SWEDISH RADIO NAVIGATION PLAN

SUMMARY 2002

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This plan is published by the Swedish Maritime Administration and has been produced by a working group within the Swedish Board of Radio Navigation.

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List of Contents

Summary

This report provides an updated summary in English of parts of the contents of the Swedish Radio Navigation Plan 2000. The summary will concentrate on requirements, policy and plans within the area of Radio Navigation Systems in use or planned to be used in Sweden. The most recent version of the plan was published in Swedish at the beginning of the year 2000 by the Swedish Maritime Administration (SMA) which by a Government decision was given the responsibility for compiling and publishing the plan. Some background and general information concerning the work with the plan will be given in the introductory part of the report.

1 INTRODUCTION

The need for an official publication describing available navigation and positioning services and the policy and plans of the authorities responsible for these services in Sweden to meet with the general requirements is very strong. The need for such a document has accelerated at a pace with the availability of more and more accurate and reliable navigation aids and the necessity of increased international co-operation in these matters.

In order to meet these requirements the first Swedish Radio Navigation Plan was published in 1991 on the initiative of and by the Swedish Board of Radio Navigation (RNN). By a decision by the Swedish Government the Swedish Maritime Administration (SMA) was later given the official responsibility for the continued work with the plan. RNN was tasked to proceed with the updating work and so a new thoroughly revised version of the plan was developed by RNN and officially published by SMA in 1997. The plan is to be updated every third year so according to this a new revised plan was published in 2000. This plan is still in use.

The Swedish Board of Radio Navigation is an association of representatives from mainly Government authorities and institutions and also companies engaged in navigational matters as users or suppliers of navigation and positioning services. The main objective of RNN is to be an informal meeting place and forum for discussions and opinions and to keep its members informed of the development and progress in general within the area of radio navigation. The Board is a representation of highly qualified members normally engaged in the handling of technical matters or high level management covering the whole of the broad areas of aviation, marine, land and military navigation and positioning applications. Thus the organisation has the necessary competence needed for the work of compiling the national radio navigation plan.

The purpose of the Swedish plan is mainly to give:

1. An up-to-date inventory of radio navigation aids available for use in Sweden and in its surroundings together with a short technical description of the function of each system, users in general and probable future development. (Not included in this summary.)

2. A survey of the development taking place in Sweden and the policy and plans of the authorities, organisations and companies responsible to meet the requirements in general.

3. A summary of views anchored to all those responsible for the services and intended for use as a relevant source for planning within the area of radio navigation and positioning.

In the following an updated summary of the Swedish Radio Navigation Plan 2000 will be given. Concentration will be on requirements in general, systems normally used today and a review of the official views, policy and plans within the fields of radio navigation and positioning services in the aviation, marine, land and military environment. The accuracy figures given are normally specified as 95 % probability values if not otherwise stated.

2 MAIN CONTENTS

The contents of the plan are divided into the following three main areas and supplements:

- Available navigation systems
- User requirements and systems normally used today
- Policy and plans
- Supplements

3 AVAILABLE NAVIGATION SYSTEMS

In the first part of the plan a survey is given of systems used or available for use today in Sweden. It is rather extensive because of the fact that many old radio navigation aids are still in operational use. Also systems planned for the near future are described with note of time for probable operation. Future systems and applications such as Galileo and use of mobile communication systems such as GSM also for positioning, and use of map matching for land navigation purposes etc. are thus touched upon.

This chapter gives a short overview of radio navigation systems available for use in Sweden and related support systems.

3.1 Terrestrial systems

3.1.1 Common systems

System	Administration Responsible	Users in Sweden	Estimated lifetime	Comments
Loran C	National	Aviation, Marine, Land	>2010	Uncertain forecast
Chayka	Russia	Aviation, Marine, Land	>2010	Uncertain forecast

3.1.2 Systems for aviation

System	Administration Responsible	Users in Sweden	Estimated lifetime	Comments
NDB	SCAA, SAF, Private, Local authorities	Aviation	>2010	
VOR	SCAA	Aviation	-2010	
DME	SCAA, SAF, Private, Local authorities	Aviation	>2020	
ILS	SCAA, SAF, Private, Local authorities	Aviation	>2010	
Fixed direction finders	SCAA, SAF	Aviation	-2010	
PAR	SAF	Aviation	-2005	
TILS	SAF	Aviation	-2015	

3.1.3 Systems for maritime use

System	Administration Responsible	Users in Sweden	Estimated lifetime	Comments
Fixed direction finders	SMA	Marine	>2010	For direction finding from shore
Racons	SMA	Marine	>2020	Support system for radar

3.1.4 Systems for land navigation/positioning

System	Administration Responsible	Users in Sweden	Estimated lifetime	Comments
GSM	Private	Land	>2020	Communication/ Navigation
GSM-R	Railway Administration	Land	>2010	Communication/ Positioning
ATC	Railway Administration	Railway use	>2020	

3.2 Onboard systems

System	Administration Responsible	Users in Sweden	Estimated lifetime	Comments
Navigation radar		Aviation, Marine,	>2020	
Map-matching		Land, Aviation	>2020	
Doppler navigation		Aviation	>2010	Special craft usage

3.3 Satellite- based systems

System	Administration Responsible	Users in Sweden	Estimated lifetime	Comments
GPS	USA (DoD/DoT)	Multimodal	>2020	Operational but developing
GLONASS	Russia	Multimodal	>2001	Not fully operational, Uncertain future
Galileo (”GNSS 2”)	EU	Multimodal	2008->	No final decision
COSPAS/SARSAT	International	SAR	>2020	
ARGOS	International	Marine, Land, Research	>2010	
ORBCOMM	International	Marine, Land	>2005	Communication system with navigation facility

3.4 Support and augmentation systems

System	Administration Responsible	Users in Sweden	Estimated lifetime	Comments
ECDIS	SMA/IHO		>2020	Standard for Electronic Nautical Charts and presentation system
INMARSAT	International	Aviation, land, marine	>2020	Communication system
Transponder – VDL	SCAA	Aviation	2002->	Localization
Transponder – AIS	SMA/IMO	Marine	>2020	Collision avoidance
Epos	Private	Land	>2010	DGPS service
EGNOS (”GNSS 1”)	EU	Multimodal	2003->	Test and development, SBAS
Mobipos	Private	Land	>2010	DGPS service
Ciceron	Private	Land	>2010	RTK service
Omnistar/Seastar	Private	Multimodal	>2010	WADGPS
Radio Beacon	SMA	Marine	>2020	DGPS
Landstar	Private	Multimodal	>2010	WADGPS
LuLIS	SAF	Land, Marine	>2010	DGPS, military

4 USER REQUIREMENTS AND SYSTEMS NORMALLY USED TODAY

4.1 Requirements in general and concepts used

The purpose of this chapter in the plan is to give a short review of the systems and methods used today in Sweden in the aviation, marine and land application areas and to identify the present user groups and summarise the needs and requirements of these groups.

