONASS.

2.4.1.2 Service Delivery

The IALA Radiobeacon DGNSS service provides the user with differential corrections (pseudorange corrections) and integrity messages for the GNSS satellites in view, principally GPS at present. The service is operational throughout Europe providing coastal coverage. The service will continue to be provided for the foreseeable future.

The service performance parameters are specified by IALA to be at least 10m absolute accuracy to the 95% level within the specified coverage area, noting that several service providers specify an accuracy level considerably better than this minimum performance requirement.

DGNSS is widely used in the maritime community by the whole range of users from commercial through to leisure. The vast majority of GPS receivers are capable of utilising RTCM SC-104 corrections and interfacing easily to an MF radio receiver. Some have the MF receiver built-in. Receiver costs are relatively low and receivers are widely available.

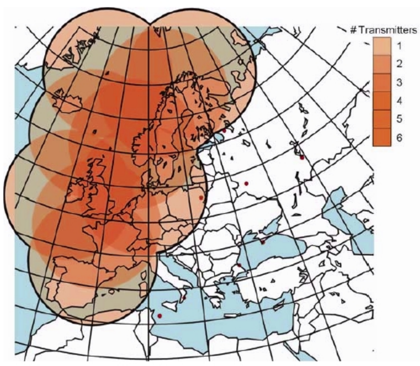
2.4.1.3 Dependencies

The IALA Radiobeacon DGNSS system is wholly dependent on space segment GNSS systems (GPS and GLONASS). It only provides augmentation to Space Based Signals and cannot function in isolation. The internationally accepted method of providing DGNSS (effectively DGPS at present) corrections to maritime users is by local broadcast stations transmitting "free-to-air" corrections on frequencies within the maritime radionavigation band (285 to 325 kHz).

The system provides extensive coverage within the European Maritime Area, including some major ports and hinterland areas. Though the coverage of all Inland waterways is not complete, a large area of Inland waterways is covered, and could be completely covered at a reasonable cost.

2.5 Loran-C CHAICKA & NELS

Loran-C was formerly developed to provide military users with a radio-navigation capability having much greater coverage and accuracy than its predecessor (Loran-A). It was subsequently selected as radio-navigation system for civil marine use in the U.S. Within North west Europe it is run as the NELS (North West European Loran-C System) and partially available within the Mediterranean under the SELS (Southern European Loran-C System (missing stations in Spain and Turkey). Loran-C can also be used for precise time interval and highly accurate frequency applications.



The Loran-C signal can be modulated to broadcast differential GPS correction data and GPS integrity information. Within the US this makes up part of the LORAN WAAS integrity service, in Europe, EUROFIX. Loran-C offers the advantages that the signal can be received even inside buildings. In other parts of the world Loran-C or the similar Russian Chayka service provide coverage over much of the Northern Hemisphere.

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

2.5.1.1 Institutional

Denmark, France, Germany, Ireland, the Netherlands and Norway signed an International agreement concerning the establishment and operation of the civil Loran-C system in

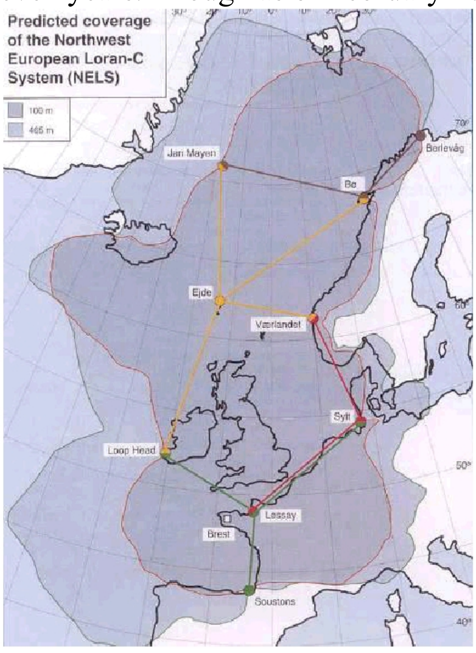
Northwest Europe and the North Atlantic in 1992. Under the signed agreement each member nation of NELS owns the facilities on its own territory and appoints a National Operational Agency (NOA) to manage these facilities and look after its national interests. The overall control of NELS rests with a Steering Committee (SC) composed of representatives from all participating nations and observers from interested nations and organisations. Everyday co-ordination of NELS operations is left to a Co-ordinating Agency (CA). Norway has accepted the role as CA, and a Norwegian Government organisation has been tasked to be responsible for the functions given the CA in the NELS agreement. Beside the member states of NELS, the following states and organisations have the status of an observer:

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

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

- Greece
- Hungary
- Slovakia
- Slovenia
- Switzerland

The future development of NELS is under consideration at the moment. The decision will be final till October 2004 since the nations have to inform the NELS Depositary in the period April - September 2004 if they want to withdraw from the NELS Agreement. If no information is received by the Depositary then the Agreement will be prolonged for another seven years. Though as of February 2004 Denmark, Germany and Norway, Ireland and Netherlands wanted to withdraw from NELS Only Denmark, Germany and Norway have had their decision confirmed by the Parliament, The situation as of the end of 2004, is unclear.



The UK has decided to install a LORAN Station in RUGBY for trials. France has stated that they want to continue Loran-C, either within NELS, or in the form of other alternatives. France has offered to take responsibility and cover the operational costs for the stations Ejde and Sylt and in addition erect 1-2 new stations in France and later on maybe further stations in case the NELS Agreement will not be continued. The German approach to continue Loran-C operation in Europe is based on private investments to fund Loran-C activities.

2.5.2 NELS Coverage

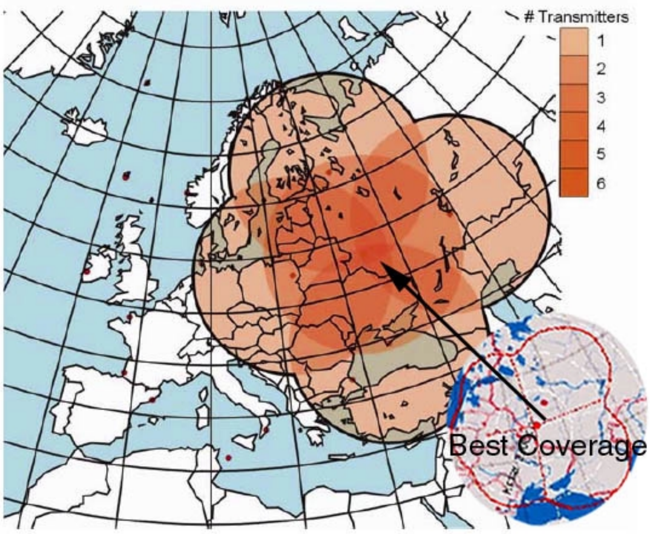
Because a Loran-C receiver computes distances from Loran-C transmitting stations using the time of arrival measurements and the propagation velocity of the radio ground wave to determine position. Small variations in the velocity of propagation due to the conductivity of the surface, between that over sea water and over different land masses are known as the Additional Secondary Factor (ASF). Corrections may be applied to compensate for this variation. Such corrections may improve the absolute accuracy of the Loran-C service in positions where the received Loran-C signal passes over anything but sea water on its way from transmitter to receiver.

The values of ASF depend mainly on the conductivity of the earth's surface along the signal paths. Sea water has high conductivity, and the ASFs of sea water are, by definition, zero. Dry soil, mountains or ice generally have low conductivity and radio signals travel over them more slowly, giving rise to substantial ASF delays and hence degradation of absolute accuracy. Though this would be very important for Inland waterway users due to the many surface types the signal will cross before arriving at the receiver, fortunately, ASFs vary little with time, and it is possible to compensate the ASF influence. This could either be done by calibrating the Loran-C position (e.g. by using GNSS), determine the local ASFs and compensate their influence, or include ASF models into the position calculation. A program for mapping of ASFs in northern Europe was carried out by NELS and an ASF electronic database is available.

