SWEDISH RADIO NAVIGATION PLAN

POLICY AND PLANS

2009

SWEDISH MARITIME ADMINISTRATION

RNP 2009

POLICY AND PLANS

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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Summary

The Swedish Radio Navigation Plan 2009 gives a short overview of the radio navigation systems that are available or expected to be available for use in Sweden, describes the user requirements and the actual and expected use of the different systems by different user groups. The plan also presents the policies and plans regarding radio navigation services from the different service providers in Sweden, which are mainly governmental administrations, responsible for different areas that require support from radio navigation systems. The use of radio navigation systems to accurately determine time and frequency is also described.

The plan is published by the Swedish Maritime Administration, which is responsible for compiling and publishing the plan by government decision. The Swedish Radio Navigation Plan is published in two separate documents, entitled: “Swedish Radio Navigation Plan, Policy and Plans” and “Radionavigeringsplan för Sverige, Systembeskrivning”. The first document is published in English to facilitate the necessary international co-operation and co-ordination of radio navigation matters. The second document is published in Swedish and gives a more detailed description of systems used or available for use in Sweden.

1 Introduction

There is a strong 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. The need for such a document has grown at pace with the availability of more and more accurate and reliable navigation aids and the necessity of increased international co-operation in this field.

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 of the Swedish Government the Swedish Maritime Administration (SMA) was later given the official responsibility for the continued work with the plan. RNN was tasked to proceed with the updating work and so a new thoroughly revised version of the plan was developed by RNN and officially published by SMA in 1997. The plan is to be updated every third year and the previous edition was published in 2006.

The Swedish Board of Radio Navigation is an association of representatives from mainly government authorities and institutions but 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 a forum for discussions and opinions and to keep its members informed of the general development and progress within the area of radio navigation. The Board represents highly qualified members normally engaged in the handling of technical matters or high level management covering the entire field of aviation, marine, land and military navigation and positioning applications. Thus the organisation has the necessary competence needed for 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 and timing aids available for use in Sweden and its surroundings together with a short technical description of the function of each system, its general use and expected future development.
2. A survey of the development taking place in Sweden and the policy and plans of the authorities, organisations and companies responsible for meeting the requirements in general.

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

Focus lies 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. From a system point of view no difference is made between navigation and positioning. The accuracy figures given are normally specified as 95 % probability values if not otherwise stated.

2 Available navigation systems

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

Terrestrial systems

Common systems

System	Administration Responsible	Users in Sweden	Estimated lifetime	Comments
Loran-C	International	Aviation, Marine, Land	-2015	Uncertain forecast
Chayka	Russia	Aviation, Marine, Land	>2015	Uncertain forecast

Systems for aviation

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

Systems for maritime use

System	Administration Responsible	Users in Sweden	Estimated lifetime	Comments
Fixed direction finders	SMA	Marine	<2015	For direction finding from shore
Racons	SMA	Marine	>2020	Support system for radar

Systems for land navigation/positioning

System	Administration Responsible	Users in Sweden	Estimated lifetime	Comments
GSM	Commercial	Land	>2020	Communication/ Localisation
GSM-R	Railway Administration	Land	>2020	Communication/ Positioning
ERTMS	Railway Administration	Railway use	>2020	
UMTS	Commercial	Land	>2020	Localisation/ Positioning

Onboard systems

System	Administration Responsible	Users in Sweden	Estimated lifetime	Comments
Navigation radar		Aviation, Marine,	>2020	
Map-matching		Land, Aviation	>2020	
Doppler navigation		Aviation	>2015	Special craft usage

Satellite based systems

System	Administration Responsible	Users in Sweden	Estimated lifetime	Comments
GPS	USA (DoD/DoT)	Multimodal	>2020	Operational but developing
GLONASS	Russia	Multimodal	>2020	At present reduced constellation. Full constellation expected 2010-11.
GALILEO	EU	Multimodal	2014->	No final decision
COSPAS/SARSAT	International	SAR	>2020	
ARGOS	International	Marine, Land, Research	>2015	
ORBCOMM	International	Marine, Land	>2015	Communication system with navigation facility