The main areas of applications are the following:

In the air: En route, approach and landing

At sea: Open sea, coastal areas, harbour and harbour approaches

On land: Depending on user category

When requirements are to be specified for a certain navigation system in different applications it is in most cases the performance with respect to coverage, accuracy, availability and integrity of the system that is of primary importance.

General requirements for a radio navigation system are that it shall cover all parts of the area or space of interest and have around-the-clock availability. The system is required to function independent of time, season of the year, weather and other environmental factors. Also it has to meet the requirements with respect to accuracy, safety, dependability and user-friendliness.

The different users have different requirements with respect to accuracy, availability, continuity and integrity. A particular user may require a position accuracy that varies with respect to the geographical area or time of day. The accuracy required varies normally from one metre up to some tens of kilometres. Specifically the requirements are high (cm) in e. g. positioning of points of reference, aerial photography, machine guidance and in geodetic and land survey measurements. In military applications, requirements for autonomy and resistance against jamming have to be considered.

The concepts that are used in the plan – “Positioning”, “Localisation”, “Navigation” and “Route guidance” respectively – are defined in the following way:

Positioning is the technique to locally establish the position of a user

Localisation means positioning and transfer of position data by the use of a communication system

Navigation is the technique for a user to find the way to a destination point along a defined route, using the process of repeated positioning

Route guidance is the technique to lead a mobile unit from a localised point to a destination point along the most appropriate route

4.2 Aviation

4.2.1 General

Aviation makes use of four-dimensional navigation support (X,Y,Z and time). Currently the time is determined by the pilot or the air traffic controller. Increased availability of exact time for the position can drastically improve the situation awareness and thus increase safety.

At navigation en route the following systems are currently in use: VOR, VOR/DME, DME/DME, IRS/INS (airborne inertial systems), GPS and NDB. For approach and/or landing ILS, VOR, DME and NDB are used.

4.2.2 Requirements

The requirements for aeronautical navigation systems, with respect to availability and integrity, vary with the phase of the flight.

For navigation en route, it is currently sufficient with an accuracy of some nautical miles (RNP-5) in the horizontal plane. In future airspace, with much higher traffic intensity, it is anticipated that the requirement in the beginning of this century will increase to less than 1 nautical mile (RNP-1). This is needed in order to achieve decreased separation between aircraft. A similar requirement is necessary for the direct flights between destinations and to avoid the need for crossing airways at critical points (VOR locations). Determination of the aircraft position in the vertical plane requires an accuracy of approximately 50 metres.

At approach and landing the following two types of procedures may be used, precision approach and non-precision approach, with different requirements for accuracy. Facilities for precision approach are important for regularity during bad weather conditions and are additionally used, by the heavy aircraft, also during good conditions. This facilitates the landing and makes the approach more comfortable for the passengers. Facilities for precision approach are categorised based on requirements for accuracy and minimum visual conditions as follows:

Category	I	II	III
Minimum vertical sight	60 m	30 m	30 - 0 m
Minimum RVR (Runway Visual Range)	550 m	200 m	200 m
Horizontal accuracy at the landing threshold	± 10.5 m	± 7.5 m	± 3 m
Vertical accuracy at the landing threshold	ca 1 m	ca 1 m	ca 1 m

For non-precision approaches the requirements for visual conditions are much higher and also dependent on the terrain close to the airport.

Equipment used for non-precision approaches is ILS without glide path, VOR, or NDB/Locator. The accuracy for these is as follows.

Equipment	Accuracy
ILS LLZ (localiser, no glide path)	± 10.5 m
VOR	± 3 °
NDB (airborne part of equipment)	± 3 °

4.2.3 The RNP Concept

The method used so far to define the required navigation capability has been to require a specific type of equipment. This has turned out to limit an optimal use of modern airborne equipment and also to slow down the development of new navigation systems.

To overcome these deficiencies, ICAO has developed a new concept, Required Navigation Performance, RNP, to define requirements for navigation capability.

Rather than requiring a certain type of equipment, RNP requires that the user is able to navigate with a defined level of precision within a certain airspace. RNP is a parameter describing maximum allowed lateral deviation from an assigned or chosen airway and also the deviation along the airway. RNP for en-route flights generally is a maximum deviation of 5 NM. For dedicated areas higher levels of precision may be defined.

Thus, RNP is a requirement for accuracy of position related to a defined flight path and at any time during the flight.

For approach, landing and departure phases, RNP is defined as a limit for lateral and vertical deviation from the assigned flight path. Two sets of limits define an inner and an outer tunnel for each approach procedure. The aircraft and the navigation system shall be designed to keep the aircraft within the inner tunnel. The probability of being inside the inner tunnel must be at least 95% while a penetration of the outer tunnel boundary is considered as an incident that may pose a safety risk. Work with definition of RNP for approach, departure and landing phases is on-going and not yet approved by ICAO.

Requirements are put on the user and the systems or combination of systems used, in order that they fulfil the aeronautical requirements for integrity and continuity of service.

The terms “Integrity“ and "Continuity of service", often denoted COS, are both safety related and are defined in ICAO Annex 10 with specific meanings. Integrity is a measure of probability that the system is functioning as intended and does not cause the aircraft to violate defined limits. Continuity of service is the probability that the system, during any time period of 15 - 30 seconds, does not cease to function. The aim of this is to safeguard that the system does not fail during the critical final phase of the approach.