2.5.2.1 System Performance

It should be borne in mind that the accuracy of LORAN refers to the position line, of which 3 are needed, and not to the final position. Therefore the current 460m absolute accuracy may well be extended to over 1km when plotted, but studies have demonstrated the repeatable horizontal accuracy in the order of 10-20m, comparable with GPS. Enhanced Loran however to is reported to be able to offer absolute accuracy of position lines between 8 to 20 metres, this therefore in practice may be better than that offered by GPS.

2.6 Chayka



Chayka (Russian for “seagull”) is a terrestrial radionavigation system very similar to Loran-C. It was established by the former Soviet Union and is still used in Russia and surrounding territories and seas. Like Loran-C Chayka consists of chains made up of a master station anda number of secondaries. Chayka works with a pulse-modulated frequency of 100 kHz. Receivers measure the time difference between the arrivals of a given wave form from the master and any particular secondary station.

Those time differences can be converted into position, velocity, and time and frequency reference information.

Each station in the Chayka networks transmits pulses with standard characteristics. All secondary stations transmit signals in packets of eight impulses at intervals of 1000 ms. For identification purposes the master emits a ninth impulse 1890 ms after the eighth. The transmission restarts after a chain-specific group repetition interval (GRI) between 40.000 and 100.000 ms. In order to allow automatic detection and identification of the signals and to reduce the influence of multiply reflected signals, the signals are phase-coded. Each secondary transmits with its own specific code delay relative to the master signal. Those delays are selected such that the order of reception of secondary signals is identical everywhere within the assigned network operation area.

2.6.1.1 Institutional

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

2.6.2 Loran & Chayka Together

By operating together LORAN and Chayka would give very good coverage of the whole of the European Inland waterway network, including the corridor to the black sea.

2.7 AIS

The automatic identification system (AIS) is an autonomous and continuous broadcast system operating in the maritime mobile VHF band at approximately 162MHz. It exchanges information, such as vessel identification, position, course, speed, ship type, cargo, destination, etc. between vessels and shore stations. The system is essentially a data communications system using self-organising time division multiple access (SoTDMA) technology.

The principal functions fulfilled by AIS are those of surveillance and information exchange, namely:

- information exchange between vessels within VHF range of each other, increasing situational awareness,
- information exchange between a vessel and a shore station to improve traffic management in congested waterways
- automatic reporting in areas of mandatory and voluntary reporting
- exchange of safety related information between vessels, and between vessels and shore station(s).

A new function will be to mark ATON’s (Aids TO Navigation) and provide virtual or psuedo marks, for example to mark a vessel tracked by radar (but without AIS), wrecks, or small craft. There is also seriouse experimentation underway to use AIS for the broadcast Differential corrections for augmentation of GNSS.

2.7.1.1 Institutional

AIS infrastructure when it is applied as an AtoN, is owned and operated by the marine Aids to Navigation service provider. In addition to the national-level authorities, AIS infrastructure can be provided by local administrations, such as port and river authorities.

Delivery of services from AIS as an Aid to Navigation are currently under development and no performance standards currently exist. However, standards for the display of AIS targets on radar and other ship borne displays are well-advanced and some applications already exist. However, using AIS base stations to broadcast DGNSS information would suit Inland general Navigation requirements.

2.8 Mobile Telephone Network based positioning

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

Currently, this technology is being studied to be used in railways for fleet management applications and passengers' information services and some railways administrations have already launched prototypes using this technology. Nowadays, this system and the services are not widely deployed and routinely used by many users. Therefore, the challenge for location-based services is to achieve critical mass and wide usage.

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

<u>Cell Of Origin (COO):</u> The location information provided is the cell where the mobile is located. There are a number of methods of doing this that include Standard Cell ID, Cell-ID STK, Cell ID IN, Cell-ID WAP, and Cell-ID CGI. However, though position accuracy can in small cells be around 100 metres, in rural areas where cell sizes are far greater, accuracies can be as poor as 35 kilometres or in the case of Cell ID CGI, 8 kilometres. This is therfore not of interest for navigation.

<u>Enhanced observed Time Difference (E-OTD):</u> It uses the difference in the Time of Arrival of the signal from different base stations in the cellular network. As the position of the base stations is known, the time differences are used to produce intersecting hyperbolic lines from which the location is estimated. The performance level in terms of accuracy would range from 55 to 500 meters. Standards are in place for E-OTD

Angle of Arrival (AOA): Using complex directional antennae at the cell sites, the direction of the mobile can be determined by the angle of arrival of the signal. When several cell sites make this determination then the location of the mobile can be established by the intersection of the obtained directions. As the magnitudes involved are angular, with larger cells the performance can be significantly lower, although a reasonable range would be from 100 to 500 meters. AOA though has not been taken up.

Assisted-GPS (A-GPS): is a combination of GPS position technology and network-based techniques to improve accuracy, availability and coverage of the solution at a reasonable cost. Because the network performs the location calculations, the handset only needs to contain a scaled-down GPS receiver. A-GPS provides a natural fit for hybrid solutions because it uses the wireless network to supply assistance data to GPS receivers in handsets. This feature makes it easy to augment the assistance-data message with low accuracy distances from handset to base stations measured by the network equipment. Such hybrid solutions benefit from the high density of base stations in dense urban environment, which are hostile to GPS signals. Conversely, rural environments provide ideal operating conditions for AGPS because GPS works well there. The performance attainable with A-GPS would be in the range of 5 to 50 meters. This is the most obviouse candidate for navigation.

Timing Advance (TA): The TA method is based on the existing GSM parameter which is known for the serving Base Transceiver Station (BTS). TA is only possible in a GSM network. Timing Advance (TA) can be used to assist all positioning methods and as a fall-back procedure. The TA signal is used to align the signal in the dedicated timeslot due to the propagation delay of the signals. The TA is a 6 bit information for the maximum defined range for GSM which is about 35 km corresponding to about 550 m for the least significant bit of the TA information. The TA method is only useful if the size of the cell is bigger than 500 m which is the case in rural and sub-urban areas.

OTDOA-IDPL: Two main proposals for downlink location in UMTS are standardised: OTDOA and OTDOA-IPDL, that is OTDOA with the base stations performing Idle Period DownLink. Significant differences in the levels of performance between these two techniques are detected. OTDOA suffers the hearability problem of CDMA systems and therefore it may occur that there is not a sufficient number of downlink pilot signals to user equipment to proceed the positioning calculation. Hence the performance of OTDOA is worse than E-OTD. OTDOA-IPDL method avoids the hearability problem as the base stations perform Idle Period DownLink (IPDL), thus the user equipment can reach a sufficient number of downlink pilot signals. However, the performance expected has only been determined by simulation and different simulations give varied results but using OTDOA-IDPL should give at best 13 meter accuracy and worst 200-500meter.

2.8.1.1 Institutional

Position information and location related products are the next class of services to be offered by mobile network operators to their customers, not only new services, but improved current services Public mobile networks (GSM, UMTS) are suitable for some applications in railways, mainly non-safety related. These networks are private or public owned and operated by public or private companies.

The European Telecommunications Standards Institute (ETSI) have recently decided (together with the ANSI) to standardise location finding services using Enhanced Observed Time Difference (E-OTD), Time of Arrival (TOA) and Assisted GPS in addition to Cell Of Origin (OOO).

2.8.1.2 Service Delivery

Depending on the technology used, network based positioning services are suited for different types of applications with different performance and overhead requirements. For instance, some non-demanding applications could very well work with a Cell of origin based positioning service. In principle, Inland navigation could be users of all this kind of services. Safety-related applications (ATP) are not likely to use them, although it may be suitable for Management of Emergencies and rescue teams.

Depending on the application and/or or service operator, raw position data or complete elaborated position information (matched position in the track and the line) could be delivered to the user. Products and receivers are both for professional users or mass-market users.

Local components are needed for some of the technologies described in addition to conventional mobile network elements. Assisted-GPS technology depends also of GPS constellation for data generation.