Support and augmentation systems

System	Administration Responsible	Users in Sweden	Estimated lifetime	Comments
ECDIS	SMA/IHO/IMO	Marine	>2020	Standard for Electronic Nautical Charts and presentation system
INMARSAT	International	Aviation, land, marine	>2020	Communication system
Transponder – VDL	SCAA	Aviation	2003->	Localisation
Transponder – AIS	SMA/IMO	Marine	>2020	Collision avoidance
Epos	Commercial	Land, Marine	>2011	DGPS service
EGNOS	ESA/EU	Multimodal	2003->	Operational
OmniSTAR/SeaSTAR/StarFIX	Commercial	Multimodal	>2010	WADGPS
Radio Beacon DGPS	SMA	Marine	>2020	DGPS
Skyfix/ Genesis/DeltaFix	Commercial	Multimodal	>2010	WADGPS
LuLIS	SAF	Land, Marine	>2010	DGPS, military

3 User requirements and systems normally used today

3.1 Requirements in general and concepts used

The purpose of this chapter 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 application areas are the following:

In the air: En route, approach and landing

At sea: General navigation, precision navigation and positioning

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 provide full coverage 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. It must also meet the requirements with respect to accuracy, safety, reliability and user-friendliness.

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 reference points, aerial photography, machine guidance and in geodetic and land survey measurements. Particularly 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 as follows:

Positioning is the technique to determine the position of the user in a defined (specified) reference system

Localisation means the remote acquisition of user position

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

3.2 Aviation

3.2.1 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.

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

3.2.2 User 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 (RNAV 5) in the horizontal plane. In view of the much higher traffic intensity expected in future airspace, it is anticipated that the requirement will increase over the coming years to less than 1 nautical mile (RNAV 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. Determination of the aircraft position in the vertical plane requires an accuracy of approximately 50 metres.

At approach and landing 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 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	~1 m	~ 1 m	~ 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	3.2.2.1 Accuracy
ILS LLZ (localizer, no glide path)	± 10.5 m
VOR	± 3 °
NDB (airborne part of equipment)	± 3 °

3.2.3 The PBN 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, and currently work is organized within Eurocontrol to refine this into a Performance Based Navigation Concept, to define requirements for navigation capability. Rather than requiring a certain type of equipment, PBN requires that the user is able to navigate with a defined level of performance within a certain airspace. PBN is a set of parametres describing, among other characteristics, the maximum allowed lateral deviation from an assigned or chosen airway and also the deviation along the airway. PBN for en-route flights generally includes a maximum deviation of 5 NM. For dedicated areas higher levels of precision may be defined.

Thus, PBN is a requirement for capability to navigate related to a defined flight path and at any time during the flight. For approach, landing and departure phases, PBN includes 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 PBN for approach, departure and landing phases is on-going and partly approved by ICAO.

Requirements are put on the user and the systems or combination of systems used, in order that they fulfill 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.

3.3 Marine

3.3.1 General

Radio navigation is used for navigation on the open sea in Swedish waters, where an accuracy of 100 m is adequate, and in the archipelagos, which requires precision navigation with an accuracy of 1-10 m. Besides optical aids to navigation and radar, GPS and DGPS are used. Positioning for hydrography, marine engineering, maintenance of Aids to Navigation etc requires an accuracy of 0.1 – 1 m.

For the maritime users the Swedish Maritime Administration has established a network of reference stations for GPS, which transmits DGPS corrections and integrity information according to RTCM SC 104 version 2.1 in 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.

Updated information on available DGPS station can be found on the IALA website http://www.iala-aism.org.

For use in the coastal area two different commercial services available: - The DGPS service Epos available r via the national FM radio broadcasting network.

- The SWEPOS RTK-network service for high precision applications, available via Internet or GSM/GPRS

The use of DGPS enables accurate radio navigation in restricted waters and archipelagos, but an equally important factor is the integrity information which provides a warning if the expected position error exceeds a preset value. The safety of navigation is increased by presenting the position in an Electronic Nautical Chart 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 AIS and/or radar and communicates with the VTS by VHF radio. Ships equipped with AIS can be automatically identified and tracked on a suitable display in the VTS and onboard other ships. A network of AIS base stations covers all Swedish waters. An exchange of AIS information with all coastal states around the Baltic is in operation since July 2005. The information exchange is expected to be further extended to include all European sea areas due to an initiative by EMSA.

3.3.2 User 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 significant level of risk a position 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 less 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.

3.4 Land

3.4.1 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, fast changes of speed and directions are common. The navigation system should be able to work accurately in such environments and difficult conditions.

