ISSN 0280-5731 LMV-rapport 1999:4

Reports in Geodesy and Geographical Information Systems

CIVIL SERVICE INTERFACE COMMITTEE
INTERNATIONAL INFORMATION SUBCOMMITTEE

7th EUROPEAN MEETING

GÄVLE, SWEDEN
3-4 DECEMBER 1998

PROCEEDINGS

edited by BO JONSSON

Gävle, Sweden
1999

NATIONAL LAND SURVEY

ISSN 0280-5731 LMV-rapport 1999:4

Reports in Geodesy and Geographical Information Systems

CIVIL SERVICE INTERFACE COMMITTEE
NTERNATIONAL INFORMATION SUBCOMMITTEE

7th EUROPEAN MEETING

GÄVLE, SWEDEN
3-4 DECEMBER 1998

PROCEEDINGS

edited by BO JONSSON

Gävle, Sweden
1999

NATIONAL LAND SURVEY

INTRODUCTION

The seventh European meeting of the International Information Sub-Committee (IISC) of the Civil GPS Service Interface Committee (CGSIC) was held on 3-4 December 1998 in Gävle, Sweden and was hosted and sponsored by the National Land Survey of Sweden.

The Civil GPS Service Interface Committee (CGSIC) is chaired by the US Department of Transportation and forms a key part of the United States GPS Management approach. The purpose of the Committee is to act as an interface group with Civil Users and to promote the exchange of GPS Information.
There are two main Sub-committees:
Timing
International Information

The purpose of the International Information Sub-Committee (IISC) is:

a) To provide an open international forum to collect and exchange information concerning GPS user needs, suggesting courses of action to CGSIC
b) To identify the needs of nations for GPS information and for distribution methods
c) To respond to requests and concerns submitted by the international civil user community
d) To conduct international GPS information studies on civil user needs

The purpose of the meeting was to address the Plans and Policies for GPS, and discuss the issues concerning GPS, GLONASS and other Satellite Based Augmentation Systems. Briefings on Services, Projects, Studies and Applications of the satellite techniques were presented. Industrial aspects of Satellite Based Navigation and Positioning Systems and Services, Applications and User Requirements were also addressed.

These proceedings contain minutes from the meeting and papers delivered by the speakers to the Editor during and after the meeting. The co-operation of all speakers in the preparation and during the meeting is acknowledged.

In the preparation of the program the co-operation of Jim Doherty, deputy chair of CGSIC, Rebecca Casswell, executive secretary of CGSIC, Mike Savill, chair of IISC and Georg Weber, vice chair of IISC and regional chair for Europe is acknowledged.

The effort of Lena Boberg for the organisation of the meeting and the assistance of Lotti Jivall and Martin Lidberg for the minutes from the meeting and the editing of these proceedings are also acknowledged.

Gävle April 1999
Bo Jonsson
Chair of the local organising committee
for the seventh European meeting of the IISC

CONTENTS

0004

1999-03-12

CIVIL GPS SERVICE INTERFACE COMMITTEE, INTERNATIONAL INFORMATION SUBCOMMITTEE

Minutes from the 7th European IISC-meeting in Sweden on 3-4 December 1998

Lotti Jivall, Bo Jonsson and Martin Lidberg, National Land Survey of Sweden

1. INTRODUCTION

The seventh European meeting of the International Information Sub-Committee (IISC) of the Civil GPS Service Interface Committee (CGSIC) was held on 3-4 December 1998 in Gavle, Sweden and was hosted by the National Land Survey of Sweden. The agenda for the meeting can be found in Annex 1.

The purpose of the meeting was to address the Plans and Policies for GPS, and discuss the issues concerning GPS, GLONASS and other Satellite Based Augmentation Systems. Briefings on Services, Projects, Studies and Applications of satellite techniques were presented. Industrial aspects of Satellite Based Navigation and Positioning Systems and Services, Applications and User requirements were also addressed.

103 participants, see Annex 2, attended the meeting and came from the following 15 nations: Belgium, Czech Republic, Denmark, Finland, Germany, Latvia, Monaco, Netherlands, Norway, Poland, Russia, Sweden, United Kingdom, and the United States of America.

The meeting was divided into the following four working sessions:

- Policies and Status of Satellite and Augmentation Systems, Session chair: Capt. James Doherty, US Coast Guard Navigation Center
- GPS Industry, Session chair: Mike Swiek, US GPS Industry Council
- Transport applications, Session chair: Mike Savill, Northern Lighthouse Board, Scotland
- Non-Transport applications, Session chair: Bo Jonsson, National Land Survey of Sweden

Additionally there were Opening and Closing Sessions, Technical Tours at National Land Survey combined with a GPS receiver exhibition, a poster display, a GPS receiver exercise and also a buffet. On December 5th a Technical Tour was arranged to the GPS radio beacon station Nynashamn and to the SWEPOS station Lovo

2. OPENING SESSION

The Deputy Director General **Stig Jönsson**, National Land Survey of Sweden welcomed all the participants to Gavle. He gave a very short overview of the tasks of the National Land Survey and the on-going GPS-activities. Finally he stressed the importance of the information exchange at the CGSIC- and IISC-meetings for the development of the GPS activities in Sweden and wished all participants a successful meeting in Gavle

The chair of the International Information Subcommittee **Mike Savill** welcomed the participants to the seventh European meeting of International Information Subcommittee. He recognised the contribution of the Swedish Land Survey to the Civil GPS Service Interface Committee and their work to arrange, organise and host this meeting.

He also acknowledged the direct support of this meeting from the US Authorities and the European Community and then introduced the following representatives:

- Joe Canny, chair of the Civil GPS Service Interface Committee, US Department of Transportation (DOT).
- Jim Doherty, deputy chair of the Civil GPS Service Interface Committee, US Coast Guard
- Rebecca Casswell, executive secretary of the Civil GPS Service Interface Committee, US Coast Guard
- Hank Skalski, US Department of Transportation liaison to the Air Force Space Command
- Fiona McFadden, The European GNSS Secretariat in Brussels
- Mike Swiek, the US GPS Industry Council

Mike Savill said that independently of the on-going formal BI-lateral discussions between the US, Europe, Japan and Russia there is a need to maintain contacts at an informal level between civil users in different countries concerned with the deployment and operation of GPS, GNSS and GLONASS. Therefore it is natural at this meeting of the United States IISC to allude to other topics such as GNSS1, GNSS2 and GLONASS.

The IISC is in progress of restructuring and George Weber from the Federal Agency for Cartography and Geodesy, Frankfurt recently became one of the four regional vice chairs who cover Europe, North America, Japan and the Far East. Regrettably George Weber, the European region vice chair, was unexpectedly unable to attend this meeting and he asked Mike Savill to convey his sincere apologies and best wishes for a successful and objective meeting.

Finally Mr Savill said that the representatives of the CGSIC and IISC would be grateful for any feedback, suggestions or ideas on how to further improve the effectiveness of the IISC and that he looked forward to a most successful objective meeting in a most appropriate location.

Captain **Jim Doherty**, deputy chair of the Civil GPS Service Interface Committee gave a short update for the Civil GPS Service Interface Committee. He reviewed the committee structure and how the CGSIC supports the Interagency GPS Executive Board (IGEB). The committee has over 500 members from 56 countries. The CGSIC has been very useful in pushing for answers to issues, such as the 1024th week rollover. In addition, the membership assists the US government to compile user requirements for the next generation of satellites.

3. SESSION 1: POLICIES and STATUS of SATELLITE and AUGMENTATION SYSTEMS

Joe Canny gave an update of the **DOT Policy and Planning on** GPS. The Interagency GPS Executive Board decided in March 1998 to add a 2nd civil signal to L2 and a 3rd signal on the Block IIFs that can support Safety-of-Life needs. Options for the 3rd signal are still examined and the decision is delayed, but there will not be any negative impact because the acquisition of the next group of IIFs is also delayed.

Japan and US have agreed on a joint statement for co-operation in the use of GPS. Negotiations are going on between US and Europe concerning GPS/GNSS related issues.

The funding structure for the sustainment of constellation, augmentations and enhancements is being considered by IGEB in order to avoid jeopardising of the GPS modernisation. The Department of Transportation in consultation with the Department of Defence (DOD) is carrying out an evaluation of the vulnerability of the US transportation infrastructure reliance on GPS. The FAA (Federal Aviation Administration) is working on an independent GPS/WAAS risk assessment for civil aviation.

Finally Mr. Canny reported on the preparations for the World Radio Conference in 2000 (WRC 2000) concerning the protection of the L-band from non-ARNS systems and on the nation-wide US DGPS network.

GNSS: The European Viewpoint, was presented by Fiona McFadden. The European GNSS approach consists of the two phases GNSS1 and GNSS2. The European Tripartite Group (ETG), consisting of Eurocontrol, European Space Agency (ESA) and European Commission (EC), collaborates on the development of the European GNSS. The European GNSS Secretariat is co-ordinating the GNSS activities.

The GNSS1 concept consists of GPS, GLONASS, Satellite Based Augmentation Systems (SBAS), Ground Based Augmentation Systems (GBAS) and User Equipment Hybridisation & Processing (ABAS). In Europe the SBAS component is EGNOS (the European Geostationary Navigation Overlay System), in US WAAS (the Wide Area Augmentation System) and in Japan MSAS (Multi - Satellite Augmentation System).

The GNSS2 concept consists of a full civilian navigation system and there are three approaches for the realisation of this system: joint development by all players, one or more major partners for Europe, or independent development by Europe. The GNSS2 FORUM is working during the time period July - December 1998 in order to support the EC decision making process. EC and ESA studies are also addressing technical issues. Decision on the option to be pursued will be taken in early 1999.

Vadim Zohlnerov, Deputy Director of the Russian Institute of Navigation presented **GLONASS: Status and Prospects.** Currently thirteen GLONASS satellites are in operation.

Concerning most recent GLONASS development, the correction of the National Standard of UTC (SU) has been conducted. This operation allowed to reduce a difference between UTC (SU) and GLONASS system down to 1 μsek. The new reference book on PZ-90 presents a new recommended coordinate transformation between PZ-90 and WGS-84.

The current economic situation certainly effects GLONASS maintenance and future development. Nevertheless, GLONASS has a high priority in Russia aerospace development. Despite the current difficulties, the Russian Government gives support to the GLONASS program based on already published official documents. The main purpose of the Federal support program for the use of the GLONASS is to forge development of user navigation equipment in Russia. Those enterprises, which were able to recruit foreign partners for joint works on combined GPS/GLONASS receivers, were the most successful.

There are GLONASS issues that are subject of continuos discussion and development. GLONASS will improve if the following main issues are resolved:

- protection of frequency band from the recently introduced new system of mobile satellite communications
- integration of international standard concerning GLONASS use
- update of the GLONASS constellation to the new generation GLONASS-M satellites without harming the existing constellation and navigation characteristics of the system
- improving reliability and accuracy of timing and positioning

The Status of the Global Positioning System (GPS) Constellation was presented by Hank Skalski. There are twenty-seven operational GPS satellites on orbit. During 1999 two launches are planned for April 22nd and during September.

The civilian GPS users are notified about the health and planned maintenance of the GPS constellation via:
- Notice Advisory to NAVSTAR Users (NANU)
- Notice to Airmen (NOTAM
- Broadcast Notice to Mariners (NM)
- Satellite Navigation message

Previously there have not been any official directives for reporting and controlling removal of a satellite from service, but now the 2nd space operations squadron has explicit guidance.

The "Guardian Tiger Team" with civil representation from US Coast Guard and Federal Aviation Administration has developed guidelines for the dissemination of information to civil users about the health and planned maintenance of the GPS constellation e. g. new NANU format, fixed NANU types, the distribution process for NOTAMs.