2.9 Inertial systems and dead reckoning

There are situations requiring a position or velocity update that should be independent of radio-navigation services. There has also been trials using inertial systems within portable devices to assist with the pilotage of vessels. (Portable Pilots Unit). In some applications it is necessary to report velocity to an accuracy that can not be provided by single antenna GPS, and where a twin antenna GPS or combined GPS fluxgate compass are cumbersome (due to the fixed baseline and horizontal separation required for the antenna) or too expensive for the application.

There are a variety of velocity sensors available on the market including vibrating gyros, Silicon single and three-axis accelerometers; advanced accurate solid-state fibre optic true-north seeking gyro-compass, "solid-state" micro-machined quartz angular rate sensors, linear servo accelerometers and MEMS low-cost, high accuracy Silicon Micro-Ring Gyro inertial navigation system (about 2 cubic centimeters in size). The prices range from a few tens of Euro to hundreds of thousands of Euro.

The Inertial Navigation solution is extremely good for measuring velocity change. It is also good at providing accurate position independent of Radio-navigation services. The accuracy decay is now extremely slow and is usually linear and therefore can be compensated. However the high cost of the inertial unit is a main obstacle to include it in the precise navigation complex for versatile areas of application (€ 150,000). It will therefore be some time before reliable systems are found within the inland navigation, port and maritime environment.

The quest today for a number of companies is to use the simple inertial measurement unit (IMU) with rough sensors for precise navigation. Companies, world-wide are developing low cost inertial devices which use the cheap compact sensors. This group of instruments is called motion sensors. However, they are not suitable as a sole system and will require periodic update.

2.10 Psuedolites and Synchrolites

There are an increasing number of applications requiring precise relative position and clock offset information in situations with limited or no visibility of the GPS satellites, or in areas where there is large multipath interference. The ground psuedolites are transmitters that emulate the signal structure of the GPS satellites can be used as additional or replacement signal sources. Transceivers (which transmit and receive GPS signals) can be used to improve standard pseudolite positioning systems. If their locations are known, transceivers can be used to remove the need for the reference antenna typically necessary in standard differential systems.

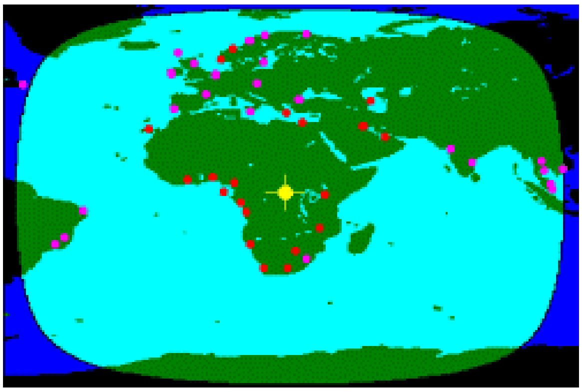
Synchrolites provide an economical alternative by using a receiver-grade clock. Synchrolites transmit a signal that has the same frequency as a received signal except modulated with a different code. Transceivers are an effective way to expand the capability of a GNSS positioning systems. This can be done by eliminating differential reference stations, allowing pseudolites to self-survey their own locations, or enabling relative positioning between multiple vehicles.

Providing RTD is focussed on high volume sales applications they can provide cm accuracy for a diverse number of local transport and positioning applications.

2.11 Space Based Carrier Phase DGPS (RTK) usable by Inland Navigation

2.11.1 OmniSTAR

The OmniSTAR system is a global real-time differential GPS broadcast system delivering corrections from an array of base stations. OmniSTAR uses a network of reference stations (or base stations) to measure Ionospheric interference and other errors inherent in the GPS system. The control centres are located in the USA and Austarlia.



This reference data is then transmitted to both global network control centres where it is checked for integrity and reliability and is then up-linked to geo-stationary satellites, which distributes the data over their respective footprints. The satellite broadcast is received at the user's location by an

Omni-directional antenna. It is then demodulated, and passed to a processor that reformats the data into corrections for use in either an internal or external differentially capable GPS receiver. The way that the data is processed inside the user equipment depends on the type of OmniSTAR receiver that is used.

OmniSTAR has around 100 reference stations globally. OmniSTAR coverage is claimed to be over 90% of the world. New reference stations are being set up to improve coverage further. The OmniSTAR Virtual Base Station (VBS) technology provides users with metre-level positioning with a correction message.

The OmniSTAR service is operated by Fugro. And accuracy is expected to within one metre.

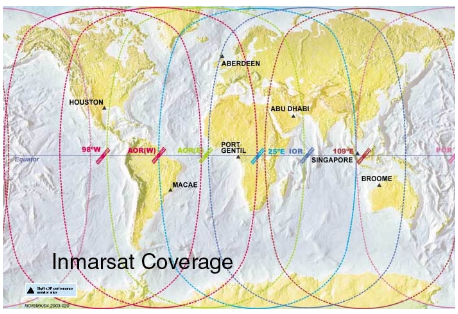
2.11.1.1 OmniSTAR-HP

The OmniSTAR-HP (High Performance) solution is a dual frequency GPS augmentation service. It provides a decimetre level DGPS service. It uses dual frequency GPS receivers to measure the true ionosphere at the reference and user locations, thus largely eliminating this error. Its performance Horizontal Accuracy 10 cm and Vertical Accuracy 20 cm up to 1000 km from the reference station.
The EA Sat offers coverage over Europe.

2.11.2 Sky Fix

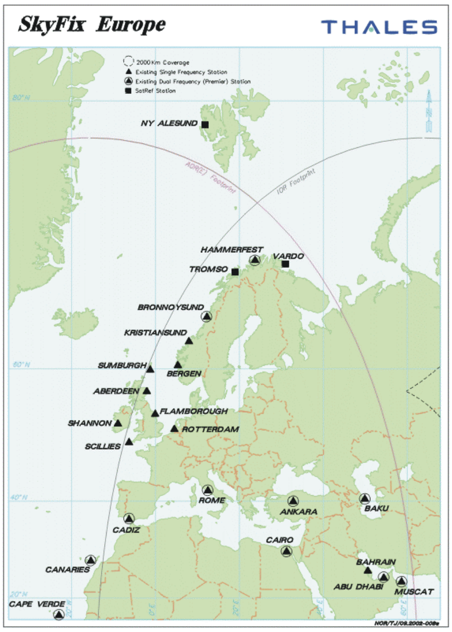
The network of reference stations comprises 85 permanent GPS installations worldwide, tied into large Geodetic Networks. Each reference station has dual redundant sets of GPS receivers, antennas and data processing and communications interfaces, and can be fully remotely controlled from the Network Control Centres. The SkyFix service is also operated by Fugro and the standard service has an accuracy of < 2 metres.

There are two Network Control Centres, in Singapore and Scotland, that deal with the Network Management and Quality Control and perform system quality control and monitoring functions. These include checks on reference station and observation performance, data link delay and reliability, overall system latency, DGPS positioning performance, and satellite broadcast power and continuity.



Correction Message broadcast is achieved using pre-assigned leased capacity on each of the four INMARSAT marine and on the regional High Power beam communication satellites.

2.11.2.1 SkyFix XP Service



SkyFix-XP service is a more accurate DGPS service that allows users to derive positions with decimetre level precision. The service is based around corrections to the broadcast GPS orbit and clock information. This technique is therefore called Satellite Differential GPS (SDGPS) as the differential corrections are for the actual satellites, as opposed to a geographical area.

The standard Differential GPS services use the fixed location of a single reference station to measure the ranges to all GPS satellites in view. These measurements are then compared to the computed ranges at that location and the resulting differences in the observations are transmitted as pseudo-range corrections.

Skyfix XP Performance gives horizontal accuracy of 10 cm and vertical accuracy of 15 cm.