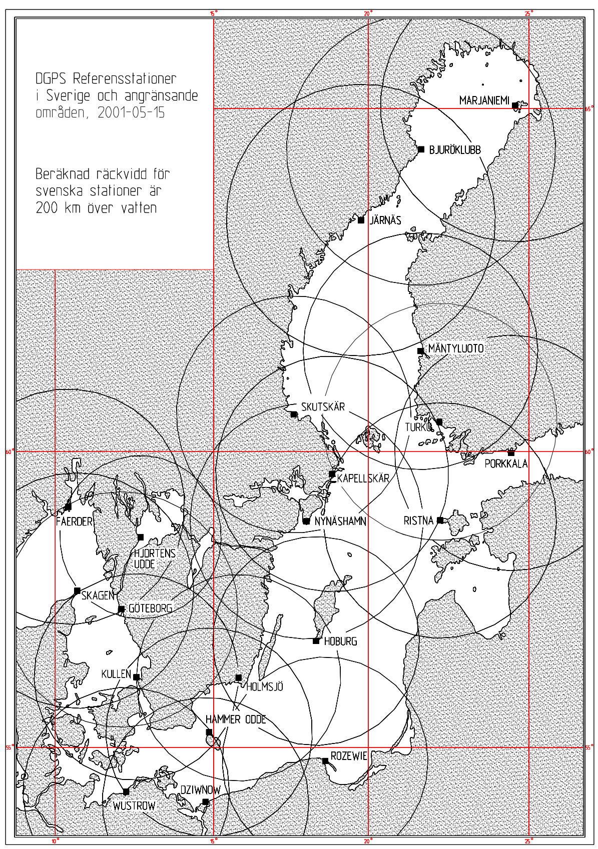
4.3 Marine

4.3.1 General

Radio navigation is used for navigation on the open sea in Swedish waters, where an accuracy of 100 –1000 m is adequate and in the archipelagos, which requires precision navigation with an accuracy of 1-50 m. Besides optical aids to navigation and radar GPS and DGPS are used.

For the maritime users the Swedish Maritime Administration has established a network of reference stations for GPS, which transmits DGPS corrections according to RTCM SC 104 version 2.1 on the Maritime Radio Beacon Band. The system has been in full operation since May 1996 but was upgraded during 2001. The service is free of charge and offers, together with the similar service from neighbouring countries, a signal availability >99.8 % in its coverage area.

Positions and coverage areas of reference stations in Sweden and neighbouring countries are indicated in the figure below.



For use in the coastal area there are also DGPS services (Epos and Mobipos) from private service providers available via the national FM radiobroadcasting network.

The use of DGPS enables accurate radio navigation in restricted waters and archipelagos. The safety of navigation is increased by presenting the position in an Electronic Nautical Charts of good quality, preferably an ECDIS.

In some areas with intensive traffic VTS (Vessel Traffic Services) has been established. The sea traffic is monitored by radar and communicates with the VTS by VHF radio. Ships equipped with AIS can automatically be identified and tracked on a suitable display in the VTS and onboard other ships. A network of AIS base stations covers all Swedish waters.

4.3.2 Requirements

The user requirements for general navigation are based on the revised IMO Resolution 815(19) which in summary requires:

- For navigation in those harbour approaches and coastal waters with a high volume of traffic and/or a less significant level of risk an accuracy better than 10 m (95%) with an availability better than 99.8 % and a time to alarm < 10 s.
- For navigation in those harbour approaches and coastal waters with a low volume of traffic and/or a significant level of risk an accuracy better than 10 m (95%) with an availability better than 99.5 % and a time to alarm < 10 s.
- For navigation on the open sea and in ocean waters an accuracy of 100 m (95%) with an availability of 99.8 %.

More stringent requirements may be necessary for ships operating above 30 knots.

Fishing and some other marine activities may require accuracy better than 10 m.

Aids to Navigation management require an accuracy of 1 – 10 m.

Surveying requires a horizontal accuracy of 0.5 – 5 m and vertically down to 0.05 m.

4.4 Land

4.4.1 General

There is a considerable difference between the environment on land compared to the environment at sea or in the air. On land there is in most cases vegetation, hills, mountains and buildings either reflecting or screening the radio navigation signal. Especially in dense forests and in urban areas reception of radio navigation signals can be very difficult. In land mobile applications, quick changes of speed and directions are common. The navigation system should be able to work accurately in this environment and difficult conditions.

Before GPS became available, there were no reliable radio navigation systems with nation-wide coverage available.

For navigation on land today, GPS is the only system with full nation-wide coverage. In several applications navigation or position acquisition using GPS only is sufficient. In most applications, however, additional methods must be used to increase accuracy and availability, such as using INS, odometer and gyros for dead reckoning and/or map matching.

An additional feature of the GPS system is that very exact time can be derived from the satellite signals, thus making time synchronisation between locations very far away possible.

4.4.2 Positioning

The use of the satellite technique has also increased the possibilities to determine the position with centimetre-level over really long distances, like some hundreds of kilometres. That means great benefits for e.g. aerial photography, connection of cadastral surveying and local reference systems to the national reference system, determination of the position in the national reference system and so on. For surveying with centimetre accuracy, where the distance between the sites are less than 20 km the GPS technique has been used routinely for several years. That means that the costs have decreased significantly, and that the quality sometimes has increased for these applications. The next step, which is already in progression, is local surveying with relative GPS in real-time some 10 kilometres from the reference station.

To get a better position accuracy than a couple of metres with GPS, simultaneous GPS measurements are required on a station with known position i.e. at least two GPS receivers are needed. If one of these is placed standing permanently on a point with known co-ordinates it is called a permanent reference station. Such a station is continuously providing the user with GPS data for post-processing and/or GPS corrections in real time. Two big advantages with these stations are that the GPS data is quality checked and that the user only needs one GPS receiver to get a high position accuracy.

The SWEPOS network is a national network of permanent reference stations, which was designed and established by the National Land Survey together with Onsala Space Observatory at the beginning of the nineties. The network is acting as a basis for the Swedish National Reference Frame. It is also providing data for a number of different purposes – everything from position determination with metre accuracy in real-time, e.g. for navigation support, to studies of movements in the Earth's crust on the millimetre-level. Based on a government decision 1995, a co-ordination group for financing and technical detail design for the further developments of SWEPOS was established.

SWEPOS reached IOC status the 1st of July 1998, i.e. that the availability of SWEPOS data for real-time applications with metre accuracy and post-processing applications with centimetre accuracy follows a predetermined specification. Twenty-one of the stations are mounted on bedrock, another ten stations are mostly located on the top of buildings. A map containing all the stations is given in 4.4.1, and an overview of the dataflow is given in 4.4.2.