Hank Skalski also presented **GPS Modernization and Operational Issues.** GPS Modernisation enhances GPS to meet Civil Safety-of-Life and Economic Needs. Key issues are: improved accuracy, availability and integrity, together with improved protection from interference and to ensure backward compatibility with existing user equipment.

Modernisation has the two main components: 1) system enhancements and 2) operational improvements. System enhancements proposals include more (30+) satellites, improved radiated power, improved timing signal, augmentations, improved user equipment, integrity channel, 2nd and 3rd civil signals. Operational improvements are e. g. interference reporting and resolution, user notification. Interference can happen both intentional (e. g. jamming) and non-intentional (e. g. out-of-band). The USCG Navigation center (NAVCEN) and the FAA National Maintenance Co-ordination Centre (NMCC) share the civil reporting responsibilities, while the military reporting responsibility is with the US Space Command.

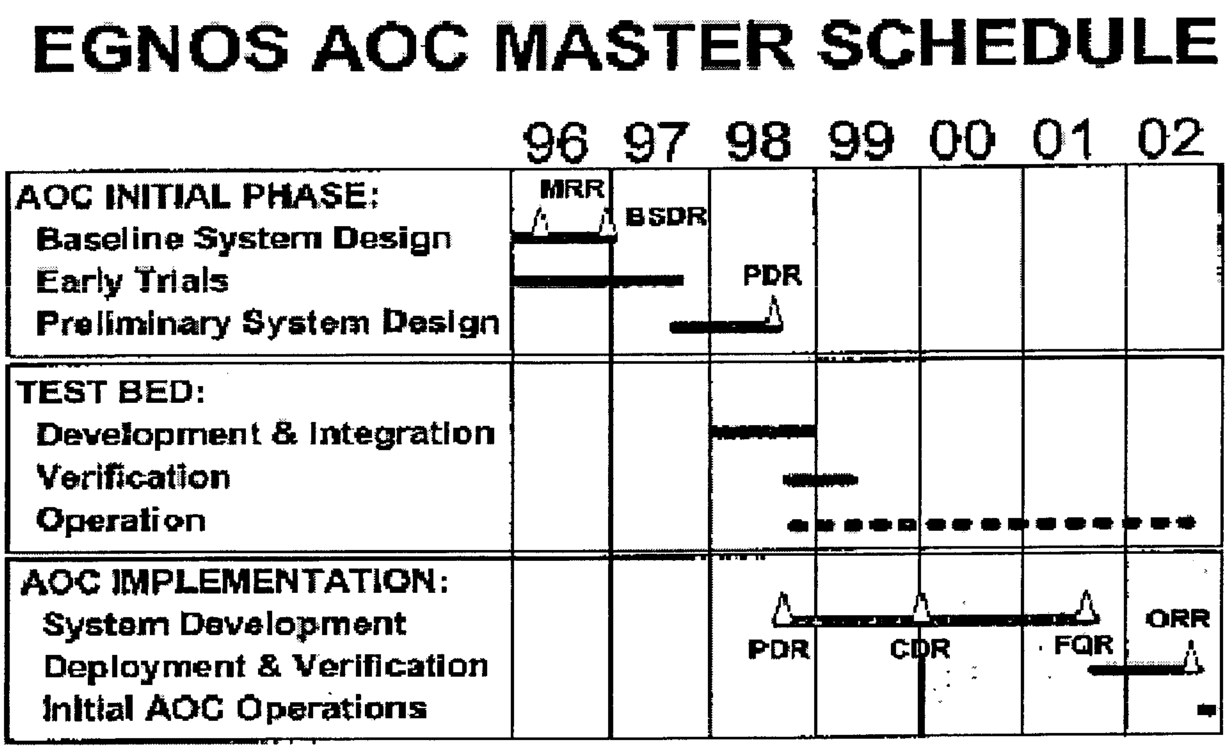
EGNOS - the European Satellite Augmentation to GPS and GLONASS was presented by Rafael Lucas, ESA, Directorate of Applications, GNSS Programs. EGNOS (the European Geostationary Navigation Overlay System) will provide a ranging signal, integrity information and Wide Area Differential corrections in order to improve accuracy, integrity, continuity, availability and safety. EGNOS has a multimodal mission, i. e. Aviation, Maritime, Road and Rail, but is driven by aeronautical requirements. The Wide area Corrections will enhance the accuracy to 7-10 meters VNSE (Vertical Navigation System Error) for GPS and 4-6 meters VNSE for GPS+GLONASS for precision approach over the territory of the European Civil Aviation Conference (ECAC) countries.

The fundamentals of EGNOS are the ground segment, the space segment, the user segment and the support segment. The ground segment consists of Ranging and Integrity Monitoring Stations (RIMS), Mission and Processing & Control Centres (MCC), Navigation Land Earth Stations (NLES) and EGNOS Wide Area Network (EWAN). Geostationary satellites (e. g. INMARSAT III, AORE/IOR and ARTEMIS) with navigation payloads are the space segment. Aeronautical, maritime and land user equipment will be developed.

The goal is to have global interoperability between GPS, GLONASS, EGNOS, WAAS and MSAS.

The following three EGNOS Operational milestones can be noted:

- Test bed. Ranging, Ground Integrity Channel (GIC) and Wide Area corrections are available from mid 1998.



- AOC (Advanced Operational Capability). Ranging, Ground Integrity Channel and Wide Area Corrections will be operational in year 2002. EGNOS will be used as primary means for En-route, Non-Precision Approach (NPA), IPV and CAT-I
- FOC, (Full Operational Capability). AOC + ground/space redundancy will be available in 2005.

Börje Forssell, Norwegian University of Science & Technology presented **EUROFIX a Cheap Alternative for Dissemination of DGPS Corrections.** The concept of EUROFIX is to broadcast DGPS data and integrity information by modulation of the LORAN-C signal. The Technical University of Delft (Netherlands) proposed the concept and experimental transmissions have been done from the Sylt station since 1997.

EUROFIX providers could broadcast accurate DGPS corrections via existing LORAN-C/Chayka stations (RTCM SC 104) and cover almost the entire continental Europe and North America. EUROFIX has been shown to offer excellent DGPS accuracy (< 3 meter) and integrity. Networked DGPS performance can be obtained with two or more stations. DGPS can continuously calibrate LORAN-C/Chayka and the calibrated LORAN-C bridges GPS coverage gaps.

The benefits of EUROFIX are cost-effective DGPS correction and integrity services, long range (<1000 km), emergency broadcast possible, multiple stations for networked DGPS, easy integration of DGPS and LORAN-C and dual-rated stations allow increased data rate.

Nation-wide Differential Global Positioning System (NDGPS) in US was presented by Captain Jim Doherty. Leveraging DOD's $12 billion investment in GPS and DOT's 40 million in DGPS, the U.S. will soon blanket the nation with the most accurate and reliable navigation system the country has ever had. It will be much more than a navigation system, when it is installed it will be used in a wide array of other applications as surveying, weather modelling and precise farming.

The Nation-wide DGPS will have the accuracy 1-3 meters in real-time and 5 centimeter using post-processing. The time to an alarm of a mal-functioning satellite will be 2-5 seconds and the availability 99.999%.

The planning of NDGPS began in January 1997 and the network is based on a co-operation between a number of governmental agencies, e. g. DOT/OST, US Coast Guard, Federal Highway Administration, Federal Aviation Administration.

NDGPS is designed to an international, non-proprietary standard, the signal will be free and the concept is currently used in 31 countries. Each NDGPS station will have a maximum operation range of 400 km. DOT will convert the stations in the Ground Wave Emergency Network (GWEN) and 67 NDGPS sites will be obtained excluded the present maritime DGPS-stations. The NDGPS -network will be used for e. g. positive train control, intelligent transportation system, State&Local government activities. The benefits to cost ratio is estimated to 152:1

4. SESSION 2: GNSS INDUSTRY

Thomas Rehn, the chair of SGIC, presented the **Scandinavian GNSS Industry Council (SGIC)**, which is a Swedish association of companies promoting and producing products and systems for satellite positioning and navigation. The objectives of SGIC are to promote commercial development of GPS and communicate to industry, User groups and Authorities. These objectives are achieved by SGIC Internet Website, arranging seminars, conferences and workshops, attending international activities on the behalf of the membership, distributing collected relevant information to members and co-operating with organisations with complementary objectives. SGIC membership is open both for commercial companies and agencies and for educational institutions, which are related to GNSS activities

A number of GNSS products and GNSS services were presented by the GNSS industry:

SAAB Dynamics	Lincs - the data link of the 21st century and NINS/NILS - an autonomous navigation and landing system
Seatex A/S	A combined GPS/GLONASS Position Reference System for DP (Dynamic Position system) Operations
Geo++	GNSS-SMART: A technique for Wide Area cm-RTK (Real-Time Kinematic positioning)
Volvo	GPS applications at Volvo
Navdata	IMOS - a central Integrity MOnitoring System
Agcom AB	A Local Area RTK (Real-Time Kinematic positioning) System based on GPS/GLONASS technology
Teracom	Nation-wide DGPS (Differential GPS) and RTK (Real-Time Kinematic positioning) Services using the FM radio network

5. SESSION 3: TRANSPORT APPLICATIONS

Fleet management for trucks at Skandia Transport

An overview of a system for management of 40 trucks at the Swedish company Skandia Transport was shown. The system, which has been in operation for one year, consists of the three main components: GPS-equipment in the vehicles, wireless network with MOBITEX and a control centre. The use of the system has shown a lot of advantages.

The Swedish/Finnish radio beacon network

The first two public DGPS-stations (March 1991) in the world for maritime navigation belong to the Finnish and Swedish DGPS-networks. The Finnish network has now five stations in operation + one Estonian station and the Swedish network consists of eight stations. Tests have been performed along the Swedish coast to study the conditions for coverage of double radio beacons.

Technology leaps to solve air congestion and accommodate traffic - growth in the 21st century - GPS and data links for Communication, Navigation and Surveillance.

The air traffic growth in the territory of the European Civil Aviation Conference (ECAC) countries requires an efficient Air Traffic Management in the future. A self-organising air traffic system based on the data link VDL Mode 4 and GPS allows "free flight" without air traffic control. Each vehicle can see all other within a certain area and can choose its own flight way. GPS is used both for positioning and time.

GPS in the National Rail Administration
The Swedish Rail Administration has used GPS for Control networks since 1989 and has performed some tests with RTK and DGPS for geodetic measurements along railways. The tests with RTK showed to low accuracy and insufficient number of available satellites, while the DGPS-tests turned out to give satisfactory results.

GPS for fleet management of ambulances
The fleet management system consists of a database with geographical information combined with the data link MOBITEX and an alarm handling system. Next year all SOS ambulances in Sweden will report their locations, determined by GPS, to the management system and soon there will be a similar fleet management system for fire - brigades as well. This system will shorten the time before the assistance arrives to those in distress

Pilot mounted GPS concept
Mounting the GPS-antenna on the helmet of the pilot and the GPS-receiver together with a computer in the pilot's leg pocket makes a very flexible system when using GPS in different aircrafts. The Swedish Defence Materiel Administration uses this concept for test and verification of radar systems.

Some results on long wave DGPS corrections dissemination in the Czech Republic.
The Czech Technical University has been running a DGPS station, equipped with three receivers, for one year. DGPS corrections are broadcasted in real time both via the VHF R (B) DS channel and a LF channel. The corrections are also stored for post-processing. Tests with the broadcasted DGPS-corrections have been performed at different places in central Europe.