2.11.3 StarFire

StarFire WADGPS utilizes a network of more than 50 GPS reference stations around the world to compute GPS satellite orbit and clock corrections, two completely redundant processing centers and multiple communication links to ensure the continuous availability of GPS corrections. It has been developed from a set of regional DGPS networks over independent continental areas. Now combined, these provide a high accuracy service forming a global network. The system provides sub-decimeter (Horizontal) real time service worldwide. It is based on technology called RTG (Real Time GIPSY) developed by the Jet Propulsion Laboratory (JPL) for NASA.

The StarFire system consists of a global network of dual frequency GPS reference receivers.

These send data to two network processing centres at Torrance and Moline in the US. GPS satellite orbit and clock corrections are calculated and then transmitted via Inmarsat satellite links to StarFire user receivers.

The StarFire DGPS service is operated by NavCom It has a Horizontal Accuracy 10 cm and Vertical Accuracy 15 cm. The StarFire signal is available virtually anywhere on the Earth's surface on land or sea from 75ºN to 75ºS latitude.

The StarFire RTK Extend concept carries through communication dropouts by allowing StarFire™ to take over when the RTK correction signal fails. RTK Extend allows the user to maintain RTK accuracy during radio outages for up to 15 minutes. If longer outages occur, StarFire's decimeter positioning accuracy is used until RTK communication is reestablished.

Using RTK Extend, the receiver is able to compute an RTK equivalent position for up to 15 minutes. If the receiver remains in RTK Extend mode for more than 15 minutes, the position solution will slowly degrade to the typical 10 cm accuracy of the StarFire system.

2.12 National & private Terrestrial DGNSS and Carrier Phase services (Real Time Kinematic).

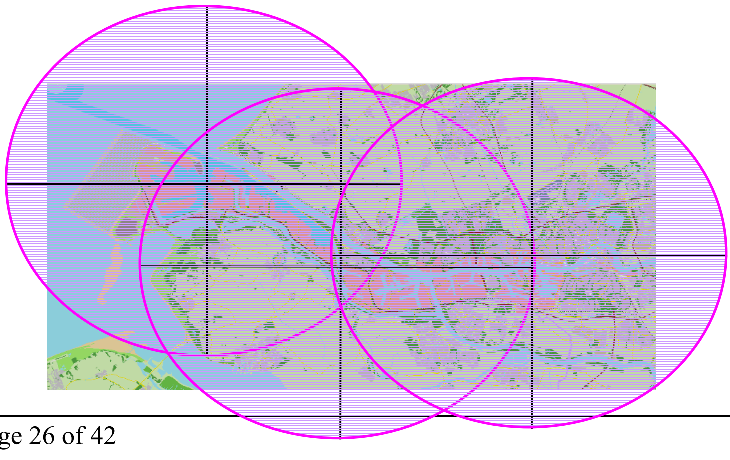
The DGNSS services are based on the IALA service described earlier in the document. Most European States now have installed or are installing networks that when used in conjunction with the maritime beacons give complete coverage of their land mass and therefore also inland waterways and ports. These services vary in accuracy but are normally between less than 1metre to 3 metres horizontal. They are not able to be used for applications requiring a vertical component due to their poor vertical accuracies.

RTK is a high precision carrier phase based positioning systems using GPS dual frequency signals. The term Real Time Kinematic (RTK) is often used to describe carrier-based positioning systems that employ static reference station(s) and moving receiver(s). Service infrastructures for carrier phase reference observations have been installed in several countries, but it is still unclear how successful these are in real time applications. Whilst excellent accuracy can be achieved in good working environments, current GPS based RTK systems have performance limitations in relation to the baseline length (reference to User separation), the need for high bandwidth data links, and their overall availability and robustness. The future introduction of satellite transmissions on three frequencies and also the future GALILEO constellation will give a processing advantages offering the potential of better performance and reliability.

There are many propriety systems available. Some are offered pay as you use, others are free to the user. They range in specification related to the initialisation time, range of use, accuracy and reliability of cycle slips. Probably one of the most successful in Europe at this time is the system in use in the Netherlands giving coverage of their three main ports.

2.12.1 Case study of Rotterdam RTK

Within Rotterdam different systems have been tried and therfore it is a useful case study due to the sharing of the waters covered by the service by both sea going and inland waterway vessels. They use a combined GPS/GLONASS correction transmission with an update rate of 5Hz. The firmware of the "JAVAD" GPS/GLONASS receivers is updated specially by AD-Navigation in Norway for their "difficult" work area in the way of obstructions and other radio signals.



They use a combined GPS/GLONASS correction transmission with an update rate of 5Hz. The firmware of the javad GPS/GLONASS receivers is updated specially for our "difficult" work area in Rotterdam (many obstructions and other radio signals) by AD-Navigation in Norway. The practical radio range in Rotterdam is about 14km. Using three base stations, they are able to cover, including overlap, 35 Kilometres, the hole of the Rotterdam working area (35km long). Where critical areas they can make use of at least two base stations.

They have had the system now running for about three years. During this time no failures have appeared. The system is RTCM compliant and gives a horizontal accuracy of 3cm, and vertical accuracy smaller than 5cm

Though at present coverage is mainly inside harbour, they have an intention to Intention to extend the system towards sea with an additional station at Goeree Lichteiland, which will cover the near deep water approach. Within the near future RTK systems will be operational in Amsterdam- and Vlissingen harbour area.

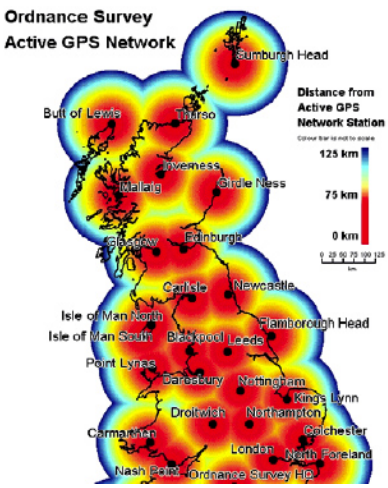
Experience from pilots who have used the system say that it has proved to be highly accurate. Under favourable conditions the RTK signal gave a position to within an accuracy of 1-2 centimetres where the rate of turn is better than 0.1 degree/minute, the heading is equal to the gyro and speed and transverse speed are better than 1-2 centimetres/second. The RTK signal for the docking mode has given accuracies measured to 1 centimetre, equal to that of the laser docking system. However, the sighting of the RTK stations were perfect for the locations were this accuracy was measured.

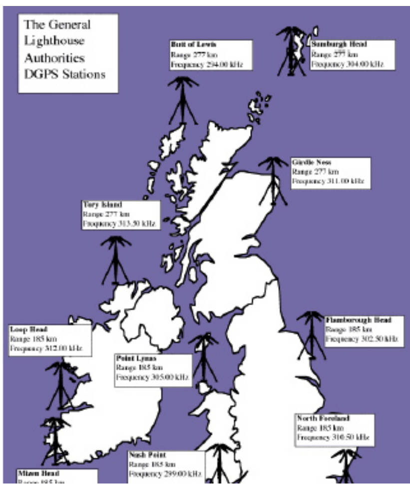
2.12.1.1 Networked Extended Range RTK.

By using a PC in a network base station, it is possible to receive RTK from a number of base stations and then compute the nearest station to a user and then send that information to the user by any suitable means of communication. This enables any number of users to be networked within a system without them themselves needing a “complete RTK kit”. Extended range can be achieved due to the fact that the monitoring stations that feed the network base station are static, unlike conventional use of RTK where the receiving station is moving with the vessel.