The positions of the SWEPOS stations are determined in the reference system SWEREF 99, which via the European system EUREF 89 is connected to the global ITRF (International Terrestrial Reference Frame). SWEREF 99 can be considered to be the same as WGS84 in Sweden and has well defined connections to the Swedish plane reference system, RT90, and the Swedish height system, RH70.

Through the stations in Onsala and Kiruna, SWEPOS is also connected to the worldwide GPS network, which is co-ordinated by IGS (International

GPS Service). The IGS network provides data e.g. for the determination of the satellite orbits and the supply of a global reference frame.

In Sweden there are two commercial DGPS services, Epos and Mobipos, both based on SWEPOS data. Epos is broadcast over Sweden on the RDS channel on the FM radio net and gives a horizontal accuracy of 1-2 metres depending on which GPS receiver is used and how the receiving conditions are for the GPS signal and the radio signal. Mobipos is broadcast over Sweden on the DARC channel on the FM net and gives an accuracy similar to that given by Epos.

There is also a local commercial RTK service at eight places (Gävle, Stockholm, Göteborg, Malmö, Hässleholm, Västerås, Jönköping and Helsingborg) in Sweden, called Ciceron. It is based on SWEPOS data and is broadcast on the DARC channel on the FM radio net. Ciceron is based on the single station RTK concept and gives the accuracy 1-4 centimetres within the radius of 20 km from the SWEPOS station.

From the SWEPOS Control Centre at the National Land Survey the full GPS data (code and carrier phase data) from all SWEPOS stations in operation at the desired time can be downloaded via Internet. Using SWEPOS data for post-processing an accuracy of one centimetre to a metre can be obtained depending on the length of the observation time and the GPS receiver used. GPS surveying with a double frequency receiver, good satellite geometry, good receiving conditions for the satellites, and a good post-processing software gives centimetre accuracy.

During 2000 and 2001 additional SWEPOS stations were established. These stations were mainly established to aid the on-going Network RTK projects. Network RTK is a RTK multi-station solution. To accomplish this a Network RTK software is used at the SWEPOS control centre, which receives the data from the surrounding SWEPOS stations and then calculates a so-called virtual reference station close to where the user is. The virtual reference station is then functionally equivalent with an ordinary reference station and sends out the corrections to the rover receiver. In co-operation with groups of users, SWEPOS provides a prototype Network RTK service in the Stockholm area and in the Southern and Western parts of Sweden.

The production of a database with simplified geographical information, based on the cadastral map, was finished in 1997. In 1995 a further development and completion of the original version was started. That has resulted in the new product, Geographical Sweden Data, which is described further in the annual Map Plan which is published by the Geological Survey, the National Maritime Administration and the National Land Survey, more information on www.lantmateriet.se.

The goal is to design the GSD bases in such a way that they can also be used for purposes other than map production, e.g. planning for transports. To achieve that, and to establish a fast production of databases, the National Land Survey is co-working as much as possible with other interested parties. GSD bases can be delivered for the country, county or municipality as vector- or rasterdata in a number of common standard formats.

***Figure 4.4.1**: The SWEPOS network as it was in June 2001*

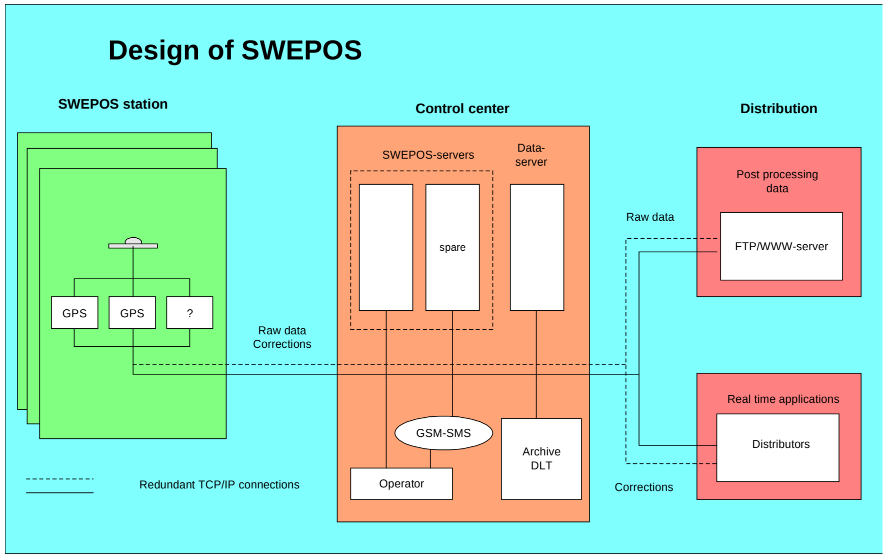


Figure 4.4.2: *Design of SWEPOS*

4.4.3 Localisation

In Fleet Management applications, a system for automatic presentation of vehicle positions is often used. The advantage of using this type of applications is that all kinds of transports can be carried out more efficiently and transports can be supervised. It is also easy to watch over valuable transports and the safety of personnel working alone. Example of users are the ambulance services, bus companies, road transport companies, the postal service, taxis etc.

Two different system principles are used:

Conventional system using an onboard unit for positioning, a transmission link to the dispatch/control centre and a presentation system. The accuracy of the position is most of the time very high, depending on the onboard unit used and the environment.

The onboard unit normally uses GPS, sometimes complemented by a unit for dead reckoning or map matching. The transmission link can be Private Mobile Radio, Mobitex, Cellular Telephone or Satellite (Inmarsat-C).

- Private Mobile Radio (PMR) normally has limited local or regional coverage. Frequencies within the land mobile bands in the 68 to 88, 138 to 174 and 378 to 470 MHz bands are used. Analogue or digital modulation can be used. Trunked systems are common among the larger systems. (In multi-channel systems, the system allocates a free channel to the user on a case by case basis.)

- Packet Radio Systems**.** Data is transmitted in small groups, packets. Charges are based on packets transmitted. The Mobitex network is a public system operating in the 80 MHz band. This network has the largest geographic coverage of all networks in Sweden.

- Cellular Telephone Networks. The GSM networks have wide coverage and are frequently used for requesting and/or transmitting positioning data, very often as SMS.