The Nordic Institute of Navigation
The Nordic Institute of Navigation is a Norwegian organisation which has 300 members, most of them in Norway. The main task of the Institute is to follow the development in navigation. The following conferences will be arranged 1999: MARE 99 in Gothenburg 21-22 April and NORNA 99, on a Viking Line ferry 23-25 November

6. SESSION 4: NON-TRANSPORT APPLICATIONS

GPS in the Swedish National Forest Inventory
The National Forest Inventory use GPS for location of field spots. The positioning is done by post-processed differential GPS. Permanent GPS stations in the SWEPOS network is used as reference stations. Real time DGPS are not used because many field spots are located where reliable DGPS corrections are not available. The experience is good, but reliable positions are not achieved for about 12% of the field plots.

GPS in Swedish Agriculture

GPS is used for several tasks such as field boundary surveys, soil sampling, crop scouting, and precision agriculture. Data from yield sensor and GPS equipment on the harvester are used to produce yield maps. These maps, combined with data from soil sampling and possibly crop scanning, determine the amount of fertiliser to be applied on each spot of the field in a variable fertiliser application. There are about 100 users of yield mapping systems in Sweden today.

GPS telemetry in wildlife research in Sweden

An animal mounted GPS equipment has been developed and is used on moos, reindeer, and roe deer in Sweden. The purpose of the positioning part of the research is to find out why the animals move as they do. Positions can be downloaded remotely from the equipment, without disturbing the animal. This system has not been tested on bears. Tests in Canada show that bears sometimes drop their equipment because of fights and bite.

Use of GPS for cadastral surveying

DGPS is used for locating and setting out property boundaries in forested areas. Today the method is cost effective for finding old boundaries and setting out new ones. But more user-friendly equipment, less weight and more reliable transmission for the DGPS corrections are required.

GPS based height reference system in Poland and Europe

An overview of European GPS campaigns was given. There are 18 different national height systems in Europe. The GPS campaigns EUREF BAL in 1993 and EUVN in 1997 (European Unified Vertical Network) aimed to get the relation between these different height systems.

Five Years of Continuous Observations in the SWEPOS Network

Horizontal movements in the crust caused by the post glacial rebound can be determined with formal errors at the 0.1 mm/year level, using the SWEPOS network. The water vapour content, in the troposphere above each station is estimated, as a by-product, in the positioning computation. The accuracy in timing can be increased from 100ns today using one satellite at a time, to 30ns for common view (two stations tracking the same satellite), and further improved to ≤1ns using the carrier phase.

Use of GPS for aerial photography

For aerial photography in Sweden GPS is used to navigate within the photo strips, to enable automatic exposures of the camera at predefined exposure positions and to determine the position of the airborne camera at the time of the exposure. The DGPS service EPOS is used for navigation in Sweden, while absolute GPS are used overseas.
Post-processed GPS are used to get accurate camera co-ordinates for use in the aerial triangulation, which reduces the need for ground control.

GPS applications in the field of archaeology and cultural environment

During 1998, several archaeological field teams have been equipped with simple GPS receivers and the DGPS service EPOS. The mission has been to identify and position archaeological and cultural sites in the county of Gavleborg. GPS is good, but needs to be cheaper, more accurate, particularly in height, and easier to handle.

7. POSTERS

A simple way of transforming coordinates between geodetic reference frames
A simple method has been developed which makes it possible to introduce a rigorously defined global reference frame without being forced to abandon the plane grid system in use. The method utilizes the Transverse Mercator projection and can replace the 7-parameter transformation in most everyday work within surveying and mapping.

Results and Achievements of the Long-term Co-operation in Geodesy and Geodynamics Gained by the Sixteen CEI (Central European Initiative) Countries
The Central European Initiative (CEI) has sixteen member states and the objective of CEI includes initialisation of scientific, economic and cultural co-operation between the countries of the Central Europe. The CEI Working Group on Science and Technology has an Earth Science Committee, which has the three sections Geology, Geophysics and Geodesy. The report shows the results and achievements of the co-operation in geodesy and geodynamics in central Europe.

8 NATIONAL REPORTS

GPS in Latvia: Past, Present and Future, 1994-1998
The GPS-campaign EUREF.BAL92 in 1992 was the beginning of large-scale works for the establishment of a geodetic network in Latvia using GPS. In the report the GPS work and its application during the period 1994-1998, which have been conducted by Latvian specialists of the National Surveying Centre of State Land Service, are considered. The National Surveying Centre was established in 1994.

GPS Applications and Developments in Poland
Poland contributes to the IGS network (International Geodynamics Service) with three permanent GPS stations and to the EUREF network with five stations. The Warsaw University of Technology works as an analysis center for a Regional network, a part of the EUREF network and he CERGOP/EXTENDED SAGETT project. The GPS Information Center continues its work and international/national seminars/conferences on GPS have been conducted.

9 CLOSING of the MEETING

Mr. Frantisek Vejrazka, University of Prag invited to the eight European IISC-meeting in Prag, Czeh Republic in December 1999.

Proceedings from the sixth European IISC-meeting in Warsaw, December 1997 is available from Mr. Janusz Zielinski, Polish Academy of Sciences, Warsaw.

Mr Mike Savill thanked all speakers for their contributions to this meeting and the audience for their participation. On the behalf of the participants he expressed thanks to National Land Survey for hosting this meeting, to Mrs. Lena Boberg for her assistance with all practical details and to Bo Jonsson and his staff for the arrangement of this meeting.

0014

Finally Mr Savill wished all a safe journey home and said that he is looking forward to the next meeting in Prag in December next year.

9. ACTIVITIES in the EVENING of DECEMBER 3rd

One of the aims of the activities on the evening of December 3rd at the canteen of the National Land Survey (NLS) was to create opportunities for information exchange between the participants of the IISC- meeting in a relaxed atmosphere. An other aim was to stimulate information exchange between the GNSS industry and the GNSS users.

A practice in transforming coordinates between different reference systems was conducted using GPS receivers, supplied by the Magellan company, Sunnyvale, US and Agcom AB, Sweden. A set of coordinates for a waypoint was supplied in the Swedish reference system (RT 90) and the task was to walk to that one of the three stations outside NLS which had the given coordinates in (RT 90) using the GPS receiver. The GPS-receiver shows the coordinates in the global reference system (WGS 84) and therefore the given coordinates must be transformed in the GPS-receiver. A small "reward" was given to the persons who arrived to the "correct" spot, which was marked with candles.

The Technical tour at the National Land Survey had the following "stations": the control center of the SWEPOS® network, GPS in aerial photography and historical maps.

The following companies and organisations participated in the exhibition: Agcom, Ashtech Europe, Enator Telub, Navdata, Noab, Scandinavian GNSS Industry Council, Spectra Precision, Swedesurvey, Swedish Maritime Administration, SWEPOS, Teracom.

10. TECHNICAL TOUR on DECEMBER 5th

Seventeen persons participated in the Tecnical Tour, which started in the morning of December 5th from Crystal Plaza Hotel in Stockholm.

The first stop was the DGPS radio beacon in Nynashamn, south of Stockholm. Nyshamn is one station in the network of eight DGPS radio beacons, which is based on the "IALA-standard" (International Association of LightHouse Authorities) and operated by the National Maritime Administration.

After a stop for a small lunch the tour reached the SWEPOS-station Lovo, west of Stockholm. The SWEPOS network consists of twenty-one stations and is designed and financed of a co-operation group of Swedish governmental agencies and companies. National Land Survey operates SWEPOS.

The tour ended in the afternoon at Crystal Plaza Hotel in a snowy Stockholm.

Agenda for the IISC-meeting on 3-4 December 1998 in Gavle

Thursday	**3 December**	
08.00	Registration	
08.30	Welcome address	Joakim Ollén, Director General, National Land Survey of Sweden
	Opening address	Mike Savill, Chair of IISC Nothern Lighthouse Board Scotland
	CGSIC update	Capt. James Dorethy US Coast Guard
Session 1	**Policies and Status of Satellite and Augmentation Systems** **Session chair: Capt. James Dorethy, US Coast Guard**	
09.10	GPS Policy	Joe Canny, chair of the CGSIC US Department of Transportation
	European Policy	Fiona Mcfadden European GNSS Secretariat
	GLONASS Up-date	Vadim Zholnerov Russian Institute of Radionavigation and Time
	US Department of State Consultations	Joe Canny US Department of Transportation
10.25	Coffee Break	
10.50	Constellation Sustainment	Hank Skalski US Department of Transportation
	GPS Modernisation and Operational Issues	Hank Skalski US Department of Transportation
	EGNOS Status	Rafael Lucas Rodriguez ESA, Netherlands
	EUROFIX – a cheap alternative for wide-area dissemination of DGPS	Börje Forssell Norwegian University of Science and Technology Trondheim
	Nation-wide DGPS in US	Capt. James Doherty US Coast Guard
12.45	Open discussion	
13.00	Lunch on your own	

Annex 1

7th European Meeting of the International Information Subcommittee 3-4 December 1998 – Agenda

Session 2	**GPS Industry** **Session chair: Mike Swiek, US GPS Industry Council**	
14.00	The Scandinavian GNSS Industry Council (SGIC)	Tomas Rehn, chair of SGIC NOAB AB, Sweden
	Lincs – the data link of the 21st century and NINS/NILS – an autonomous navigation and landing system	Peter Bergljung Saab Dynamics, Sweden
	A Combined GPS / GLONASS Position Reference System for DP Operations	Trond Schwenk Seatex A/S, Norway
	GNSS-SMART: A technique for wide area cm-RTK	Gerhard Wübbena Geo++, Germany
15.10	Coffee break	
15.35	GPS applications at Volvo	Sven Jonsson Volvo Technological Development Corporation, Sweden
	IMOS – a central integrity monitoring system	Ilari Koskelo, Navdata, Finland
	A Local Area RTK System based on GPS/GLONASS technology	Björn Ågårdh Agcom AB, Sweden
	Nation-wide DGPS and RTK services using the FM radio network	Peter Ericson, Teracom, Sweden
16.35-17.00	Open discussion	
17.55 – 22.00	Technical tours at National Land Survey Exhibition Posters Buffet	
	Friday 4 December	
Session 3	**Transport applications** **Session chair: Mike Savill, the Northern Lighthouse Board, Scotland**	
08.30	Fleet management for trucks at Skandia Transport	Per Bergström B&M System Development, Sweden
	The Swedish/Finnish radio beacon network	Christian Axelsson/Rolf Bäckström National Maritime Administration/National Board of Navigation
	Technology leaps to solve air congestion and accommodate traffic – growth in the 21st century - GPS and data link for Communication, Navigation and Surveillance	Gunnar Frisk Swedish Civil Aviation Administration

Annex 1

7th European Meeting of the International Information Subcommittee 3-4 December 1998 – Agenda

	GPS in the Swedish National Rail Administration	Marie Malmberg and Sten Lundén Swedish National Rail Administration
09.50	Coffee break	
10.15	GPS for fleet management of ambulances	Per Palm SOS alarm, Sweden
	Pilot mounted GPS concept	Patric Jansson Telub, Enator, Sweden
	Some results on long wave DGPS corrections dissemination in the Czech Republic.	F. Vejrazka Department of Radio Engineering, Czech Technical University, Prague
	The Nordic Institute of Navigation	Bengt Ståhl, chair of the Nordic Institute of Navigation
11.25	Open discussion	
11.45	Lunch on your own	
Session 4	**Non-Transport applications** **Session chair: Bo Jonsson, National Land Survey of Sweden**	
12.45	GPS in the Swedish National Forest Inventory	Härje Bååth Dept. of Forest Resource Management, Swedish University of Agricultural Sciences
	GPS in Swedish Agriculture	Per-Anders Algerbo Swedish Institute of Agricultural Engineering
	GPS telemetry in animal ecological research in Sweden	Lars Edenius Dept. of Animal Ecology, Swedish University of Agricultural Sciences
	Use of GPS for cadastral surveying	Roland Jansson National Land Survey of Sweden
13.45	Coffee break	
14.10	GPS based height reference system in Poland and Europe.	Janusz Zielinski, Space Research Centre, Polish Academy of Sciences, Poland
	Five years of continuous observations in the SWEPOS network: Applications in geodesy, geophysics, remote sensing of the atmosphere, navigation, and time-transfer.	Jan Johansson, Onsala Space Observatory and Swedish National Testing and Research Institute