2.13 Available and potential European National Services covering Inland waterways

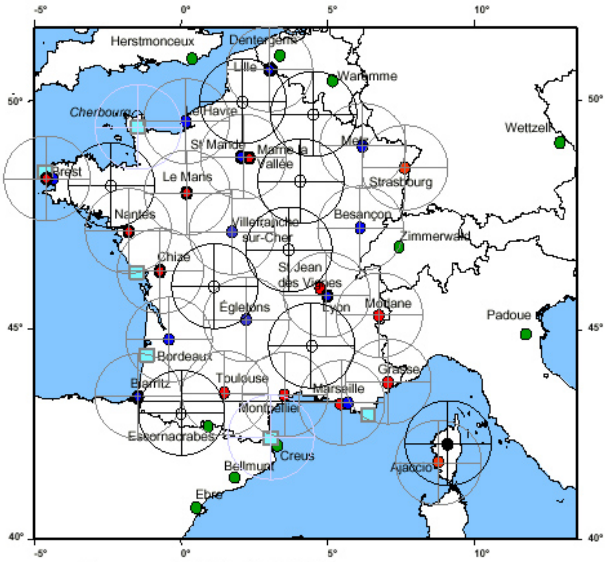
At present France, Netherlands, Switzerland and Germany, have operational RTK services. Austria is in the process of bringing a service on-line. Hungary is also planning as national service. Other than these services project is called EUROP is now underway to extend the SAPOS concept, used in Switzerland and Austria (SWIPOS & APOS) throughout Central Europe. All these countries also





offer a nationwide DGNSS service. The UK DGNSS may also be relevant to users of river sea vessels and is therefore included in this part.

2.13.1 France RGP Service

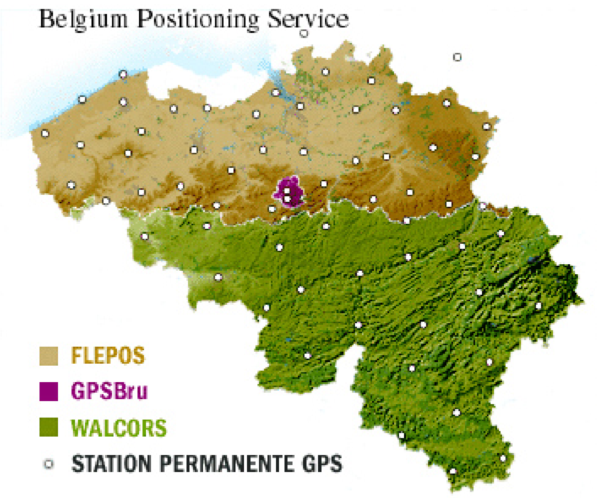


France RGP (DGPS)

The French National RGP DGNSS service when combined with the Maritime beacons gives complete coverage of all French ports and inland waterways.

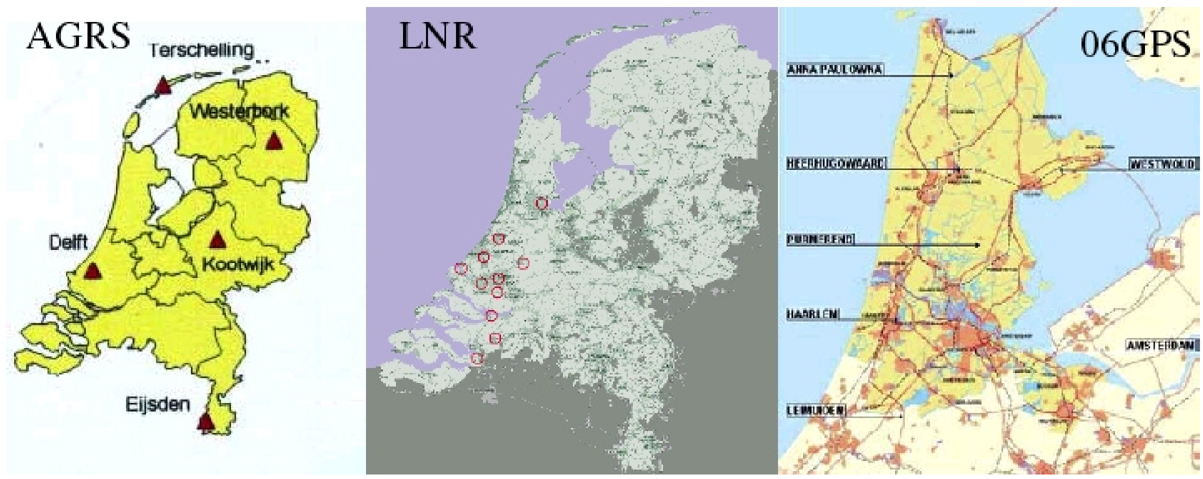
2.13.2 Belgium FLEPOS, GPS Bruxelles and WALCORS Service

Within Belgium both DGNSS and RTK services are available, however the RTK service up to now has not been used like in Netherlands for maritime of port operations.



2.13.3 Netherlands AGRS, LNR & 06GPS

The Dutch service is operated by their"Rijksdriehoeksmeting" ("National Ordnance Datum") from the Survey Department (NAP) from the Dutch Ministry of Transport, Public Works and Watermanagement are maintaining the Dutch Geometric Infrastructure. These organizations are responsible for maintaining and publication of planimetric (x- and y- coordinates) and height related information. This infrastructure is the basis for all geodetic- and survey- works in the Netherlands. The AGRS service operates a DGNSS service wheras the LNR and 06



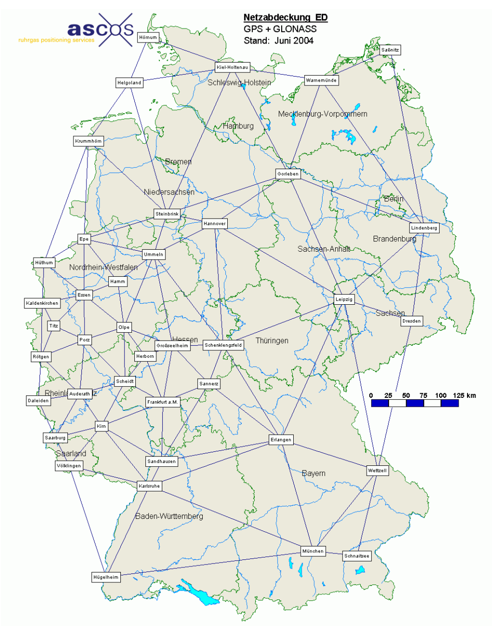
GPS operate RTK services.

2.13.4 Germany SAPOS

Within Germany the SAPOS EPS offers real time positioning with an accuracy of 1 to 3 meters. Reference stations permanently measure distances to the GPS satellites from which they determine correction values. The correction data are available to the user in real time (in standardized format).

The satellite positioning service SAPOS makes available the official reference system at a nation-wide level by modern methods. A system of GPS reference stations forms the basis of this system. This service is available with high reliability. SAPOS HEPS High-Precision Real Time Positioning Service offers real time positioning with accuracy of 1-5 centimetres. The user may, in addition to the EPS correction also have resource to the carrier phase correction data of the satellite signals in real time which supports precise positioning.

2.13.4.1 Ascos – ruhrgas positioning services (Germany)



The Ruhrgas AG provides real time correction data for GPS and GLONASS positioning under the brand name ascos. Data for post processing are available as well. In close co-operation with the SAPOS reference stations the service can be provided Germany-wide. Correction data are transmitted via GSM in RTCM format at a rate of 1 second. The data are neither compressed nor encrypted.