- Satellite Systems. For example the Inmarsat-C system has global coverage (except the Polar Regions). Text and data can be transmitted at 600 bit/s. Inmarsat-C is a store and forward system. The equipment and antennas are very small and suitable for Vehicle installations.

Cellular system, where the cellular telephone system calculates the position of the vehicles' mobile phone and transmits the position via Internet to the presentation system at the dispatch centre at regular intervals. The cellular system determines the position of the mobile using antenna direction data and the measured time for a signal sent from the nearest base station to, and then returned from the vehicles. Such a service has recently been introduced in Sweden. The accuracy of the position is at present not very high as only one base station is used for the determination of the position. The accuracy depends on the opening angle of the base station antenna and the coverage of the base station.

Industry standard. A group of Swedish companies has established an industry standard for interfacing between the different system units in AFT systems, OVLS (**O**pen Protocols for interfacing **V**ehicle **L**ocation **S**ub-systems). This standard has become an official Swedish Standard. However, most systems in use utilise for cost reasons a simplified subset of this standard or the manufacturers own protocols.

4.4.4 Guidance

Recently a number of services of type "Find nearest resource" have been introduced to GSM users. The resource can be a hotel, a petrol station, a car repair shop, a restaurant etc. It is also possible to get a weather report for the areas where the mobile is located.

This service is accessed via SMS or WAP. A short message is sent to the system with a request for information. The GSM system determines the location of the mobile as described above and then sends a message, which contains the requested information back to the mobile.

4.4.5 User requirements

Accuracy:	
Navigation	30 metres or better horizontally
Localising	100 metre or better horizontally
Data acquisition	for geographic data bases: 2 metres or better horizontally and vertically
Geodetic measurements	relative position accuracy: 1 **-** 2 centimetres (67%) horizontally 0.5 - 4 centimetres (67%) vertically
Availability:	Several user categories require 99.7 %
Integrity:	Time to warning of malfunction of the GPS system varies between 1 and 15 seconds, depending on application.

5 POLICY AND PLANS

5.1 Introduction

5.1.1 Responsibilities in general

Radio navigation systems for aviation and marine applications are normally of a global extent and are handled and negotiated in international organisations like ICAO and IMO. Sweden is represented in these organisations and has to comply with the decisions and regulations submitted.

In Sweden the responsibility for installation, operation and maintenance of navigation systems is delegated from the Ministry level to the authorities concerned. Thus the responsibility for aviation navigation lies with the Swedish Civil Aviation Administration (SCAA) and the Swedish Maritime Administration (SMA) is responsible for all marine navigation matters. Both SCAA and SMA belong under the Ministry of Industry.

The National Land Survey (NLS), the National Road Administration (NRA) and the National Railway Administration are the main interested authorities for land navigation applications and many activities are made in co-operation. In this case no international bodies are yet regulating and controlling the international use as is the case of ICAO and IMO. NLS belongs under the Ministry of Environment while the other two authorities belong under the Ministry of Industry.

The Swedish government authorities all have the unique right to make the final decision to acquire and introduce new navigation systems within their respective field of responsibilities. They also issue regulations and recommendations regarding the use of existing or new navigation systems or equipment. Also private telecom operators – for instance GSM operators have this right to develop mobile communication systems usable also for navigation or localisation purposes.

The Swedish Armed Forces (SAF) have always shown a strong interest in the use of radio navigation and have also been supporting the efforts made by the civil authorities. The Armed Forces Headquarters (HKV) is responsible for plans and policies. The Defence Materiel Administration

(FMV) is responsible for acquisition of weapons and support systems like radio navigation equipment.

The responsibility for the use and allocation of frequencies for navigation and communication systems on a national basis, licence issuing etc is in the hands of the National Post and Telecom Agency (PTS).

The development of navigation and localisation systems and services in Sweden is characterised by close co-operation between industry, government agencies and research institutes at university levels.

The output of this co-operation normally results in services that satisfy the requirements of a broad group of users on a national basis.

There is also close co-operation within the commercial area. The Scandinavian GNSS Industry Council (SGIC) was formed in 1996. It is a Swedish association of companies promoting and producing products and systems for satellite positioning and navigation. The objects of SGIC are to promote commercial development of GPS and communicate to industry, user groups and government agencies by for instance arranging seminars, conferences and workshops and attending international activities on behalf of the members.

The Ministry of Industry, the Ministry of Environment and the Ministry of Defence are the ministries responsible for radio navigation and related areas.

5.1.2 Summary of current activities

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

In Sweden a net of Marine Radio Beacon reference stations have been operational since 1996. The system is operated and monitored by the Swedish Maritime Administration and financed by ordinary shipping fees. Thus there are no direct user fees. The system has been developed in close co-operation with all other Nordic countries with an interest in accurate marine navigation.

Within a densification programme the maritime reference net has recently been expanded into ten stations. The goal that all surrounding waters should be covered by signals from at least two radio beacons is thus obtained. This system now covers all areas of Swedish waters with high accuracy (1-2 m). Together with use of radar, Racons and GNSS transponders in AIS applications the Marine Radio Beacon system will satisfy all the requirements for marine navigation in Swedish and adjacent waters.

The Swedish Network of Permanent Reference Stations (SWEPOS) was established as a collaboration project between National Land Survey and Onsala Space Observatory. The SWEPOS service is designed and financed by a co-operation group of Swedish government agencies and managed by NLS. All services are based on subscription and user fees covering parts of NLS operation costs for the system.

The network – which has been operational since 1998 – and now consists of 21 complete reference stations covering the main parts of the Swedish in-land and coastal waters has come to wide-spread use, mainly for positioning, localisation and navigation. In particular it has been extremely valuable in the core activities of geodetic measurements and map production.

SWEPOS data for Real Time Kinematics (RTK) or post-processing purposes on the centimetre- level are available on the FM radio DARC channel (Ciceron) and by the NLS services WWW/FTP and SWEPOS Web respectively. DGPS data in real-time on the metre-level are available on the FM radio RDS channel (Epos), FM radio DARC channel (Mobipos) and by the global WADGPS service run by the multi-national company Fugro.