Before GPS became operational, there were no reliable radio navigation systems with nation-wide coverage available. The introduction of GPS for navigation and positioning has increased the efficiency in many applications on land.

For navigation on land, GNSS is the only system with full nationwide coverage. In several applications navigation or positioning using GPS only is sufficient. In many applications, however, additional methods must be used to increase accuracy and availability, such as INS, odometre and gyros for dead reckoning and/or map matching.

An additional feature of GNSS is that very accurate time can be derived from the satellite signals, thus making time synchronisation possible between locations very far apart.

3.4.2 Positioning

The use of satellites for positioning has increased the possibility to determine the position at centimetre level over really long distances, up to hundreds of kilometres. This means great benefits for e.g. aerial photography, connection of cadastral surveying and local reference systems to the national reference system and data capture for Geographic Information Systems (GIS). The GPS technique has been used routinely for several years for local surveying and for surveying of geodetic control networks. The costs have decreased significantly and the quality has sometimes increased for these applications. Machine guidance is one of the latest applications, now routinely utilised.

To improve the accuracy obtained from GPS, relative measurements are required. To facilitate this for land applications in Sweden a network of permanent reference GPS stations, SWEPOS®, was established during the nineties. Since 1st of July 1998 SWEPOS is operational in IOC mode, i.e. for positioning in real-time with metre level accuracy and by post-processing with centimetre level accuracy. The 21 first of the SWEPOS stations are mounted on bedrock and have redundant equipment for GNSS observations, communications, power supply etc. These stations are the basis of the Swedish national reference frame, SWEREF 99, which via the European system EUREF 89 is connected to the global ITRF (International Terrestrial Reference Frame). Another 12 SWEPOS stations (September 2009) are mounted on bedrock and have redundant equipment in the same amount as the 21 first station. These kinds of stations are classified as "Class A-Stations", the best kind of reference stations for GNSS (a work performed by the Nordic Commission of Geodesy in 2005). Another 145 (September 2009) stations are mostly located on top of buildings and have less redundant equipment and are classified as "Class B-Stations". The main task for these stations is to provide data to a regional positioning service for positioning in real-time with centimetre level accuracy (SWEPOS Network RTK service).

SWEPOS is providing data for a number of different applications, from positioning with metre accuracy in real-time, e.g. for navigation support, to studies of crustal movements (geophysical research) at millimetre level in post-processing mode. SWEPOS is developed and operated by Lantmäteriet.

Data from the SWEPOS network is available to the end user via the following services:

- Post-processing data in RINEX format through a WWW/FTP service
- Automatic Computation Service on the SWEPOS web
- The DGPS service Epos operated by Teracom AB. The corrections are broadcast in RTCM format via the RDS channel on the FM network, channel P4. The accuracy of the service is approximately 1 metre.
- SWEPOS Network RTK service – a nationwide service for positioning in real-time. The accuracy of the service is a few centimetres.
- SWEPOS Network DGNSS service – a nationwide service for positioning in real-time. The accuracy of the service is approximately 0.3 m in horizontal position.

The production of all Swedish official topographic and general maps is now totally based on the use of automated methods. This means that all objects shown on the maps are available in digital vector-based geographic databases. The official maps themselves are not only available in printed form but also as digital high-resolution raster maps. All this digital material can be and is already to quite some extent used for navigational purposes in particular in combination with GPS positioning. Typical applications are navigation in aerial photography and surveillance and navigation of taxi and emergency fleets. The official digital land maps and data are produced by Lantmäteriet and are open for use for the whole country.

3.4.3 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 monitor valuable transports and the safety of personnel working alone. Examples of users are the ambulance services, bus companies, road transport companies, the postal service, taxis etc.

Two different system principles are used:

***Conventional system* -** the system is 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. GPRS is used more and more frequently due to good performance and lower cost compared with 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 vehicle’s 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. The accuracy of the position is at present around 300 m in urban, 1-2 km in suburban and 5-10 km in rural areas. Such a service has recently been introduced in Sweden. The accuracy of the position is at present not very high since only one base station is used for determining the position. The accuracy depends for instance on the opening angle of the base station antenna and the coverage area of the base station or the density of base stations.

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. The international LIF/OMA MLP (Mobile Location Protocol) is widely used in both mobile positioning and A-GPS.

However, for cost reasons most systems in use utilise a simplified subset of this standard or the manufacturer’s own proprietary protocols.