The ascos service is operated by a private company and provides two services:

PED - Precise real-time service having an accuracy 2 cm

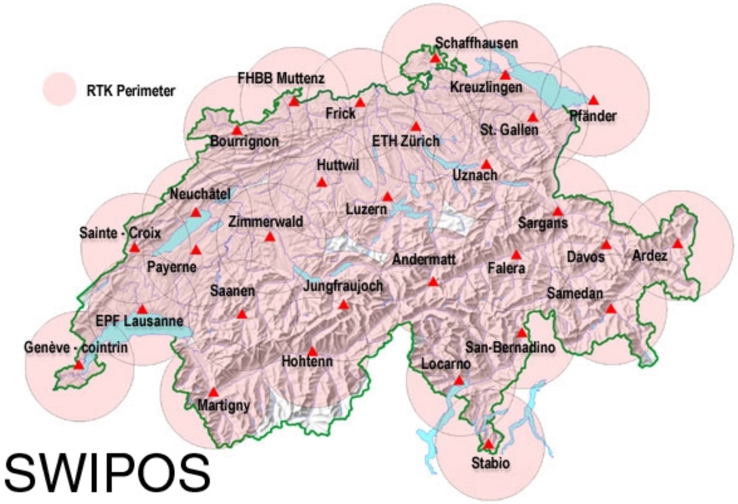
ED - Real-time service having an accuracy 30 cm

AMDS (Germany)

The AMDS DGPS Service is operated by a private company, EuroNav Service GmbH to meet the requirements of real time applications in the 0,5 to 2 m accuracy level. Three long wave transmitters broadcast corrections at a rate of 3-5 seconds in RTCM 2.0 format. The user needs an AMDS/dGPS-Box II and a licence.

2.13.5 Switzerland SWIPOS

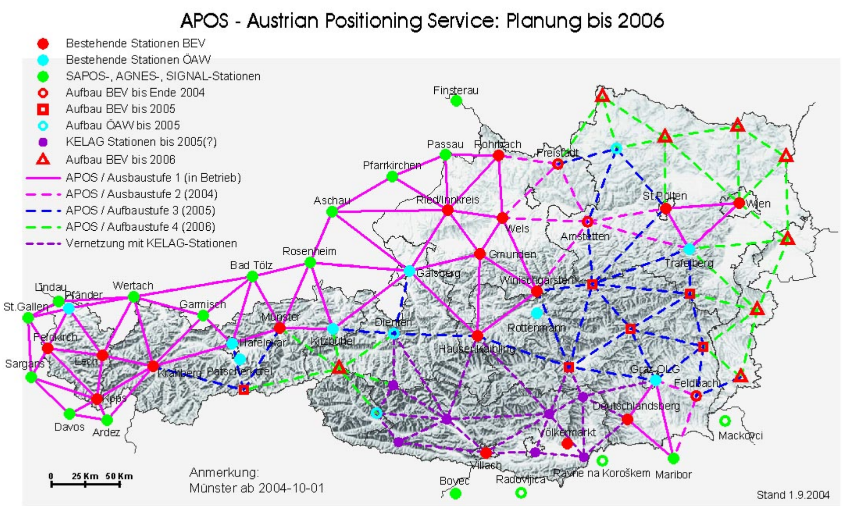
Swipos is operated by the Swiss Federal Office of Topography. Swipos-NAV swipos-NAV is a positioning service via VHF/RDS (until end of 2004) or GSM for applications at the accuracy level of meters. Access via internet is available, too (NTRIP format).



Correction data are calculated from the automated Swiss GPS network AGNES. The data (RTCM 2.3) are free of charge; the user has to pay for communication costs only.

2.13.6 Austria APOS

DGPS and RTK will be provided by the Bundesamt für Eich- und Vermessungswesen (Federal Office for Metrology and Surveying, BEV).



The service of APOS (Austrian Positioning Service) started in 2003 and will be made public in 2006. There are at present more than 36 reference stations and when complete there will be between 70 and 75 offering two levels of service.

The stations are based in Austria, Germany (SAPOS), Switzerland (SWIPOS) and one test station in Slovenia. The services offered will be;

- Real Time Kinematic offering ± 20cm accuracy

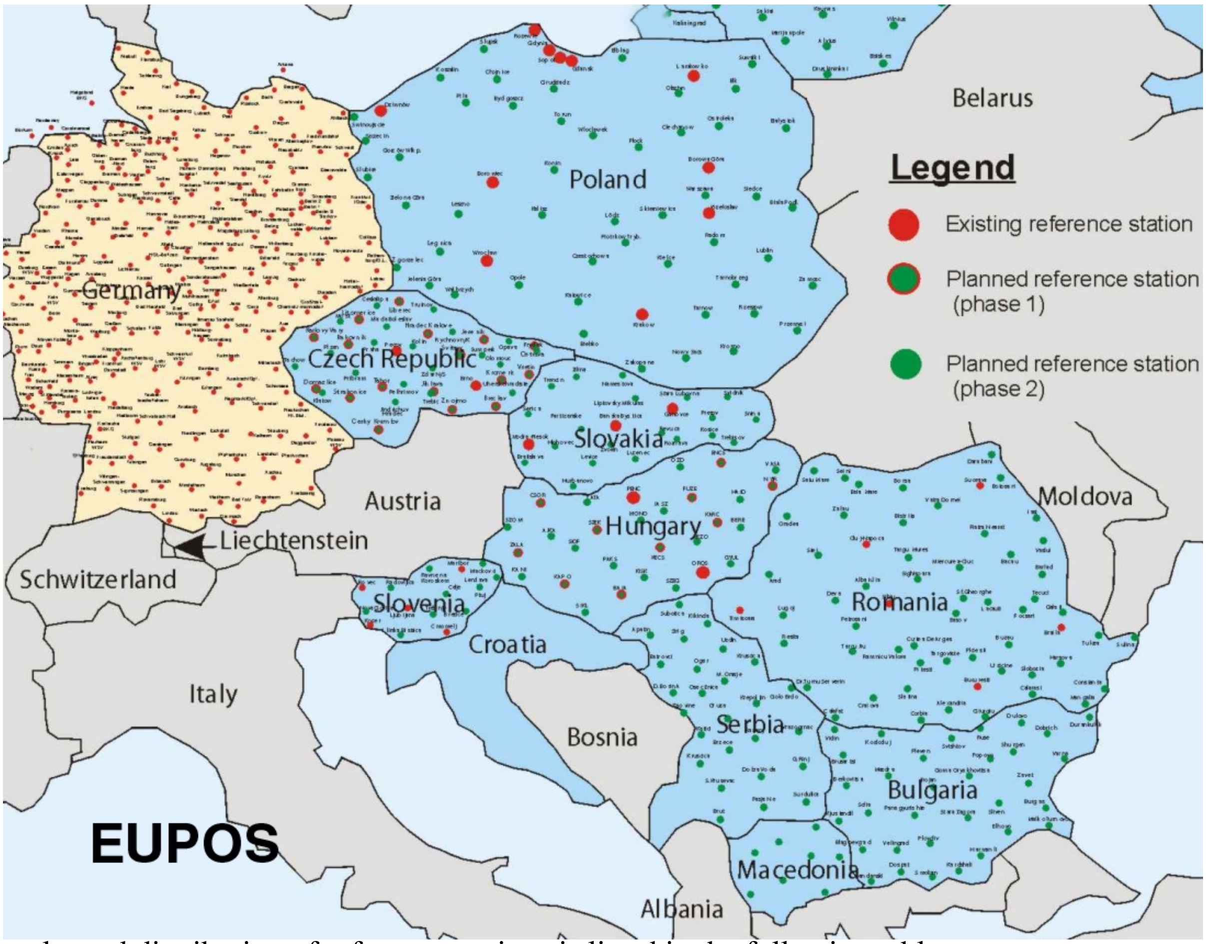
- DGPS service offering ± 50 cm accuracy.

2.13.7 EUPOS (European Position Determination System)

The project European Positioning Determination System (EUPOS ®) is an initiative having the aim to establish a uniform multifunctional DGNSS basis infrastructure in Central and Eastern Europe (CEE) on the base of the common reference frame ETRS89, unified data formats and international standards.

EUPOS is a regional extension compatible to the running “German National Survey Satellite Positioning Service” SAPOS ®. Existing European infrastructures will be taken into account, particularly EUREF as a fundamental realisation of the ETRS89. EUPOS will provide DGNSS correction data based on a network of permanent GNSS reference stations for real time positioning and navigation as well as GNSS observation data for post processing positioning EUPOS will be able to support precise positioning and navigation with high accuracy (metre, sub-metre, centimetre in real time and centimetre and sub-centimetre in post processing) as well as with guaranteed availability and quality.