5.2 Aviation

The current work is based on a study of future systems initiated by ICAO in 1983 (Future Aeronautical Navigation System – FANS). At that time it was realised that the system architecture of today would not meet the future increased demands for Communication, Navigation and Surveillance. The first phase of the study was completed by 1988. This resulted in the approval of a concept for CNS/ATM ("Communication-Navigation-Surveillance"/"Air Traffic Management"). The second phase, completed in 1993, focused on ATM. This concept is based on a combination of ground-based and satellite-based facilities. The current trend is for a higher degree of dependence on satellite-based systems, like GNSS, and the use of ground-based systems for backup. The objective is that the CNS/ATM concept should be fully implemented by 2010.

A prerequisite for the use of satellite-based facilities is a transition to a global geodetic datum and WGS 84 has been decided, by ICAO, to be the standard to be used in aviation.

5.2.1 RNAV (Area Navigation)

Airborne management systems are increasingly used for navigation purposes to include RNAV functions where the system makes use of multiple sources (based on GNSS, VOR/DME or only DME) to calculate the position of the aircraft.

In such systems, the defined airways are no longer confined to lines between the geographical locations of the ground-based facilities. Thus, the airspace can be used more efficiently, including shortening of airways, without the need for repeated changes in the infrastructure. The first phase was introduced in 1998 with requirements adapted for flights en route. Higher precision requirements for flights in terminal areas will be first introduced in 2002 in Stockholm terminal area.

5.2.2 Satellite-Based Approach and Landing

In 1998 operational tests were started in Sweden, with non-precision approaches based on GPS to the airports at Norrköping and Ängelholm, in co-operation with two airlines. At the end of 1998 additional tests started at Linköping airport, with a third airline involved. These tests have expanded and continued during 1999 and 2000.

The objective is to be able to approve the use of GPS for non-precision approaches, in 2002, at a number of airports.

5.2.3 ADS (Automatic Dependent Surveillance)

The aviation plans for navigation and surveillance include a system named ADS (Automatic Dependent Surveillance).

In ADS, the position of the aircraft, as derived from its navigation system, is transmitted via a link (satellite, VHF link or other means) to the ground for use by the display system in air traffic control. The system can also be used on the ground, for the location of aircraft and vehicles on the runway/taxiway system.

The Swedish development of a GNSS transponder has to some extent contributed to the present differentiation between ADS-B (for broadcast) and ADS-C (for contract). ADS-C is currently used in some oceanic areas with position reports approximately every 5th minute via satellite. ADS-B is in operational use at Stockholm/Arlanda, where the system, developed in Sweden, is used for tracking of snow clearance vehicles on the runways.

5.3 Marine

The maritime sector utilises the available satellite navigation system, GPS, which fulfils the IMO requirement concerning accuracy and availability for general navigation, however without integrity control. As an augmentation, DGPS is provided both nationally and internationally for navigation, surveying, off-shore activities, fishing, fairway service etc. GLONASS is not considered as a fully usable alternative at present.

It is expected that future GNSS will fulfil the requirements of IMO Resolution A 915(22) “Revised maritime policy and requirements for a future global navigation satellite system (GNSS)". Galileo is expected to be the main navigation system together with a modernised GPS.

The Swedish maritime DGPS system, which was established in co-operation with the neighbouring countries, transmits corrections according to the method established by IALA using the RTCM SC-104 Recommended Standards, Version 2.1. The system has recently (Sept 2001) been adjusted to the new frequency plan for the European Maritime Area. The system has also been updated to reach a signal availability better than 99.8 % in the coverage area. Double coverage in the coverage area was achieved by establishing some new stations and relocation of some existing stations. Totally 10 maritime DGPS stations are now in operation in Sweden and no further changes are planned.

In some coastal areas DGPS/RTK service from a private service provider is available via the national VHF radio broadcasting system. This service, which gives centimetre accuracy, is expected to be extended to larger areas.

Navigation using radar is in many areas an important method and SMA will continue to provide racons and radar reflectors at critical positions.

The Swedish Maritime Administration encourage the development of autonomous ship-based systems using for example a combination of radar-based map matching and an inertial system, to be used as an onboard back-up system.

5.4 Land

5.4.1 GNSS-based

To fulfil the need of a network with permanent reference stations for GPS for navigation and positioning mainly for land use, based on a government decision 1995, a co-ordination group for financing and technical detail design has been formed for such a network. The network has been named SWEPOS. The co-ordination group consists of the following governmental agencies: the National Railway Administration, the National Road Administration, the Swedish Civil Aviation Administration, the National Maritime Administration, the Telecommunication Administration and the National Land Survey. The National Land Survey is responsible for both the development and the operation of SWEPOS.

SWEPOS reached IOC-status on the 1st of July 1998, which means that the availability for SWEPOS data for real-time applications with metre accuracy and post-processing applications with centimetre accuracy fulfils a predetermined specification. IOC-status means that the availability for the whole of SWEPOS is specified to 99% on a quarter of a year. The next goal for the availability is 99% for one station every month. The long-term goal is 99.99% for the whole of SWEPOS on one year. To be able to reach that a “Wide Area DGPS” system will be necessary.

User fees for SWEPOS data was introduced on the 1st of July 1997 and the aim is that they will contribute to the operation and upgrades. The National Land Survey has since the turn of the year 95/96 received explicit responsibility in its instruction for establishing and running SWEPOS. A WADGPS concept is under development, which is expected to improve the horizontal accuracy in position from metre accuracy to half metre accuracy. During 2002 SWEPOS is expected to provide a prototype service for navigation/position determination with centimetre accuracy in the parts of Sweden where a need for such a service exists. A map containing all the SWEPOS stations is given in 4.4.1, and an overview of the SWEPOS dataflow is given in 4.4.2.

At the SWEPOS Control Centre today (January 2002) quality checked pseudo range corrections (DGPS corrections), RTK data and double frequency observation data are available every second from all of the SWEPOS stations. DGPS and RTK data are sent directly to the distributors for distribution in real-time to the end users. There are also quality checked complete GPS observation data available for downloading through Internet for postprocessing.

Warning messages, pseudo range corrections and GPS observation data from the SWEPOS network are provided in the recommended standard formats RTCM and RINEX.