Annex 1

7th European Meeting of the International Information Subcommittee 3-4 December 1998 – Agenda

	Use of GPS for aerial photography	Magnus Pettersson National Land Survey
	GPS applications in the field of archaeology and cultural environment	Bo Ulfhielm County museum of Gävleborg, Sweden
15.15	General discussion	
15.45	Closing of the meeting	
16.00	Bus departure for Arlanda and Stockholm City	

Annex 2

7th European Meeting of the International Information Subcommittee 3-4 December 1998 – List of participants

Name	Institute	Telephone/Fax	E-mail
Algerbro Per-Anders	Swedish Institute of Agricultural Eginering P.O. Box 7033 75007 Uppsala Sweden	Tel +4618303355 Fax +4618300956	Per-anders.algerbo@jti.slu.se
Andersen Nils	National Survey and Cadastre Rentemestervej 8 DK 2400 København Denmark	Tel+45 35875050 Fax +45 35875057	na@kms.dk
Andersson Börje	Spectra Precision Grönlid 57291 Oskarshamn Sweden	Tel +46705595960 Fax +46706100960	Bad@gecon.se
Ansons Maris	Latvian CAA Airport Riga LV 1053 Latvia	Tel +3717207586 Fax +3717207300	Ansons@latcaa.gov.lv
Arnzén Sylve	FOA 17290 Stockholm Sweden	Tel +4687063663 Fax +4687063651	Arnzén@sto.foa.se
Arrhén Göran	Spectra Precision Box 64 182 11 Danderyd Sweden	Tel: 4686221114 Fax: 4687532464	goar@spectraprecision.se
Axelsson Christian	Swedish Maritime Administration 601 78 Norrköping Sweden	Tel +4611191406 Fax +4611126791	cristian.axelsson@sjofartsverket.se
Beeckman Jean Pierre	Institut Geographique National Abbaye de la Cambre 13 B-1000 Bruevelles Belgium	Tel +3226298432 Fax +3226298450	Jpb@ngi.be
Bergljung Peter	Saab Dynamics Fack 581 88 Lindköping Sweden	Tel +4613186000 Fax +4613186300	Peter.berljung@dynamics.saab.se
Bergman Bo	YDAB AB Nettovägen 7 175 41 Järfälla Sweden	Tel + 46858400821 Fax +46858400820	bob@ydab.se
Bergström Per	B&M Systemutveckling AB Box 805 75108 Uppsala Sweden	Tel +4618143400 Fax +4618143444	Perb@bmsystem.se
Björklund Sofia	National Land Survey 801 82 Gävle Sweden	Tel +4626633857 Fax +4626610676	sofia.bjorklund@lm.se
Bockmann Lars	Norwegian Mapping Authority Kartverksveien 21 3500 Hønefoss Norway	Tel +4732118100 Fax +4732118101	Lars.bockmann@gdiv.statkart.no

Annex 2

7th European Meeting of the International Information Subcommittee 3-4 December 1998 – List of participants

Brundin Sverker	Mora Tech Box 7 182 11 Danderyd Sweden	Tel +46854496100 Tel: +46854496132 Fax + 46854496101	Sverker.brundin@moratech.se
Burgerfeldt Dorota	Mora Tech Box 7 182 11 Danderyd Sweden	Tel +46854496100 Fax + 46854496101	
Butler Bruce	Trimble Navigation Trimble House Meridian Office Park Osborn Way Hook Hampshire RC 27 9 H United Kingdom	Tel +441256746224 Fax +441256760148	Bruce_butler@trimble.com
Bååth Härje	Department of Forest Resource Management and Geomatics SLU 90183 Umeå Sweden	Tel +46907865000	Harje.baath@resgeom.slu.se
Bäckström Rolf	Finnish Maritime Administration P.O.B. 171 00181 Helsingfors Finland	Tel+358204484262 Fax + 358204484470	Rolf.backstrom@fma.fi
Börjesson Jörgen	Onsala Space Observatory 439 92 Onsala Sweden	Tel +46317725575 Fax 463117725590	Ajb@oso.chalmers.se
Canny Joseph	U.S Department of Transportation 400 7th Street. SW Washington DC 20590 USA	Tel +12023664540 Fax +12023667127	Joe.canny@ost.dot.gov
Casswell Rebecca	U.S. Coast Guard Navigation Center 7323 Telegraph Road Alexandria, VA 22315-3998 USA	Tel +17033135930 Fax +17033135805	Rcasswell@smtp.navcen.uscg.mil
Davidson Martin	National Research Defence Establishment,FOA 7 Box 1165 581 11 Linköping Sweden	Tel +4613378345 Fax +4613378009	Martin@lin.foa.se
Doherty James	U.S Coast Guard Navigation Center 7323 Telegraph Road Alexandria VA 22315-3998 USA	Tel +17033135800 Fax +17033135805	jdoherty@navcen.uscg.mil
Edenius Lars	Dept of Animal Ecology SLU, 90183 Umeå Sweden	Tel +46907866621, +46705501970 Fax +46907866817	Lars.edenius@szooek.slu.se
Ekman Peter	TERACOM AB Box 903 971 27 Luleå Sweden	Tel 46920239500 Fax +46920239661	pee@teracom.se

Annex 2

7th European Meeting of the International Information Subcommittee 3-4 December 1998 – List of participants

Elksnis Vairis	Latvian CAA Airport Riga LV 1053 Lativa	Tel +3717207586 Fax +3717207300	Admin@latcaa.gov.lv
Engfeldt Andreas	National Land Survey 801 82 Gävle Sweden	Tel +4626633793 Fax +4626610676	Andreas.engfeldt@lm.se
Ericson Peter	TERACOM AB Box 903 971 27 Luleå Sweden	Tel +46920239500 Fax +46920239666	Pet.@teracom.se
Eurenius Bengt	National Land Survey 801 82 Gävle Sweden	Tel +4626633743 Fax +4626654095	bengt.eurenius@lm.se
Forssell Börje	Norwegian University of Science & Technology Telecommunications NTNU N-7034 Trondheim Norway	Tel +4773592653 Fax+ 4773507322	forssell@tele.ntnu.no
Fredriksson Roger	ANNOVA Box 449 90109 Umeå Sweden	Tel +4690135220 Fax +4690135220	
Freij Lars	National Rail Administration Nygatan 41 801 05 Gävle Sweden	Tel +4626144239	Lars.freij@mitt.banverket.se
Frisk Anders	National Land Survey 801 82 Gävle Sweden	Tel +4626633744 Fax +4626610676	Anders.frisk@lm.se
Frisk Gunnar	Swedish Civil Aviation Administration 60179 Norrköping Sweden	Tel+4611192674 Fax +4611192670	Gunnar.frisk@ans.lfv.se
Gerina Inga	National Surveying Centre of The State Land Service 11 Novebra Karstmala LV-1050 Riga Latvia	Tel +3717213628 Fax 3717227858	
Grubbström Greger	ANNOVA Box 449 90109 Umeå Sweden	Tel +4690151475 Fax +4690135220	
Gustavsson Niklas R	ANNOVA Box 449 90109 Umeå Sweden	Tel +4690135220 Fax +4690151475	n.gustavsson@annova.se
Hedling Gunnar	National Land Survey 801 82 Gävle Sweden	Tel +4626633741 Fax +4626610676	Gunnar.hedling@lm.se
Hermodsson Örjan	National Heritage Board Box 5405 114 84 Stockholm Sweden	Tel +46851918544 Fax +4686678943	hhn@RA.se
Holdinger Ola	Spectra Precision AB Box 64 182 11 Danderyd Sweden	Tel + 4686221265 Fax + 4687559217	olmo@spectraprecision.se

Annex 2

7th European Meeting of the International Information Subcommittee 3-4 December 1998 – List of participants

Holm John	Orblet Technologies AB Magnus Ladulåsgatan 16 118 66 Stockholm Sweden	Tel +4684289020 Fax+ 4684289021	Gps.@orbcom.se
Horemuz Milan	Dep of geodesy and photogrammetry KTH 10044 Stockholm Sweden	Tel +4687907334 Fax 4687907343	Milanh@geomatics.kth.se
Hägg Anette	TERACOM AB Box 903 971 27 Luleå Sweden	Tel +46920239500 Fax 46920239661	Hag@teracom.se
Jaldehag Kenneth	Swedish National Testing and Research Institute Box 854 501 15 Borås Sweden	Tel +4633165408 Fax +4633125038	Kenneth.jaldehag@sp.se
Jansson Patric	EnatorTelub AB Box 1381 171 27 Solna Sweden	Tel +4687055091 Fax +468821967	patric.jansson@enator.se
Jansson Roland	National Land Survey Stationsgatan 7 971 26 Luleå Sweden	Tel +460992096600 Fax +460992016890	Roland.l.jansson@.lm.se
Jivall Lotti	National Land Survey 801 82 Gävle Sweden	Tel + 4626633740 Fax + 4626610676	Lotti.jivall@lm.se
Johansson Jan	Onsala Space Observatory 439 92 Onsala Sweden	Tel +46317725558 Fax +46317725590	Jmj@oso.chalmers.se Jan.johansson@sp.se
Johansson Lars T	SAAB Dynamics AB Fack 58188 Linköping Sweden	Tel +4613186270 Fax +4613186300	lars.t.johansson@dynamics.saab.se
Jonsson Bo	National Land Survey 801 82 Gävle Sweden	Tel + 4626633738 Fax + 4626610676	Bo.jonsson@lm.se
Jonsson Sven	Volvo Technological Development Corp Dept 6640 CTP 41288 Göteborg Sweden	Tel + 46317724072 Fax + 46317724070	Svjo@vtd.volvo.se
Johnston Gordon	Racal Surveys LTD. South Denes Great Yarmouth UK	Tel + 44(0)1493857011 Fax + 44(0)1493852420	johnstong@racal-survey.co.uk
Klomp Harald	Hogia Räddningssystem AB 444 28 Stenungsund Sweden	Tel +4630366783 Tel +4630366730 Fax +4630369127	Harald.klomp@hogia.se
Koskelo Ilari	Navdata OY Eskolantie 1 00720 Helsinki Finland	Tel +358927095341 Fax +358927095343	Navdata@clinet.fi

Annex 2

7th European Meeting of the International Information Subcommittee 3-4 December 1998 – List of participants