EUPOS will offer two services of interest to the Inland waterway community. The EUPOS ® DGNSS service will provide for real time applications with an accuracy of at worst 3 metres and as high as 0.5 m. This will provide ample accuracy for navigation and AIS information. Whereas the EUPOS ® RTK CDGNSS service will provide for precise real time position determination by carrier phase measurements with an accuracy of about under 10 cm and as high as two centimetres. A third Geodetic service will provide for survey applications.



The planned distribution of reference stations is listed in the following table.

Country	Area km^2	Number of planned reference stations	Average distance between stations km
Bulgaria	110,990	23	70
Croatia	56,540	11	70
Czech Republic	78,870	16	70
Hungary	93,030	19	70
Macedonia	25,710	8	70
Poland	312,680	75	66
Romania	237,500	48	70
Serbia Montenegro	88,360	18	70
Slovakia	49,040	10	70
Slovenia	20,250	8	70
Total	1,072,970	236	69.6

3 USER & STAKEHOLDER REQUIREMENTS

3.1 European Radionavigation Plan Study (Helios Tech)

Quoted text related to Inland Navigation:- "*Historically, inland waterways applications have not been considered explicitly. These requirements, and associated services, are generally governed by local or regional authorities (e.g. Central Commission for Navigation on the Rhine, the Danube Commission), which may or may not adopt IMO recommendations. In the absence of alternative material, it has been assumed that the IMO requirements are representative. Augmented GPS systems are used to support inland navigation, which is safety critical, along with visual aids.*"

For the past few years, experts representing members states, professional institutions or users, have been meeting on a regular basis to determine a "European Radio Navigation Plan" that would cover all user process technological and policy issues. The European radionavigation planning process has also been attended by representatives from "The Russia Federation", and "United States of America".

It is evident that now the process is complete, that Road, leisure and Inland navigation requirements have not been fully covered. In respect of Inland waterways (Inland Navigation), has not been addressed at all. The following table tries to identify all current and emerging processes that are carried out.

3.2 Inland navigation requirements for radio navigation services

A main consideration for inland navigation is the interface of Inland Navigation with the Maritime sector. The operation requirement is not just restricted to navigation, where accuracies of 3 or more metres is probably sufficient, but for other processes requiring a level of equality of information (accuracy, timing, integrity etc.) with other vessels and infrastructure services.

The Inland Navigation VTS services also must be interoperable with the maritime sector, due to the common use of port, locks, rivers and canal infrastructures. Some critical applications will also require radio-navigation services that can provide integrity, authenticity and higher accuracy.

3.2.1 Current and emerging processes within Inland navigation

Radio Navigation Characteristics for Current and Emerging Inland Navigation Processes													
Process Operation Requirements.							GNSS Parameter requirement						
Process	Accuracy		Tolerance		System Equality	Process Range[1]	Integrity			Availability % per 30 days	Continuity % over 3 hours	Coverage	Fix Intervals
	H ↔	V ↕	H ↔	V ↕			Alert Limit (metres)	Time to Alarm (Seconds)	Integrity Risk (per 3 hours)				
Local / Port Traffic Management (VTS)	1[2]	N/A	0.2	N/A	✓	10 km	5	10	10^{-5}	99.8	99.97	Local	1
Berthing	0.5	0.2	0.05	0.2	✓	0.1 km	1.25	10	10^{-5}	99.8	99.97	Local	1
Locking & Restricted waters	0.5	0.2	0.05	0.2	✓	1 km	1.25	10	10^{-5}	99.8	99.97	Local	1
Navigation – River / Canal - Open	3	N/A	0.3	N/A	✗	1000 km	7.5	10	10^{-5}	99.8	99.97	Regional	1
Navigation Port	1	N/A	0.1	N/A	✓	100 km	2.5	10	10^{-5}	99.8	99.97	Local	1
RIS (AIS application) Position	3[3]	N/A	0.3	N/A	✓	1000 km	7.5	10	10^{-5}	99.8	99.97	Regional	1
Emergency / Safety	1	N/A	0.1	N/A	✓	100 km	2.5	10	10^{-5}	99.8	99.97	Local	1
Border Customs / Immigration	20	N/A	0.2	N/A	✗	1000 km	50	10	10^{-5}	99.8	99.97	Regional	1
Law enforcement	3	N/A	3	N/A	✗	1000 km	7.5	10	10^{-5}	99.8	99.97	Regional	1
Resource - Logistic Management	20	N/A	0.2	N/A	✗	1000 km	50	10	10^{-5}	99.8	99.97	Global	1
Dredging	0.10	0.05	0.01	0.001	✓	10 km	0.25	10	10^{-5}	99.8	99.97	Local	1
ATON (Aids to navigation)	1	N/A	0.1	N/A	✓	100 km	2.5	10	10^{-5}	99.8	99.97	Regional	1
Construction	0.10	0.05	0.01	0.001	✓	10 km	0.25	10	10^{-5}	99.8	99.97	Local	1
Container / Low Loader / swap body management	1	1	0.1	0.1	✓	1 km	2.5	10	10^{-5}	99.8	99.97	Local	1
Ice Breakers	1	N/A	0.1	N/A	✓	10 km	2.5	10	10^{-5}	99.8	99.97	Regional	1
Loading	N/A	0.01	N/A	0.001	✓	1 km	0.02	10	10^{-5}	99.8	99.97	Local	1
Dynamic Under keel Clearance / Path prediction	0.10	0.05	0.01	0.001	✓	1 km	0.25	10	10^{-5}	99.8	99.97	Local	1

[1] Process range for the purposes of this table relates to the distance from point of origin, or the distance between boundaries that the operation will require same accuracy.
[2] 1m has been used so that Inland navigation can be interoperable with Seagoing ships (IMO.A915)
[3] Vienna has a requirement of 67% better than 3m and 95% better than 5m.

Co-operative Automatic Docking / Locking	0.10	0.05	0.01	0.001	✓	1 km	0.25	10	10^{-5}	99.8	99.97	Local	1
Automatic Collision Detection and Avoidance	3[4]	N/A	0.3	N/A	✓	1 km	7.5	10	10^{-5}	99.8	99.97	Local	1
Automatic Collision Avoidance	1.5	N/A	0.2	N/A	✓	1 km	7.5	10	10^{-5}	99.8	99.97	Local	
Automatic Track Control	1	N/A	0.1	N/A	✓	10 km	2.5	10	10^{-5}	99.8	99.97	local	1

[4] Heading information that today is not the available in inland navigation will be required.

4 EMERGING SOLUTIONS FOR LONG RANGE AIS AND TRACKING

4.1.1 Emerging LRIT Services

- ORBCOMM
- NCUBE (Norwegian Experimental Space based AIS platform)
- GALILEO SMS

A modified ORBCOMM constellation is to be trailed form January 2006 by the USCG to determine whether they can monitor VHF AIS from Space. Maritime Domain Awareness initiative. If successful and if concerns over ITU regarding the use of VHF marine AIS bands for non-terrestrial use can be overcome. It is likely that the USCG will proceed to adopt this service as part of their homeland security programme. The aim would be to use ORBCOMM alongside complimentary satellite and high altitude imaging techniques (Synthetic Aperture Radar etc.) whereby any detected targets within 2000 miles of the US Coast that where not transmitting on VHF AIS and thus detected by ORBCOMM would be investigated. Though the declared interest is only within 2000 miles of the US coast line, the facility would be available world wide, and thus it may be promoted for Long Range AIS in the near future. Due consideration should also be given to the possibility that if all vessels in the world where to be fitted with Class A and Class B AIS, ORBCOMM would have the possibility of detecting some 13,000,000 vessels.

A Norwegian University, with support from a European AIS systems company, is developing a small, low cost experimental satellite "NCUBE" able to receive terrestrial AIS information Their intention is to determine whether this can be used for Long range AIS. The expected launch date will be February 2005 and the intention is to commence experimentation in space in early 2005. The USCG has unofficially expressed interest in the results of this experimentation.