Emergency services. The United States of America has instituted a Federal Regulation, US E911 FCC Regulation, which stipulates that "As of October 1, 2001, licensees subject to this section must provide to the designated Public Safety Answering Point the location of a 911 call by longitude and latitude within a radius of 125 metres using root mean square techniques."

A corresponding effort is made in Europe where the European Commission has constituted a group, E112 CGALIS, which is short for the Co-ordination Group on Access to Location Information by Emergency Services. Included in the group are system vendors and Public Safety Answering Point Operators. An EU directive has been issued and is under implementation in member states. There is no mandatory requirement for GNSS-functionality in the mobile phones for emergency services. The discussions in the group indicate that there will be no mandatory requirement for GNSS-functionality in the mobile phones based on emergency service needs only. Positioning based on Cell-ID will be the basic requirement and higher accuracy will be provided when deployed for commercial reasons.

3.4.4 Guidance

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 phone is located.

This service is accessed via SMS or WAP-portals. For example, 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 to the mobile, containing the requested information. information.

An other trend is in e.g. Google Maps where the application asks a 3rd party company of the location of a GSM cell. That information has earlier been provided by one or users collecting the relationship between own GPS coordinates and the GSM cell plan

3.5 Time and frequency

3.5.1 GNSS

Global Navigation Satellite Systems are the dominating technique providing dissemination of time and frequency. Today GNSS combines low cost with high accuracy but suffers from the lack of integrity information. Wide Area Augmentation Systems (WAAS and EGNOS) add reliability to the services existing today (GPS and later, probably GLONASS). The potential of the modernized GPS and new services such as GALILEO and COMPASS will involve both better reliability and higher accuracy as today.

3.5.2 Satellite broadcast

Even though basically all communication satellites have the capability to provide time, the total number of users (and services) has decreased since GPS became operational. The Two Way Satellite Time and Frequency Transfer (TWSTFT) technique is the most accurate method today but suffers from lack of availability and a high cost. Thus, the technique is only useful for high-accuracy applications such as direct comparisons between atomic clocks hosted at National Metrology Institutes as SP Technical Research Institute of Sweden.

3.5.3 Low Frequency (LF)

Even though many transmitters exist today there is continuous discussion on whether all these systems are required today. The future existence of the LF-broadcast systems in general is not clear. However, due to technical reasons the most commonly used LF transmitter in Sweden is DCF77 in Germany and the future of DCF77 has not been questioned up to now. Due to limitations in coverage, the LF systems should be used with care in critical applications. There are currently no Swedish plans to develop LF-broadcast services for time and frequency dissemination.

3.5.4 Other systems

GNSS, Satellite broadcast and LF-transmitters are all radio-based systems which can be jammed. The Swedish Post and Telecom Agency (PTS) monitors the electronic communications and postal sectors and in order to increase the robustness of time distribution in Sweden PTS has financed a project to investigate the possibility to use the data already transmitted in optical fibre networks, and recover the time information from this data. The technique is based on passive listening to existing data traffic on the Internet and will be installed between high priority clock centres in Sweden as a complement to time dissemination methods using GNSS.

3.5.5 Network Time Protocol, NTP

For time dissemination to computers the Network Time Protocol is widely used. NTP is running on any computer platform and is used to synchronize computers over the Internet. Time over NTP is provided by time servers and there are numerous NTP-servers all over the world, see www.ntp.org.

As to provide robust and correct time, SP as a National Metrology Institute co-operates with Netnod Internet Exchange in Sweden AB on the installation and operation of NTP-servers at three Swedish Internet Exchange Points. Clock systems are placed in Stockholm, Göteborg and Malmö and are all placed in well protected under ground laboratories. Each clock system supports two NTP-servers which gives time as a free service and a part of the infrastructure for Internet in Sweden directly traceable to UTC (SP).

The Internet addresses for the servers are:

Göteborg:	ntp1.gbg.netnod.se
	ntp2.gbg.netnod.se
Stockholm:	ntp1.sth.netnod.se
	ntp2.sth.netnod.se
Malmö:	ntp1.mmo.netnod.se
	ntp2.mmo.netnod.se

The availability and correctness of the servers are continuously monitored by SP and are presented at http://www.sp.se/en/index/services/time_sync/ntp/server/Sidor/default.aspx

At present SP offers an authenticated NTP-service that uses NTPv4 auto key (IFF identity scheme). The service is under evaluation during 2009 and is expected to be officially launched during 2010. The address to the server which only answers by authenticated NTP-packets is: ntp3.sp.se

4 Policy and plans

4.1 Responsibilities in general

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 all modes of transport lies with the Swedish Transport Agency with respect to regulation, operational requirements and certification.