Lee Lynn	United Kingdom Hydrographic office Admiralty Way Taunton Somerset TAI 2DN United Kingdom	Tel +44(0)1823337900 Fax +44(0)1823334752	lynn@nprs.hydro.gov.uk
Lidberg Martin	National Land Survey 801 82 Gävle Sweden	Tel +4626633842 Fax +4626610676	Martin.lidberg@lm.se
Lindgren Mårten	FMV:TelekomS 11588 Stockholm Sweden	Tel: +4687825596	Mnlin@fmv.se
Lissel Lars-Olov	Swedish National Road Administration Röda vägen 1 78187 Borlänge Sweden	Tel +4624375609 Fax +4624394340	Lars-olov.lissel@vv.se
Lundén Sten	Swedish National Rail Administration 781 85 Borlänge Sweden	Tel +46243445635 Fax + 46243445617	sten.lunden@hk.banverket.se
Lycksell Robert	Cartesia AB Storgatan 28 921 31 Lycksele Sweden	Tel +4695012005 Fax 4695015858	Robert.lycksell@cartesia.se
Malmberg Marie	Swedish National Rail Administration 781 85 Borlänge Sweden	Tel +46243445629 Fax +46243445617	marie.malmberg.@hk.banverket.se
Mcfadden Fiona	European GNSS Secretariat 52 Avenue de Cortenbergh B-1000 Brussels Belgium	Tel +3227433087 Fax +3227433081	fmcfadden@estec.esa.nl
Moore Terry	IESSG The University of Nottingham University Park Nottingham NG 7 2RD United Kingdom	Tel +441159513886 Fax +441159513881	Terry.moore@nottingham.ac.uk
Ollén Joakim	National Land Survey 801 82 Gävle Sweden	Tel +4626633323 Fax +4626613277	Joakim.ollen@lm.se
Osorio Isabel	University of Porto Alamede do Monte da Virgem 4430-146 Vila Nova de Gaia Portugal	Tel +35127820404 Fax +35127827253	iposorio@oa.fc.up.pt
Ottoson Christina	Ashtech Europe Ltd 5 Curfew Yard. Thames Street Windsor, Berkshire. SL4 1 SN United Kingdom	Tel + 441753835700 Fax +441753835710	Christina@ashtech.co.uk
Palm Per	SOS Alarm AB Box 5776 114 87 Stockholm Sweden	Tel:+4684073020	per.palm@sosalarm.se
Panek Petr	DICOM Ltd Otevrena 1324 CZ 272 00 Kladno Czech Republic	Tel +420224352244 Fax +42023119801	Panek@feld.cvut.cz
Pettersson Magnus	National Land Survey 801 82 Gävle Sweden	Tel + 4626633366 Fax +4626654755	Magnus.pettersson@lm.se

Annex 2

7th European Meeting of the International Information Subcommittee 3-4 December 1998 – List of participants

Plasil Jiri	Czech Technical University Technicka 2 Prague-Dejvice 16627 Czech Republic	Tel +420224352268	Plasilj@feld.cvut.cz
Rantakokko Helene	Defence Materiel Administration FMV Elektro Östermalmsg 87 11588 Stockholm Sweden	Tel +4687825958 Fax +4687825541	heran@fmv.se
Rehn Tomas	NOAB Veddestavägen 17 17562 Järfälla Sweden	Tel +468362930 Fax +4687957829	Tomas.rehn@noab.se
Reit Bo-Gunnar	National Land Survey 801 82 Gävle Sweden	Tel +4626633735 Fax + 4626610676	bo-gunnar.reit@lm.se
Rodriges Rafael Lucas	ESA/ESTEC P.O.Box 299 2200 AG Noondwijk ZH Netherlands	Tel +31715653891 Fax +31715654598	Rlucas@estec.esa.nl
Rohde Hans	International Hydrographic Bureau 4 quai Antoine 1 er BPMC98011445 Monaco	Tel +37793108106 Fax +37793108140	pah@ihb.mc
Roupé Per-Åke	City Planning Authority Box 2554 40317 Gothenburg Sweden	Tel +4631611596 Fax +4631611513	per-ake.roupe@stadsbyggnad.goteborg.se
Samuelsson Bengt	NorrköpingLocal Authority GIS-enheten 601 81 Norrköping Sweden	Tel +4611151382 Fax + 4611102707	bengt.samuelson@norrkoping.se
Savill Mike	Northern Lighthouse Board 84 George Street Edingburgh EH 2 3 DA Scotland United Kingdom	Tel +44(0)1314733155 Fax +44(0)1312202093	msavill.rlk@dial.pipex.com
Shan Jie	Department of Technology University of Gävle 80176 Gävle Sweden	Tel +4626648845 Fax +4626648828	Jsa@hig.se
Simonsson Patrik	EnatorTelub AB Box 1381 171 27 Solna Sweden	Tel +4687055053 Fax +468821967	patrik.simonsson@enator.se
Sjöberg Lars E	Dep of Geodesy and photogrammetry 10044 Stockholm Sweden	Tel + 4687907330 Fax +4687907343	sjoberg@geomatics.kth.se
Sjölin Jonas	Norrköping Local Authority GIS-enheten 601 81 Norrköping Sweden	Tel +4611151382 Fax+ 4611102707	jonas.sjolin@norrkoping.se

Annex 2

7th European Meeting of the International Information Subcommittee 3-4 December 1998 – List of participants

Skalski Hank	US Department of Transportation HQ AFSPC/OST, 150 Vandenberg St Suite 1105 Peterson AFB Colorado 80914-4020, USA	Tel +17195542570 Fax +17195549604	Hskalski@spacecom.af.mil
Sledzinski Janusz	Institute of Geodesy & Geodetic Astronomy Pl Politechnikl 1 00-661 Warsaw Poland	Tel +48226228515 Fax +48226210052	sledzinski@gik.pw.edu.pl
Sporron Lars	Swedish National Road Administration Röda vägen 1 78187 Borlänge Sweden	Tel +4624375857 Fax +4624375270	Lars.sporron@vv.se
Ståhl Bengt	Aero-Marin Navigation Måsvägen 24 183 57 Täby Sweden	Tel + 4687566589 Fax +4687566589	bengtstahl@swipnet.se
Sundberg Henrik	TERACOM AB Box 903 971 27 Luleå Sweden	Tel +46920239500 Fax +46920239661	Hsg@teracom.se
Swiek F Michael	United States GPS Industry Council Suite 520 1100 Connectiocut Ave NW Washington DC 20036 USA	Tel +2028620136 Fax +2028623929	mskwiek@aol.com
Sygel Kristoffer	Ashtech Europe Ltd 5 Curfew Yard Thames Street Windsor United Kingdom	Te+1441753835711 Fax +441753835710	kristoffer@ashetch.co.uk
Sörvik Bengt	Nordpointer AB Box 857 801 31 Gävle Sweden	Tel +4626652015 Fax +4626614120	Bengt.sorvik@nordpointer.se
Schwenk Trond	Seatex A/S Pir senteret 7005 Trondheim Norway	Tel +4773545500 Fax +4773515020	trond.schwenk@seatex.no
Ulfhielm Bo	County museum of Gävleborg Box 746 801 28 Gävle Sweden	Tel +4626655611 Fax 4626655629	Bo.ulfhielm@xlm.se
Ullvetter Christer	Swedish Civil Aviation Administration 601 79 Norrköping Sweden	Tel + 4611192312 Fax + 4611192515	christer.ullvetter@fltsafety.lfv.se
Vad Jensen Henrik	Danish Road Directorate Th Helstedsvej 11 8660 Skanderborg Denmark	Tel +4589932294 Fax +4586521701	Hvj@vd.dk
Wallin Tomas	Orblet Technologies AB Magus Ladulåsgatan 16 118 66 Stockholm Sweden	Tel +4684289020 Fax 4684289021	gps@orbcom.se

Annex 2

7th European Meeting of the International Information Subcommittee 3-4 December 1998 – List of participants

Vasiljevs Jevgenijs	National Surveying Centre of the State Land Service 11 Novebra Karstmala 31 LV 1050, Riga Latvia	Tel +3717213628 Fax+ 3717227858	Zee@lzkc.org.lv
Vejrazka Frantisek	Czech Technical University of Prague Technicka 2 166 27 Praha 6 Czech Czech Republic	Tel +420224352246 Fax+ 420224355829	vejrazka@feld.cvut.cz
Viskers Imants	Lativian CAA Airport Riga LV 1053 Lativa	Tel +3717207586 Fax + 3717207300	viskers@latcaa.gov.lv
Wübbena Gerhard	Geo++ Steinniede 8 D-30827 Garbsen Germany	Tel+49513146890 Fax +495131468999	geopp@ibm.net
Zholnerov Vadim	Russian Institute of Radionavigation and Time (RIRT) 2, Rastrelli sq St Petersburg 193124 Russia	Fax +8122731033	pisarev@rirt.spb.su
Zielinski Janusz	Space Research Centre Polish Academy of Sciences Bartycka 18A 00-716 Warsaw Poland	Tel +48226511808 Fax +4822403131	jbz@cbk.waw.pl
Ågårdh Björn	Agcom AB Dalavägen 15 A 43632 Askim Sweden	Tel +4631685870 Fax +4631685970	Bjorn.agardh@ag-com.se

IISC GAYLE INTRODUCTION

THANK YOU FOR THE INTRODUCTION. I WOULD LIKE TO WARMLY WELCOME EVERYONE TO THE MEETING.

IT IS IMPORTANT TO RECOGNISE THE CONTRIBUTION OF THE SWEDISH NATIONAL LAND SURVEY TO THE ACTIVITIES OF THE CIVIL GPS INTERFACE COMMITTEE AND ALSO THEIR WORK TO ARRANGE, ORGANISE, AND HOST THIS MEETING. IN PARTICULAR, THE SUBCOMMITTEE WISH TO THANK LENA BOBERG AND BO JONSSON FOR THEIR EFFORTS.

IT IS ALSO IMPORTANT TO ACKNOWLEDGE THE DIRECT SUPPORT OF THE US AUTHORITIES AND THE EUROPEAN COMMUNITY FOR THIS MEETING. I WOULD LIKE TO QUICKLY INTRODUCE, JOE CANNY, JIM DOHERTY, REBECCA CASSWELL, HANK SKALSKI AND ALSO FIONA MCFADDEN FROM THE EUROPEAN GNSS SECRETARIAT. FURTHERMORE THE SUPPORT OF THE US AND SCANDINAVIAN GPS INDUSTRY COUNCILS MUST BE ACKNOWLEDGED AND THEREFORE I WISH INTRODUCE THEIR REPRESENTATIVES MICHAEL SWIEK AND THOMAS REHN RESPECTIVELY.

THIS MEETING DOES PROVIDE A PLATFORM FOR CIVIL USERS AND PERHAPS MILITARY USERS TO OBTAIN GREATER INFORMATION AND UNDERSTANDING ABOUT THE CHARACTERISTICS OF GPS. FURTHERMORE, IT ENABLES CIVIL GPS USERS TO SHARE THEIR EXPERIENCES AND VIEWS WITH OTHER USERS, ALSO TO DISCUSS THEIR ACTIVITIES RELATED TO THE USE OF OTHER SATELLITE LINKED TECHNOLOGY AND APPLICATIONS.

INDEPENDENTLY OF THE ONGOING FORMAL BI-LATERAL DISCUSSIONS BETWEEN THE US, EUROPE, JAPAN AND RUSSIA, THERE IS A NEED TO MAINTAIN CONTACT AT AN INFORMAL LEVEL BETWEEN CIVIL USERS IN THE DIFFERENT COUNTRIES CONCERNED WITH THE DEPLOYMENT AND OPERATION OF GPS, GNSS AND GLONASS. THEREFORE IT IS NATURAL AT THIS MEETING OF THE UNITED STATES IISC TO ALLUDE TO OTHER TOPICS SUCH AS GNSS 1, GNSS2 AND GLONASS.

REGRETTABLY, GEORGE WEBER, THE EUROPEAN REGION VICE CHAIR WAS UNEXPECTEDLY UNABLE TO ATTEND DUE THE RECENT DEATH OF HIS MOTHER. HE HAS ASKED ME CONVEY HIS SINCERE APOLOGIES TO YOU ALL AND SENDS HIS BEST WISHES FOR A SUCCESSFUL AND OBJECTIVE MEETING.