In the research and development project NeW-RTK, which was a co-operation between the National Land Survey, Onsala Space Observatory, the Swedish National Testing and Research Institute and Teracom AB, the conditions for a national RTK service were investigated. That developed into several other RTK projects, such as SKAN-RTK (in the southern part of Sweden) and Position Stockholm-Mälaren (around the Stockholm area). In those projects it has been used by Network-RTK for production, and the results have been so promising so there will be new projects at larger areas in the beginning of 2002.

On the Nordic level there is also a co-operation project, “A Nordic Real-time Positioning Service”, in progress. The parts in this project are the Mapping Authorities in Denmark, Norway and Sweden, and the purpose of the project is to investigate the possibilities for a Nordic RTK service.

Today (January 2002) a double frequency GPS/GLONASS receiver is installed in the SWEPOS stations of Kiruna, Mårtsbo, Onsala and Borås. A single frequency GPS/GLONASS receiver is also installed in the SWEPOS station of Visby.

The production of a database with geographical information in a simplified shape, based on the economic map, was finished in 1997. In 1995 a further development and completion of the original version was started. That has resulted in the new product, Geographical Sweden Data, which is described further in the annual Map plan which is published by the Geological Survey, the National Maritime Administration and the National Land Survey.

The National Road Administration has been commissioned to establish a national road database, NVDB, which is a concept for data supply about the whole net of roads in Sweden and certain fundamental characteristics connected to the net of roads. A production centre for the NVDB has been built up at the National Land Survey.

5.4.2 GSM-based

The accuracy of positioning using the GSM system will increase considerably when more than one base-station gets involved in the calculation of the position. It is expected that this will be introduced during the period 2002 - 2003.

The legal requirement in the USA is that it shall be possible to localise all mobile phones with an accuracy of 125 metres. EC will most likely introduce similar requirements or recommendations within one or two years. This is of particular interest to search and rescue organisations.

Systems using combinations of GSM positioning and map matching are under development for various applications.

A number of new services using the possibilities given by GSM positioning will be introduced during the coming years, for example different alarm applications.

New cellular systems like GPRS and UMTS will be alternatives for the link between the mobile unit and the dispatch centre. Iridium and Globalstar will introduce data transmission possibilities in the near future and thus complement Inmarsat-C as a link between the mobile and the dispatch centre when global coverage is required.

5.5 Defence applications

POLICY

The need for high precision navigation, positioning and guidance for different platforms and systems is clearly identified, in particular in the future concept of “Network-Based Warfare”.

Using Global Navigation Satellite Systems (GNSS), it is possible to accomplish these demands and on top of that, GNSS are very cost effective compared with other methods such as Inertial Navigation Systems (INS). GNSS, however, are highly vulnerable for intentional jamming and should not be used as a stand-alone system for navigation, positioning and guidance.

The Swedish Defence policy using GNSS is:

- GNSS shall not be used as a stand-alone system and shall be looked upon as an add-on system to other navigation techniques.
- Traditional navigation skills shall be maintained
- It shall be possible for the user to have quality and integrity control of the output from a GNSS receiver.
- Wherever possible, preparation for P (Y) code receivers shall be made.
- Procurement of GNSS receivers shall be by FMV or through industry agreements signed by DMA.

LAND APPLICATIONS

<u>Today</u>
Today GNSS are used widely, mainly for navigation integrated with INS and Dead Reckoning (DR) systems.

For some applications in the artillery and in air defence units, terrestrial surveying methods are used for location and bearing determination. For more accurate mobile platforms such as mortars, long range artillery and observation post vehicles, INS and highly accurate reference geodetic points are used.

Tomorrow

The effort of spreading integrated navigation systems to low-end users (light vehicles, foot soldiers) continues. The development of smaller, cheaper, less power consuming inertial sensors is interesting for positioning and bearing determination.

NAVAL APPLICATIONS

Today

Naval surface units use mainly radar, GPS and DGPS as add-on systems to the on-board DR systems (gyro compasses, log). Hyperfix still serves as a back up system.

For sub-surface vehicles the primary navigation system is INS supported by GNSS whenever it is available.

For safety of life applications, e.g. handling and clearing of mines, other HF radio navigation systems can be used.

Tomorrow

Generally there is a trend towards increased use of INS as a main navigation system integrated with other sensors. Decca Navigator has been taken out of use and Hyperfix is being used only as a back up system until all installations are taken out of service.

Increased use of the transponder system based on GPS for identification and short message communication is foreseen. It is also possible that the transponder system will be extended to other functions than positioning and navigation.

MILITARY AVIATION

Today

Swedish Military Combat Aircraft (AJS 37 VIGGEN and JAS 39 GRIPEN) use INS or Doppler radar (DN) for regular navigation. Position updates are usually made optically or with radar.

Training and command aircraft use the civil NDB, VOR and DME systems while transport aircraft additionally use INS. Rescue helicopters use INS and DN integrated with DME and GPS as basic navigation system.

As a landing system, the AJS 37 VIGGEN and the JAS 39 GRIPEN use Tactical ILS (TILS), a microwave system designed exclusively for military purposes. Training, command and transport aircraft employ civil ILS for landing on civil airports and military airports equipped with ILS.

All military types of aircraft are equipped for radio communication and have the possibility of communication with the Air Traffic Control (ATC) functions in order to get flight information based on a ground-based radar (PAR) for precision landings, Cat I. For bad weather conditions the VHF direction finder (VDF) system is still in use for in-flight fixes and landings at military airports.

<u>Tomorrow</u>
A continued use of INS can be predicted, as well as a need to be able to combine or complement this with TERNAV, Terrain navigation, or GPS/DGPS.

Two systems for JAS 39 GRIPEN are under development. NINS, New Integrated Navigation System, and NILS, New Integrated Landing System. Both systems are based on INS and TERNAV. It will be possible to integrate GPS and DME as complements in NINS.

All non-combat aircraft, as well as rescue helicopters and transport aircraft will most likely be equipped with GPS receivers as a complement to already existing equipment.

Future use of existing systems like NDB, VOR and DME is co-ordinated by ICAO and depends on needs in international civil aviation.

The military landing system, TILS, and the civil ILS is expected to stay in use for several years. All radar landing systems have been modified and equipped with modern electronics and are expected to remain in use until 2005. The military VHF direction finder (VDF) is expected to stay in use until 2007 as a complement to other systems.