The responsibility for service provision lies with the LFV Group and the Swedish Maritime Administration (SMA) for aviation and marine navigation matters respectively. Both LFV and SMA belong under the Ministry of Industry, Employment and Communications. Lantmäteriet (the National Land Survey), the National Road Administration (NRA) and the National Railway Administration are the main 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. Lantmäteriet belongs under the Ministry of Environment.

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 commercial 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) has always shown a strong interest in the use of radio navigation and has 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 the 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, license 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 level.

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

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

It is of vital importance to consider and assess the vulnerability and risks of using satellite navigation systems. The extremely low power levels of the satellite signals make them very susceptible to accidental or malicious interference. The reliance especially on GPS is increasing in all types of positioning, navigation and timing. For the safety of the whole of the transport sector it is of great importance to consider all possible areas of vulnerability. The Swedish authorities responsible for delivering navigation services in Sweden are aware of these problems and plan to make allowance for measures to reduce or mitigate such effects, also in consideration of the need to maintain adequate national security levels.

4.2 Aviation

4.2.1 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 as a primary source, the aim is, in accordance with international agreements, to replace this with augmentation for GNSS (DGPS using type certified equipment), while the DME/DME coverage en route is refined for back-up purposes. Extensive testing, and further development, based on use of GPS for applications in airspace and for ground movement control, is carried out by the LFV Group in co-operation with industry and airlines together with participation from other European countries. The introduction of augmentation systems to GNSS is expected to facilitate future air traffic control and make it more efficient.

4.2.2 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 were first introduced in 2002 in Stockholm terminal area. A number of new DME stations have been installed in the area to achieve the required precision. In the next years a number of new DME stations in Sweden are planned, and the VOR network is expected to be obsolete in 2015.

4.2.3 Satellite-Based Approach and Landing

A few airports now have received approval for the use of GNSS for non-precision approaches. A plan for full implementation of PBN, including approach procedures based on GNSS, is under development and will be delivered to ICAO by the end of 2009.

4.2.4 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 use at Stockholm/Arlanda for tracking of vehicles on the runways. Trials are currently performed at Kiruna and Stockholm/Arlanda with ADS-B ground stations using VHF data links (VDL) for air traffic services. Approximately 20 ADS-B stations with DGPS reference are planned across Sweden to be implemented by 2010, mainly at larger airports.

4.3 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. DGPS increase accuracy and provide integrity information to GPS users. GLONASS is not considered as a fully usable alternative at present.

It is expected that future GNSS will fulfill 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 neighboring countries, transmits corrections according to the method established by IALA using the RTCM SC-104 Recommended Standards, Version 2.1. The system has been adjusted to the new frequency plan for the European Maritime Area. The system has also been updated to reach 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 11 maritime DGPS stations are now in operation in Sweden. Studies are performed to develop a concept for future DGNSS. This may include corrections for new GNSS and improved accuracy.

In most coastal areas is a network RTK service available commercially. This service, which gives centimetre accuracy, is used for high precision applications, such as dynamic under keel clearance measurement.

Navigation using radar is in many areas an important method and SMA will continue to provide racons and radar reflectors at critical positions. However, after the decision by IMO (MSC79 resolution 192(79) to remove the requirement on S-band radar to activate racons. the racon service will in the foreseeable future, not be available or impaired for ships using so called “New Technology” radar in the S-band.

The Maritime Department of The Swedish Transport Agency and the Swedish Maritime Administration are participating in the work on the IMO-initiative “e-Navigation”. It is proposed that e-Navigation would require the introduction of a backup-system to GNSS. A candidate system is e-Loran, presently under test by some foreign administrations. The Swedish administrations are monitoring the development.

The Swedish Maritime Administration encourages 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.

4.4 Land

4.4.1 GNSS-based

GPS is currently the only nationwide reliable system available for navigation, localisation and positioning on land. To improve the accuracy received from GPS in land applications in Sweden, a network of permanent reference stations for GPS, SWEPOS, was established during the nineties, in co-operation between Lantmäteriet, Onsala Space observatory and a group of governmental agencies and state companies. Lantmäteriet is operating, monitoring and developing SWEPOS. All services are based on subscription and user fees cover part of the operation costs of the system.