THE IISC IS IN THE PROCESS OF RESTRUCTURING AND GEORGE WEBER RECENTLY BECAME ONE OF THE FOUR REGIONAL VICE CHAIRS COVERING EUROPE, NORTH AMERICA, JAPAN AND THE FAR EAST, AND AUSTRALISIA AND THE PACIFIC ISLANDS.

THE INTEREST IN THE IISC IS INCREASING, THEREFORE IT NEEDS TO BECOME MORE MANAGEABLE, MORE OBJECTIVE, MORE EFFECTIVE AND MORE RESPONSIVE TO THE NEEDS OF ITS MEMBERS. THE IISC OFFICIALS ARE ENDEAVOURING TO STIMULATE INTEREST IN ITS ACTIVITIES, TO PURSUE MEANINGFUL OBJECTIVES AND TO PROVIDE BENEFITS TO ITS MEETING ATTENDEES.

THE EFFORTS OF THE IISC OFFICIALS HAVE SO FAR PROVED COMMENDABLY SUCCESSFUL, BUT IT IS DEMANDING TO PROVIDE AN ATTRACTIVE AGENDA FOR EVERY IISC MEETING. HOWEVER, RECENT MEETINGS HAVE BEEN WELL ATTENDED WITH AT LEAST 100 ATTENDEES AND EXCEPTIONALLY 465 FOR THE JULY 1998 TOYKO MEETING. A SUMMARY REPORT OF THE TOKYO MEETING CAN BE MADE AVAILABLE TO YOU.

THE CGSIC OPERATES IN ACCORDANCE WITH AN EXECUTIVE BUSINESS PLAN (EBP). THE IMMINENT REVISION OF THE EBP WILL NECESSITATE SOME MINOR CHANGES IN THE CHARTER FOR THE IISC.

THE PROGRAM FOR THE NEXT TWO DAYS IS ATTRACTIVE AND INTERESTING, I DO HOPE YOUR MEETING ATTENDANCE WILL BE BENEFICIAL. DO PLEASE APPROACH THE US REPRESENTATIVES AND OF COURSE FIONA, WITH ANY QUESTIONS THAT YOU HAVE, HOWEVER MINOR THEY MAY BE. THIS MEETING IS YOUR OPPORTUNITY AS A CIVIL GPS USER TO CONVEY YOUR CONCERNS, IDEAS AND ISSUES, AND DISCUSS THEM IN DETAIL WITH REPRESENTATIVES OF THE SYSTEM PROVIDERS..

ON A PERSONAL NOTE, IT IS MY PRIVILEGE TO ACT AS THE IISC CHAIR AND TO BE IN THIS PART OF SWEDEN FOR THE FIRST TIME SINCE 1960. IF YOU HAVE QUERIES OR QUESTIONS ABOUT THE IISC, DO APPROACH MYSELF OR REBECCA CASSWELL AND WE WILL BE PLEASED TO TRY AND RESPOND TO THEM.

DO PLEASE AIM TO OBTAIN THE MAXIMUM BENEFIT FROM THIS MEETING AND THE REPRESENTATIVES OF THE CGSIC AND IISC WILL BE VERY GRATEFUL FOR ANY FEEDBACK, SUGGESTIONS OR IDEAS ON HOW TO FURTHER IMPROVE THE EFFECTIVENESS OF THE IISC. I LOOK FORWARD TO A MOST SUCCESSFUL MEETING IN A MOST APPROPRIATE LOCATION.

THANK YOU FOR THE OPPORTUNITY TO ADDRESS YOU ALL.

DOT POLICY AND PLANNING

Joe Canny
Deputy Assistant Secretary for Transportation Policy

US Department of Transportation

As Presented at IISC meeting
December '98

Overview

- Interagency GPS Executive Board
- Additional Civil GPS Frequencies
- International Consultations
- GPS Funding Issue
- GPS Vulnerability Assessment
- Spectrum Issues
- Nationwide DGPS
- Federal Radionavigation Plan

2

INTERAGENCY GPS EXECUTIVE BOARD

- Meeting March 27, 1998 IGEB agreed to implement two additional civil GPS signals.
- Meeting July 1 reviewed progress on selection of additional civil GPS signals.
- Next meeting targeted for early-mid December.

3

ADDITIONAL CIVIL GPS SIGNALS

- **IGEB decided (March 1998) to add 2nd civil signal to L2 and a 3rd signal on the Blk IIFs that can support Safety-of-Life Needs.**
- **Examining Options for 3rd signal.**
  - DOT Requires ARNS Protected Freq.
  - Analyze Impact to satellites (Signal, Power, Cost)
  - Analyze Impact to existing systems
  - Resolve Funding Issues
  - Potential Opportunities for Signal Power and Structure Enhancements
- **Decision delayed, but no negative impact because acquisition of next group of IIFs also delayed.**

4

INTERNATIONAL CONSULTATIONS

- **U.S. - Japan Agreement - Joint Statement**
  - Both Governments convinced of need to prevent misuse of GPS and its augmentations without unduly disrupting or degrading civilian uses
  - Both Governments intend to cooperate to promote and facilitate civilian uses of GPS
- **U.S. Proposals to European Tripartite Group**
  - U.S. ready to consider opportunities for expanding European insight into operation, management, and modernization of GPS civil functions
  - Europe would consider equivalent US treatment within GNSS-2
  - Both sides share expectation that consultations will help respective authorities identify ways to deal with GPS/GNSS related issues that may arise as uses of GPS/GNSS increase

GPS FUNDING ISSUE

- Current Funding Environment
  - DOD Budgeted to Sustain Constellation
  - Civil Agencies must fund augmentations and enhancements for civil benefits in their individual budgets.
  - Funds for Improvements to GPS compete with other priorities in DOD and Civil Agency budgets - Jeopardizes GPS Modernization.
- National Funding Strategy
  - Being considered by the IGEB
  - Does Not Hold Modernization Hostage to a Single Agency's Budget Request

GPS VULNERABILITY ASSESSMENT

- **PDD 63 Directs DOT, in Consultation with DOD, to evaluate vulnerability of National Transportation Infrastructure reliance on GPS.**
- **Volpe Transportation System Center has begun work on study to address vulnerabilities of civil applications.**
  - Interim Report expected in April 1999
  - Final Report Expected in December 1999
  - Consultation w/ FAA, DOD, Private Sector
- **FAA working with ATA, AOPA, and Johns Hopkins APL to perform independent GPS/WAAS risk assessment for civil aviation.**

SPECTRUM ISSUES

- **Preparing for WRC 2000**
  - Protecting L1 Band from non-ARNS systems
    - *After careful consideration, Working Party 8D agreed that sharing of the band with MSS is not feasible.*
  - Clearing L1 Band of footnotes for non-ARNS systems
  - Space-to-Space (**s-s**) Allocation for L2
    - *Expands from Space-to-Earth (**s-E**)to (**s-E and s-s**).*
  - International Coordination of new GPS Frequencies
- **Amend L-band SPS Signal Spec.**
  - Ranging signal is 2.046 MHz null-to-null
  - Transmitted Ranging Signal extends through the band 1563.42 to 1587.42 MHz

NATIONWIDE DGPS

- **Public Law 105-66 Provides Authority**
- **$31M to Implement; $6M Annual O&M**
- **$2.4M in FY98 to begin implementation**
- **$5.5 Received in FY99.**
- **Cost/Benefit ratio 1:152 in favor of Benefit**
  - *Railroads, Highways, Agriculture, Environmental, Forestry, Emergency Response*
- **Double Coverage - 67 NDGPS sites Plus Maritime DGPS sites**
  - *Two NDGPS sites transmitting - two more to begin transmitting in about two weeks*
- **Installations completed by end of 2002.**

THE WHITE HOUSE

Office of the Press Secretary
(New York, New York)

For Immediate Release September 22, 1998

JOINT STATEMENT BY THE GOVERNMENT OF THE UNITED STATES OF AMERICA AND THE GOVERNMENT OF JAPAN ON COOPERATION IN THE USE OF THE GLOBAL POSITIONING SYSTEM

On the basis of a series of discussions between representatives and experts of the Government of the United States and the Government of Japan, U.S. President William Clinton and Japanese Prime Minister Keizou Obuchi have issued this Joint Statement regarding cooperation in the use of the Global Positioning System (GPS) Standard Positioning Service for global positioning and other applications.

Background

GPS is a constellation of orbiting satellites operated by the United States, which provides signals to aid position-location, navigation, and precision timing for civil and military purposes. GPS, as an evolving system, is becoming more important for a wide variety of civilian, commercial, and scientific applications such as car navigation, mapping and land surveying, maritime shipping, and international air traffic management.

The United States Government is operating a maritime Differential Global Positioning System (DGPS), and the Government of Japan is operating a similar system. Both Governments are developing augmentation systems to support air navigation--the United States is developing the Wide Area Augmentation System (WAAS), and Japan is developing the Multi-functional Transport Satellite (MTSAT)-based Satellite Augmentation System (MSAS).

The commercial GPS equipment and services industries of the United States and Japan lead the world, and augmentation systems to enhance the use of the GPS Standard Positioning Service could further expand civil, commercial, and scientific markets.

Building a Cooperative Relationship

The United States Government intends to continue to provide the GPS Standard Positioning Service for peaceful civil, commercial, and scientific use on a continuous, worldwide basis, free of direct user fees.

The Government of Japan intends to work closely with the United States to promote broad and effective use of the GPS Standard Positioning Service as a worldwide positioning, navigation, and timing standard.

Both Governments are convinced of the need to prevent the misuse of GPS and its augmentation systems without unduly disrupting or degrading civilian uses, as well as of the need to prepare for emergency situations.

Both Governments intend to cooperate to promote and facilitate civilian uses of GPS. It is anticipated that cooperation will:

- promote compatibility of operating standards for GPS technologies, equipment, and services;
- help develop effective approaches toward providing adequate radio frequency allocations for GPS and other radionavigation systems;
- identify potential barriers to the growth of commercial applications of GPS and appropriate preventative measures;
- encourage trade and investment in GPS equipment and services as a means of enhancing the information infrastructure of the Asia-Pacific region; and
- facilitate exchange of information on GPS-related matters of interest to both countries, such as enhancement of global positioning, navigation, and timing technologies and capabilities.

The two Governments intend to work together as appropriate on GPS-related issues that arise in the International Civil Aviation Organization, the International Maritime Organization, the International Telecommunication Union, and Asia Pacific Economic Cooperation, or in other international organizations or meetings.

Cooperative Mechanism

The Government of the United States and the Government of Japan have decided to establish a mechanism for bilateral cooperation relating to the use of the GPS Standard Positioning Service, as follows:

- A plenary meeting will be held annually to review and discuss matters of importance regarding the use of the GPS Standard Positioning Service.
- Working groups will be set up under the plenary meeting to discuss issues of mutual interest. Discussions will focus initially on commercial and scientific use and transportation safety, including measures to identify and report intentional and unintentional interference, the use of the GPS Standard Positioning Service in emergency situations, and an emergency notification system. Each working group will annually report to the plenary meeting the outcome of its work.

The two Governments share the expectation that this mechanism will help the two Governments identify ways to deal with GPS-related issues that may arise as civilian use of GPS increases, and take actions as appropriate.