4.1.2 ORBCOMM (& N CUBE)

ORBCOMM & NCUBE are polar orbiting and will offer coverage of the world, but not all at the same time, whether missing areas of coverage, which will constantly change, are significant, and whether garbling in busy waters is a problem is a subject for further study.

The collection of AIS data on the satellite will be subject to significant garbling due to the large number of AIS terminals in well-used maritime environments. The Class B AIS environment could significantly compound this challenge if this goes ahead in the 160Mhz

VHF band. This will result in very few updates in high-density areas and the best efficiency being obtained in low-density areas.

The Doppler shift caused by the movement of the satellite will lead to the AIS signals being spread over a wider band than currently considered for terrestrial systems only. This requires complex receiver technologies to be deployed on the satellite to compensate for these shifts in received AIS carrier frequency.

Though not a declared aim, if the ORBCOMM constellation is able to transmit on the AIS band, on one hand it could prevent some garbling by intervening with the self timing (TDMA) and reallocating new time slots which could be a good thing, but on the other hand it could also possibly provide psuedo AIS information, (there is an AIS message protocol used by VTS to create psuedo AIS targets to highlight small vessels or objects that do are not fitted with AIS, or vessels, whose AIS is not functional) and if used in this way, the ORBCOMM system could cause havoc.

4.1.3 GALILEO (or other satellite based) SMS

Galileo is planned to be operational by 2008, though now more likely to be 2010 and is expected to have spare payload capacity on one third of the satellites. The redundancy is due to the sharing of the MEOSAR Search and Rescue Mission with GPS II and GLASNOS. One of the potential missions being studied as of April 2005, is to have as part of its payload as a SMS transponder that could be used for long range two-way SMS communication. The timescales for research are similar to that of ORBCOMM. If a devoted SMS service were to be offered, and supported by Member States, DG TREN, EMSA as well as INE and the river commissions of Europe, we could be served with a very good solution for Long Range Identification and tracking, as well as for Safety and navigation messaging. However, a clear and informed policy action would be needed to ensure acceptability by non-EU flag states and the IMO. Galileo SMS stands alone giving major LRIT benefits that cannot be guaranteed by other commercially operated services. Being European owned, it would give added surety for European security needs.

The potential GALILEO SMS service is as yet undefined, but if operated as a safety service paid for by the users of the LRIT information, flag states, then would not be a commercial service, (though it might be operated by a commercial identity) and as such would be more manageable for LRIT, and would mitigate risk for safety information to be blocked by commercial traffic. GALILEO will give global coverage but the main drawback to it is that, as for LRAIS via ORBCOMM, as yet it does not exist, and the SMS LRIT capability is still undefined and in fact undecided.

The potential LRIT capability that can be offered by GALILEO SMS, could in-fact facilitate all the requirements to meet SafeSeaNet as well as enable maritime regions to better assess risk and as a result be proactive in their decisions. Because the service is not commercial it is suitable for a GALILEO mission (can not use GALILEO for subsidising commercial communications).

Because the service will be controlled by Europe, and will be newly available in three to four years, and because the service offered would be interoperable and share the same transponder as Search and Rescue enhanced services, it would be an attractive proposition. However, though this is a very attractive candidate, it would need political support at a very early stage for it to have a chance at success, particularly in light of COMSAR February 2005 and MSC May 2005 where LRIT is to be discussed..

The costs of the operation of SMS via satellite using GALILEO, could be easily met by member states within Europe, and other parties outside Europe that would like to used the increased functionality that it can offer.

Work will begin as early as January 2005 for the research and development stage of SMS LRIT via GALILEO.

4.1.4 Inland Waterways Interoperability

Whether selecting GALILEO SMS, or ORBCOMM the inland waterways also can be included within coverage of the same system. This has a distinct advantage in that for tracing for security or safety reasons, both communities can be monitored by the same gender of technology, and from time to time both share the same waters.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1.1 Reliability & Redundancy - Dual or Triple Service

Because in the unlikely event, a vessel dependent on one space based radio-navigation service provider system, might be fed with misleading information in event of space segment signal or system failure / (GPS Malfunction SV 23 - January 2004), for inland areas, particularly those that may be environmentally sensitive, it may be advisable for the vessels radio-navigation fit to have the capability of receiving information from more than one service. This would mean that the vessel could not rely on GPS alone, and would have to be capable of receiving information from another service (GALILEO, GLONASS or LORAN/CHAIKA). Such a requirement would involve specification of suitable solutions at have an acceptable level of services / information equality throughout the Inland waterway network. A working group should study whether back up services are required.

5.1.2 Authenticity and integrity

The passage of inland navigation vessels themselves, or the cargo they carry may be from outside the EU 25. If for security, customs, environmental protection or immigration reasons it is required that the information transmitted by AIS or LRIT is authentic and has a high level of integrity EGNOS or EUROFIX enabled receivers would need to be used in the short term, and GALILEO from 2011(+). GPS 3 will also have integrity and authenticity information but will not be available probably until 2015.

Consensus from various departments in most member states may have to be consulted in light of recent reporting initiatives.

If required Navigation receivers would have to be EGNOS or Eurofix capable.

5.1.3 Accuracy levels & Interoperability

The paper has identified and given a technical capability summary of many terrestrial and satellite based radio-navigation services that are available or emerging for Inland navigation use. Ideally all inland navigation vessels must be interoperable each other, and those that share inland, coastal or port waters with sea going vessels must also be interoperable with them too. Other position dependent information such as AIS that is designed to be used by other vessels or infrastructures must also have a level of equality sufficient to ensure safety.

For the majority of navigation requirements it therefore makes sense to use the IALA compatible national DGNSS networks for navigation, but for applications that demand accuracies of better than 1 metre, use can be made of the national existing and proposed RTK networks. RTK often carries a cost. A working group should look at the cost in various states and consider how these can be met.

Navigation receivers should be capable of receiving all European RTK and DGNSS services.

5.1.4 Holes in service provision

Due to canyon effect within mountainous or city areas, or large steel structures in port areas, the constellation might be in shadow, or might be subject to multi-path errors. In these cases measures must be taken to ensure continuity of the navigation services as demanded by the vessel and infrastructure. This might be achieved by a greater number of satellites in the future (inclusion of GALILEO) use of EGNOS or LORAN, or by using local services RTK or psuedolites. This will almost certainly effect receivers to be carried.

Awareness of the potential break in coverage must be realised and consensus throughout the community for remedial measures to mitigate problems.

5.1.5 Psuedolites – Friend or Foe

The use of psuedolites as previously mentioned, will give benefit to applications aforementioned. However, there is a very real possibility that the transmissions required for navigation, might also interfere with normal non-psuedolite enabled receivers. Therefore before implementing psuedolite technology steps must be taken to ensure that their signals will not spoof or jam normal GNSS receivers.

6 RECOMMENDATIONS AND CONCLUSIONS

Review current and emerging processes to determine the position accuracy and relative position accuracy demanded by them.

Review the cocktail of radionavigation services available for provision, and decide on services recommended for use by Inland navigation. This should consider the availability and potential expansion of LORAN, standard provision of RTK corrections either by GSM or VHF to facilitate the availability of lower cost standard receivers for inland navigation, and the possible use of EGNOS and IALA DGNSS.

Ensure that any local element or receiver development for navigation is backward compatible to integrate GALILEO open service when available.

Review work of the project EUPOS to determine a RTK availability for all stretches of inland waterways where metre or sub-metre accuracy is required. (infrastructures for marginal vessels, Hungary Danube for safety etc.)

Monitor Galileo Advanced Concepts project work on 2 way SMS messaging via GALILEO, and or other emerging SMS via satellite services that can fulfil AIS / Long Range Identification and tracking for security, safety, environmental protection and administration applications.

Monitor USCG trials for use of modified ORBCOMM constellation that will monitor, downlink and record all class A and B VHF AIS surface transmissions world-wide, irrespective on whether they be on a ship or inland waterway vessel.