Since 1st of July 1998 SWEPOS is operational in IOC mode, i.e. for positioning in real-time with metre level accuracy and by post-processing with centimetre level accuracy. The availability of 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% for a quarter of a year. The long-term goal is 99.99% for the whole of SWEPOS for one year. Warning messages, pseudo-range corrections and GPS observation data from the SWEPOS network are provided in the recommended standard formats RTCM and RINEX.

Between 2000 and 2002 a number of additional SWEPOS stations were established for regional positioning services with centimetre level accuracy. At 1st of January 2004 those regional areas formed the service SWEPOS Network RTK service. Since then the area included has grown and since the summer of 2009 it has become a nationwide service with full coverage of

Sweden. A cooperation concerning exchange of data along the borders to Norway and Finland with SATREF (Norwegian Mapping Authorities) and GPSNet.fi (Geotrim OY) has also started and is working well.

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

4.4.2 Cellular phone based

Positioning by means of cellular phone systems will increase considerably when implemented in 112 emergency systems due to EU regulations.

Systems using combinations of GSM positioning and map matching were introduced in 2005 (e.g. Wayfinder, Wisepilot etc) and 2007 with Google Maps

Cellular systems like GPRS on 2G or 3G/UMTS has such a stability that they can serve as the link between the mobile unit and the control centre. Iridium and Globalstar has data transmission possibilities and thus complement Inmarsat-C as a link between the mobile and the control centre when global coverage is required.

4.5 Time and frequency

Section 4.5 from Radio Navigation plan 2006

4.5.1 GNSS

Global Navigation Satellite Systems are already the dominating technique providing dissemination of time and frequency. Today GNSS combines low cost with the highest accuracy but suffers from the lack of integrity information. Wide Area Augmentation Systems (WAAS and EGNOS) add reliability to the services existing today (GPS and later, probably GLONASS). The potential of the modernized GPS and new services such as GALILEO involves both better reliability and higher accuracy.

4.5.2 Satellite broadcast

Even though basically all communication satellites have the capability to provide time, the total number of users (and services) has decreased since GPS became operational. The Two-Way Satellite Time and Frequency Transfer (TWSTFT) technique is the most accurate method today but suffers from lack of availability and a high cost. Thus, the technique is only useful for high-accuracy application such as direct comparisons between atomic clocks hosted at National Metrology Institutes.

4.5.3 Low Frequency (LF)

Even though many transmitters exist today there is continuous discussion on whether these systems are required today. Sometimes this becomes a political issue since countries feel the obligation to continue to run a system even though it only has a few users. The future existence of the LF-broadcast systems is not clear. Due to the limited coverage, the LF systems could only be used as a complement to others. There are currently no Swedish plans to develop LF-broadcast services for time and frequency dissemination.

4.5.4 Other systems

In addition to GNSS-based time dissemination recent development includes distribution methods over communication and computer networks. Network Time Protocol (NTP) running on any computer platform is commonly used to synchronize computers over the Internet. For more demanding applications the methods of two-way transfer (similar to TWSTFT) over optical fibers could be applied. Swedish research projects are currently undertaken to investigate the possibilities of this technique.

4.6 Defence applications

4.6.1 Policy

The need for high precision navigation, positioning and guidance for different platforms and systems is clearly identified.

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. USA and NATO has defined the concept Navigation Warfare and if the Armed Forces should be able to join a USA or NATO led operation there can be a need of military receivers (PPS-receivers)

The Swedish Armed Forces 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.
- Military GPS (PPS) should be used by rapid reaction units, weapon systems, qualified platforms and where there is an Electronic Warfare threat against civil GNSS.
- Civil GNSS should be used under peacelike circumstances, training etc.
- The user should be able to check the quality of position and shall understand the effect on the platform if the position is degrading.
- Procurement of GNSS receivers shall be by FMV or in consultation with FMV.

5 International co-operation

5.1 Aviation

SCAA participate in the work of several international organisations, where ICAO (International Civil Aviation Organisation) represents the foundation for agreements and rules for aviation in a global perspective. Other organisations are ECAC (European Civil Aviation Conference) focused on transport politics, EUROCONTROL, with several departments engaged mainly in matters related to air traffic control, and EASA (The European Aviation Safety Agency) dealing with rulemaking for flight safety, certification and air traffic services.