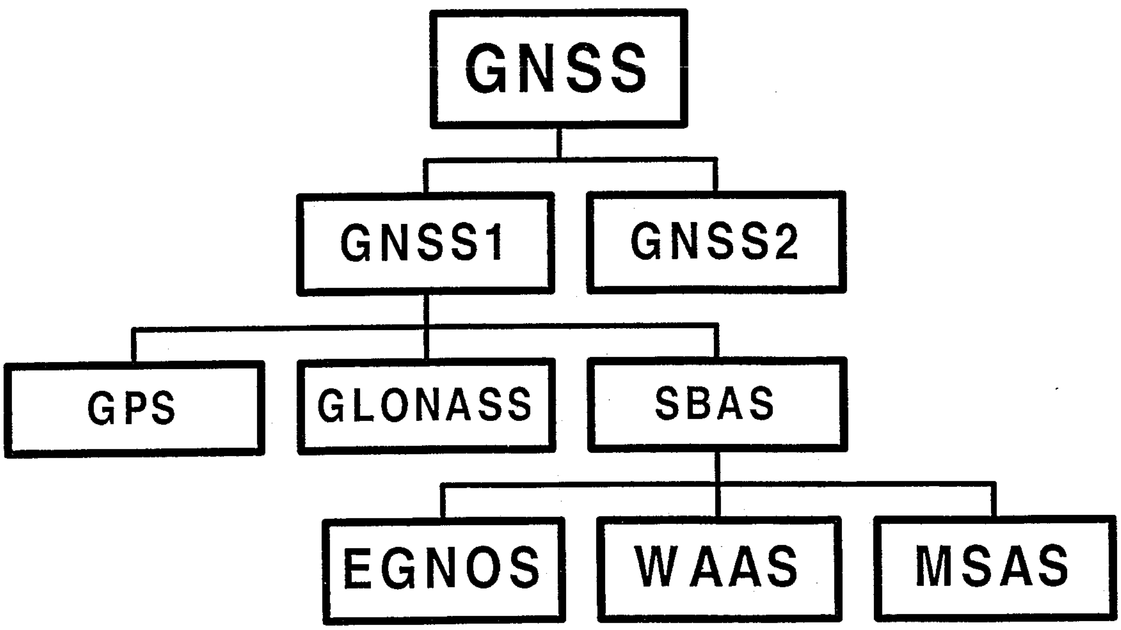
###

GNSS: The European Viewpoint

Fiona McFadden
European GNSS Secretariat
Luc Tytgat
European Commission DGVII

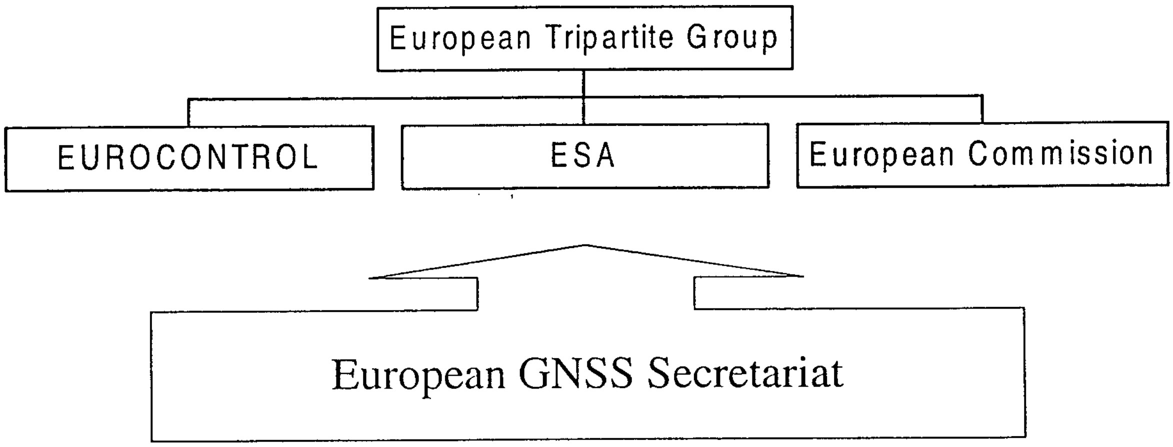
CGSIC International Information Sub-Committee, Gavle, Sweden, 3-4 December 1998

Introduction



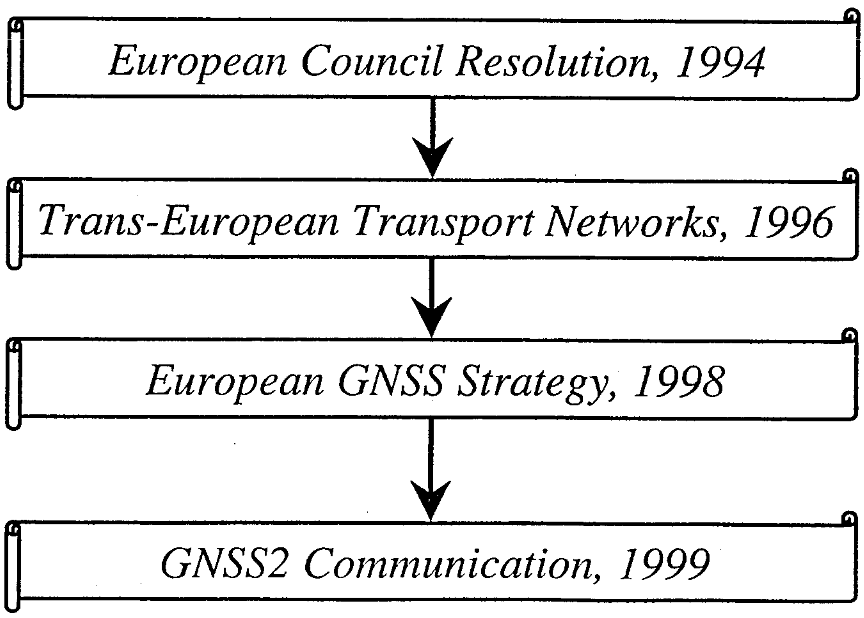
CGSIC International Information Sub-Committee, Gavle, Sweden, 3-4 December 1998

European GNSS Arrangements



CGSIC International Information Sub-Committee, Gavle, Sweden, 3-4 December 1998

GNSS Legislative Milestones

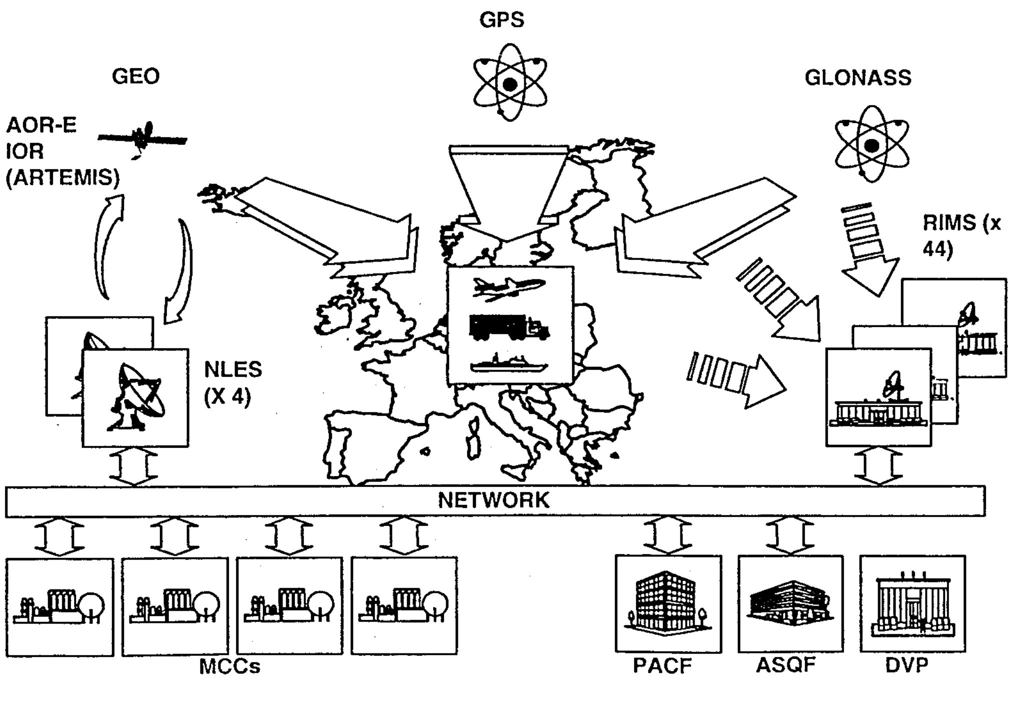


GNSS1: EGNOS

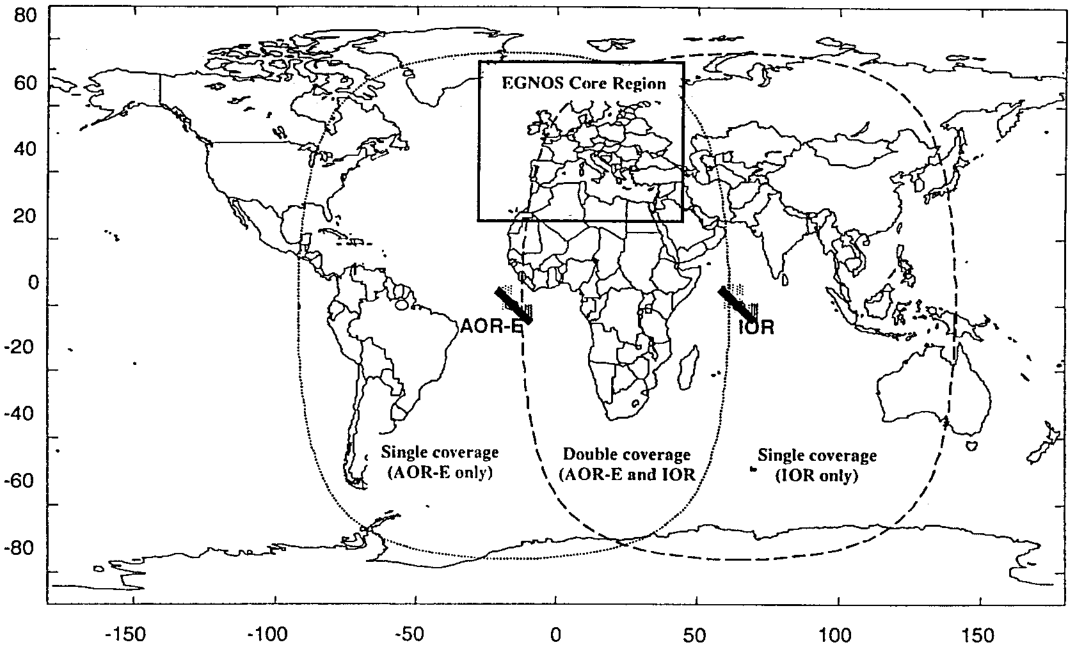
- Satellite Based Augmentation System
  - Ranging Signal
  - Integrity Information
  - Wide Area Differential Corrections
- Improves accuracy, integrity, continuity, and availability

CGSIC International Information Sub-Committee, Gavle, Sweden, 3-4 December 1998

GNSS1: Technical Architecture



GNSS1: EGNOS



CGSIC International Information Sub-Committee, Gavle, Sweden, 3-4 December 1998

GNSS: A Multi-Modal Approach

- Gathering Requirements
  - High Level Group
  - ERNP
  - User Groups

GNSS: A Multi-Modal Approach

- Disseminating Information
  - Education & Awareness
  - Conference Presentations
  - Public Relations Exercises

CGSIC International Information Sub-Committee, Gavle, Sweden, 3-4 December 1998

GNSS: A Multi-Modal Approach

- Demonstrations
  - MAGNET for user equipment
  - ICELAND for interoperability
  - EGNOS System Test-Bed