5.6 International Cooperation

5.6.1 Aviation

SCAA co-operates with several international organisations, where ICAO (International Civil Aviation Organisation), a UN specialised organisation, represents the foundation for agreements and rules for aviation in a global perspective. Other organisations are ECAC (European Civil Aviation Conference) focused at transport politics, EUROCONTROL, with several departments engaged mainly in matters related to air traffic control, and JAA (Joint Aviation Authorities) dealing with flight safety and certification.

Following Sweden's joining the European Union (EU), their law-making functions have become an important part influencing aviation matters, through the Directorates (DG) of the Commission, in the development of areas such as economy, environment, technique and competition.

Apart from the international organisations, with their rules and directives that directly affect the services and products of SCAA, co-operation takes place with representation from various specialised areas including airport management.

5.6.2 Marine

In the maritime area works three major international organisations, IMO, IHO and IALA. IMO (International Maritime Organisation) is a UN agency dealing mainly with safety related issues. IHO (International Hydrographic Organisation) is an inter-governmental consultative and technical organisation working with the requirements for surveying and the standardisation of nautical charts. IALA (International Association of Marine Aids to Navigation and Lighthouse Authorities) develops recommendations and proposes standards for radio navigation, AIS, lighthouses and other Aids to Navigation in the maritime area.

On a regional basis EMRF (European Maritime Radio navigation Forum) is a focal point for maritime interest in radio navigation matters. For the future the European Union is expected to have an important role for co-operation and harmonisation of European radio navigation services.

The implementation of the marine DGPS service has been co-ordinated bilaterally with the neighbouring countries.

5.6.3 Land

For navigation applications on land there are no international co-operative organisations that cover the whole field.

Questions regarding reference systems, data format for post-processing applications and GPS technique are treated in working groups / committees within the International Association of Geodesy (IAG).

For design of the reference stations the National Land Survey together with Onsala Space Observatory are members of the International GPS Service (IGS). The National Land Survey also takes an active part in the Nordic Commission of Geodesy (NKG), where there is a working group that works with questions about establishment and running of permanent reference stations for GPS. The National Land Survey has also regular contacts with their brother organisations in other countries regarding GPS technique and reference stations for GPS.

For the practical production of databases for geographical information there is a certain co-operation within Eurogeographics, which is a co-operative organisation between the map producing authorities in Europe.

An extensive standardisation work is going on within the standardisation projects CEN/TC 287 and ISO/TC211. Among others there are a description model for geodetic reference systems and a format for transfer of GPS data.

For the railway working area there is an international co-operation within UIC (International Union of Railways), with among others the work with ETCS and GSM-R. The National Railway Administration is taking an active part in their work and has also a co-operation with the Railway Administrations in the other Nordic countries.

6 SUPPLEMENTS

6.1 List of abbreviations

ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-C	Automatic Dependent Surveillance – Contract
AFT	Automatic Fleet Tracking
AIS	Automatic Information System
ARGOS	Advanced Research and Geographic Observation Satellite
ATC	Automatic Traffic Control
ATC	Automatic Train Control
ATM	Air Traffic Management
CNS	Communication-Navigation-Surveillance
COS	Continuity of Service
COSPAS	Cosmicheskay Sistyema Poiska Avariynich Sudov (Space System for the Search of Vessels in Distress)
DARC	Data Radio Channel
DGPS	Differential Global Positioning System
DMA	Defence Mapping Agency
DME	Distance Measuring Equipment
DoD	Department of Defence (USA)
DoT	Department of Transport (USA)
DR	Dead Reckoning
ECAC	European Civil Aviation Conference
ECDIS	Electronic Chart Display and Information System
EGNOS	European Geostationary Navigation Overlay System
EMRF	European Maritime Radio navigation Forum
EUREF 89	EURopean REFerence System –89
FANS	Future Aeronautical Navigation System
FMV	Defence Materiel Administration
GLONASS	GLObal Navigation Satellite System
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSD	Geographical Data Sweden
GSM	Global System for Mobile Communication

GSM-R	Global System for Mobile Communication – Railway
HKV	Armed Forces Headquarters
IAG	International Association of Geodesy
IALA	International Association of marine aids to navigation and Lighthouse Authorities
ICAO	International Civil Aviation Organisation
IGS	International GPS Service for geodynamics
IHO	International Hydrographic Organisation
ILS	Instrument Landing System
IMO	International Maritime Organisation
INMARSAT	International Maritime Satellite Organisation
INS	Inertial Navigation System
IOC	Initial Operation Capability
IRS	Inertial Reference System
ITRF	International Terrestrial Reference Frame
JAA	Joint Aviation Authorities
LORAN	LOng Range Navigation System
NDB	Non-Directional Beacon
NILS	New Integrated Landing System
NINS	New Integrated Navigation System
NKG	Nordic Commission of Geodesy
NLS	National Land Survey
NRA	National Railway Administration
NVDB	National Road Administration Data Base
OVLS	Open protocols for interfacing Vehicle Location Sub-systems
PAR	Precision Approach Radar
PAR	Precision Approach Radar
PMR	Private Mobile Radio
PTS	National Post and Telecom Agency
RDS	Radio Data System
RH70	Swedish height system
RINEX	Reciever INdependent EXchange format
RNAV	Area Navigation
RNN	Swedish Board of Radio Navigation
RNP	Required Navigation Performance
RT 90	Swedish plane reference system
RTCM SC	Radio Technical Commission for Maritime Services Special Committee

RTK	Real Time Kinematic
RVR	Runway Visual Range
SAF	Swedish Armed Forces
SARSAT	Search And Rescue Satellite Aided Tracking
SAS	Scandinavian Airline System
SBAS	Satellite Based Augmentation System
SCAA	Swedish Civil Aviation Administration
SGIC	Scandinavian GNSS Industry Council
SMA	Swedish Maritime Administration
SMS	Short Message Service
SWEPOS	Swedish network of fixed reference stations for GPS
SWEREF 93	SWEdish REFerence System –93
TERNAV	TERrain NAVigation
TILS	Tactical Instrument Landing System
TN	Inertial Navigation
UIC	International Union of Railways
UMTS	Universal Mobile Telecommunication System
WADGPS	Wide Area DGPS
WAP	Wireless Application Protocol
VDF	VFH Direction Finding
VDL	VHF Digital Link
WGS 84	World Geodetic System 84
VOR	VHF OmniRange
VTS	Vessel Traffic Service