The European Union (EU) law-making functions are an important part influencing aviation matters, through the Directorates (DG) of the Commission, in the development of areas such as economy, environment, technique, services and competition.

5.2 Marine

There are three major international organisations - IMO, IHO and IALA - in the maritime area. 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 with the development of the European Radio Navigation Plan (ERNP). Further on, the European Union, and its safety agency EMSA, will have a big influence on the requirements on radio navigation for shipping in European waters.

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

5.3 Land

Section 5.3 from Radio Navigation plan 2006

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 GNSS technique are treated in working groups / committees within the International Association of Geodesy (IAG).

For design of the reference stations Lantmäteriet together with Onsala Space Observatory are members of the International GNSS Service (IGS). Lantmäteriet 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 operation of permanent GPS reference stations. Lantmäteriet has also regular contacts with its 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 co-operation within Eurogeographics, which is a co-operative organisation between the map producing authorities in Europe.

For the railway working area there is an international co-operation within UIC (International Union of Railways) and EIM (European Rail Infrastructure Managers), with among others the work with ERTMS (European Railway Traffic Management System) 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 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	Air Traffic Control
ATM	Air Traffic Management
BIPM	International Bureau of Weights and Measures
CGALIS	Co-ordination Group on Access to Location Information by Emergency Services
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
DG	Directorate of the Commission
DGPS	Differential Global Positioning System
DMA	Defence Mapping Agency
DME	Distance Measuring Equipment
DN	Doppler Navigation
DoD	Department of Defence (USA)
DoT	Department of Transportation (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
Epos	Commercially operated DGPS service
ERNP	European Radio Navigation Plan
ERTMS	European Railway Traffic Management System
EUREF 89	EURopean REFerence System –89
FANS	Future Aeronautical Navigation System
FM	Swedish Armed Forces
FMV	Defence Materiel Administration
FOI	Swedish Defense Research A7gency
FTP	File Transfer Protocol
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
ICAO	International Civil Aviation Organisation
IERS	International Earth Rotation Service
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
ITRS	International Terrestrial Reference System
JAA	Joint Aviation Authorities
LF	Low frequency
LLZ	Localizer
LORAN	LOng Range Navigation System
LuLIS	Air Situation Information System
NDB	Non-Directional Beacon
NILS	New Integrated Landing System
NINS	New Integrated Navigation System
NKG	Nordic Commission of Geodesy
NM	Nautical Mile
NRA	National Railway Administration
NTP	Network Time Protocol
NVDB	National Road Administration Data Base
OVLS	Open protocols for interfacing Vehicle Location Sub-systems
PAR	Precision Approach Radar
PBN	Performance Based Navigation
PMR	Private Mobile Radio
PTS	National Post and Telecom Agency
RDS	Radio Data System

RH 2000	Swedish height system
RINEX	Reciever INdependent EXchange format
RNAV	Area Navigation
RNN	Swedish Board of Radio Navigation
RNP	Required Navigation Performance (will be successively replaced by PBN)
RT 90	Swedish plane reference system
RTCM SC	Radio Technical Commission for Maritime Services Special Committee
RTK	Real Time Kinematic
RVR	Runway Visual Range
SA	Selective Availability
SAF	Swedish Armed Forces
SARSAT	Search And Rescue Satellite Aided Tracking
SAS	Scandinavian Airline System
SBAS	Satellite Based Augmentation System
SCAA	Swedish Civil Aviation Authority
SGIC	Scandinavian GNSS Industry Council
SMA	Swedish Maritime Administration
SMS	Short Message Service
SWEPOS	Swedish network of fixed reference stations for GPS
SWEREF 99	SWEdish REFerence System –99
SWEREF 99 TM	Swedish plane reference system
TAI	International Atomic Time
TERNAV	TERrain NAVigation
TILS	Tactical Instrument Landing System
TN	Inertial Navigation
TWSTFT	Two-Way Satellite Time and Frequency Transfer
TWSTT	Two-Way Satellite Time Transfer
UIC	International Union of Railways
UMTS	Universal Mobile Telecommunication System
USNO	US Naval Observatory
UT1	Universal Time
UTC	Universal Time Coordinated
VDF	VFH Direction Finding
VDL	VHF Digital Link
VOR	VHF OmniRange
VTS	Vessel Traffic Service
WADGPS	Wide Area DGPS
WAP	Wireless Application Protocol
WGS 84	World Geodetic System 84