GNSS2: Background

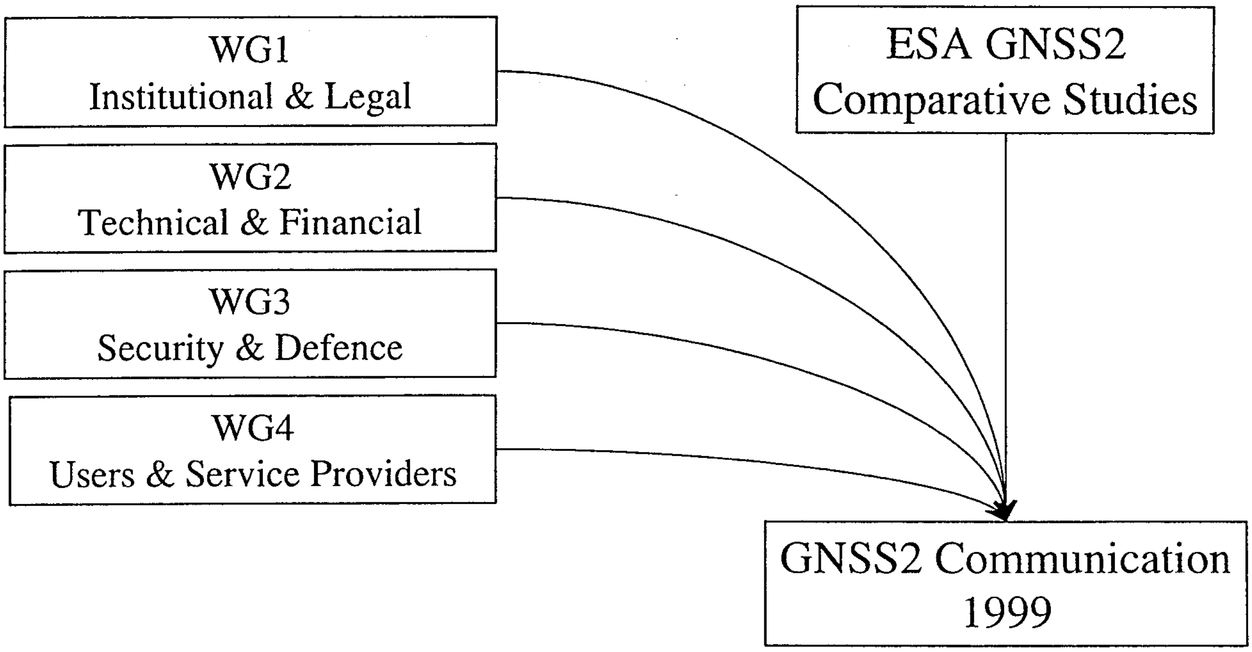
- Commission Communication
- Three Approaches
  - joint development by all players
  - one or more major partners for Europe
  - independent development by Europe
- Research activities and negotiations are being undertaken to select the most favourable option

CGSIC International Information Sub-Committee, Gavle, Sweden, 3-4 December 1998

GNSS2: FORUM

- July - December 1998
  - To support the EC decision making process
  - define requirements
  - create evaluation framework and criteria
  - assess options
  - 4 working groups
    - WG1: Institutional and legal issues
    - WG2: Technical and financial issues
    - WG3: Security and defence considerations
    - WG4: Users and service requirements
  - Work will be complete in December 1998

GNSS2: FORUM



CGSIC International Information Sub-Committee, Gavle, Sweden, 3-4 December 1998

Technical Activities

- ESA Comparative Studies
  - Address the 3 political options for GNSS-2
  - All viable alternative architectures must be investigated
    - cost-effectiveness
    - safety
    - European control
    - European industrial opportunity
    - compatibility with military needs
  - Coordinated with GNSS-2 forum

Technical Studies

- EC and ESA studies addressing technical issues
  - satellite constellations (LEO, MEO, IGSO, etc)
  - signal-structure
  - frequency spectrum
  - clocks
- Decisions on the option to be pursued will be taken in early 1999

CGSIC International Information Sub-Committee, Gavle, Sweden, 3-4 December 1998

Summary

- European GNSS Developments
  - User-driven
  - Multi-modal
  - Enable global seamless navigation

GLONASS : Status and Prospects

Vadim Zholnerov[1]

[1]Prof. Vadim Zholnerov, Deputy Director of the Russian Institute of Radionavigation and Time (RIRT), 2 Rastrelli square, Saint Petersburg, 193124, Russia, Tel : (7-812)274-6607, Fax : (7-812)273-1033.

ABSTRACT. This paper deals with the current GLONASS constellation status and the program for constellation maintenance and improvement. GLONASS error budget is also investigated. The main part of the future development is the GLONASS-M satellite upgrade. The details of the two stages of this upgrade are presented. The changes in Russian economy, structure of management and production have made a deep impact upon all essential elements of the GLONASS which are considered here. Also in the paper the Russian Frequency Band Protection Plan is specified and the adjustments to the Interface Control Document are highlighted. In conclusion, GLONASS current position in Russian aerospace development and its prospective are presented.

1. INTRODUCTION

GLONASS, the Russian satellite radionavigation system, was presented to the international community in 1988 as an available navigation system enabling free use of its signals. In September, 1993 GLONASS was put into operation and since then is an important element of the global infrastructure for positioning and timing support.

As soon as GLONASS is implemented by the International Civil Aviation Organization (ICAO) and International Maritime Organization (IMO), the Russian government will realize its international obligations on maintenance and further development of previously announced GLONASS parameters, constellation and control segment components.

GLONASS is under the operative command and control of the Ministry of Defense of the Russian Federation. Within the Ministry of Defense, responsibility for information service on GLONASS falls under the Scientific Information Coordination Center (KNITC). At the same time, the use of GLONASS for civilian applications is the responsibility of the Russian Space Agency (RKA).

The GLONASS constellation is operated by the Ground Based Control Complex. It consists of the System Control Center in Golitsyno-2 (Moscow region), several Command Tracking Stations and Quantum Optical Tracking Stations over the Russian territory. It also includes the Central Synchronizer which is a high precise atomic clock on the base of hydrogen atomic frequency standards for forming GLONASS system time scale.

The GLONASS system integrator is the Research and Production Association of Applied Mechanics (NPO PM). This enterprise, which is located in Krasnoyarsk city area of Siberia, is responsible for space segment development and particularly for spacecraft design. It also designs software for System Control Center. There are some other enterprises and institutions that are engaged in GLONASS development. Among them the Institute of Space Device Engineering (NII KP), which designed the Ground Based Control Complex and user navigation equipment, and the Russian Institute of Radionavigation and Time (RIRT) in St.Petersburg which develops the master clock system, satellite clocks and user navigation equipment. The current Block IIc GLONASS satellite has three cesium atomic beam frequency standards, produced by RIRT. The Central Scientific Institute of Machine Building (TcNII-Mach) and Moscow Aviation Institute (MAI) also take part in research and development, mostly as consultants to the primary contractors.

2. GLONASS CURRENT STATUS

The original GLONASS constellation was envisaged 24 satellites in three orbital planes with ascending nodes 120^0 apart. It was proposed that satellites should be equally spaced in each plane with argument of latitude displacement of 45^0. The planes themselves have 15-degrees argument of latitude displacement. The constellation should be populated by filling these predefined orbital slots. A mean rate of

orbital plane precession is $0.59251 \cdot 10^{-3}$ radian/day. Each satellite operates in almost circular 19,100 km orbit (with 0±0.01 eccentricity) at an inclination angle of $64.8^0 \pm 0.3^0$, and completes one orbit in 11 hours 15 minutes 44 seconds ± 5 seconds.
Currently there are 13 operational satellites and one spare in the GLONASS constellation. The following is the GLONASS status as of November 16, 1998.

Table 1

GLONASS number	COSMOS number	plane/ slot	Freq. number	Production	Launch date	Satellite status	Termination date
758	2275	3/18	10	11.04.94	04.09.94	Operational	
760	2276	3/17	24	11.04.94	18.05.94	Operational	
767	2287	2/12	22	11.08.94	07.09.94	Unusable	05.11.98
770	2288	2/14	9	11.08.94	04.09.94	Unusable	20.11.97
775	2289	2/16	22	11.08.94	07.09.94	Operational	
762	2294	1/4	12	20.11.94	11.12.94	Operational	
763	2295	1/3	21	20.11.94	15.12.94	Operational	
764	2296	1/6	13	20.11.94	16.12.94	Operational	
765	2307	3/20	1	07.03.95	30.03.95	Operational	
766	2308	3/22	10	07.03.95	05.04.95	Operational	
780	2316	2/15	4	24.07.95	26.08.95	Operational	
781	2317	2/10	9	24.07.95	22.08.95	Operational	
785	2318	2/11	4	24.07.95	22.08.95	Operational	
776	2323	2/9	6	14.12.95	07.01.96	Operational	
778	2324	2/9	11	14.12.95		Spare	
782	2325	2/13	6	14.12.95	18.01.96	Operational	

To maintain and improve the constellation, two launches have been scheduled for this year and next year. GLONASS satellites are launched three at a time by a Proton launch vehicle. Initially the spacecraft enters an intermediate 200 km circular orbit. From this orbit they are transferred to an elliptical orbit with an apogee of 19,100 km. After perigee correction the satellites enter a GLONASS circular orbit. Each satellite has correction engines for final insertion into the planned orbit slot. The launch, positioning and checkout in average take about 1 month. A Proton launch that will position satellite group N28 (consisting of 3 GLONASS satellite) was scheduled for the 3rd quarter of 1998 and then postponed to the 4th. The following Proton launch is expected within the first two quarters of 1999. This launch will place into orbit two GLONASS satellites and the first GLONASS-M (stage 1) satellite.

The most interesting aspect for users is the cooperative utilization of GPS and GLONASS. The accuracy, availability and integrity of a joint system is much better than those of any single system. This give the international community new opportunities in worldwide cooperation for navigational programs and can give a number of advantages for regional augmentation systems, such as EGNOS and MSAS.

Concerning most recent GLONASS development, the correction of the National Standard of UTC(SU) had been conducted. This operation allowed to reduce a difference between UTC(SU) and GLONASS System time down to 1 mks. The work on Earth rotation data transfer and comparison between UTC, GPS and GLONASS time scales continues in order to guarantee UTC transfer through GLONASS with precision of 20 ns. The new reference book on PZ-90 is issued by Topography Service of the Russian Defense Ministry. This book presents a recommended matrix for coordinate transformation between PZ-90 and WGS-84.

In order to highlight the GLONASS characteristics let us consider the GLONASS system error budget. We can divide the measurement errors into two groups : instrumental errors and ionospheric and tropospheric errors. Let us divide the instrumental errors of pseudorange measurements, in their turn, into the following three sorts of errors :

- errors of the mutual synchronization of navigational signals;
- input error of the receiver;
- error caused by non-identity of the receiver channels.

Analysis shows [1,2] that the GLONASS error budget for a favorable session (where both observed satellites have high elevations) is as follows :

- synchronization error $\sigma_D^{(1)} = 6$ m;
- input error $\sigma_D^{(2)} = 2.5$ m;
- channels non-identity error $\sigma_D^{(3)} = 1.2$ m;
- ionospheric error (maximum solar activity) $\sigma_D^{(4)} = 9...11.5$ m;
- total error $\sigma_D = 11...13$ m.

This value is uniformly distributed and has zero expectation; maximal error corresponds to $2\sigma_D$ and is equal to $\sigma_{Dmax} = \pm 26$ m.

Now let us consider sources of errors and error budget for the measurement of the pseudorange rates difference relative to two observed satellites with altitudes in the range between 300 km and 1,400 km. Basic sources of the pseudo range rate errors are the following :

- fluctuation of the onboard GLONASS satellite frequency reference;
- instability of the phase characteristic of the GLONASS satellite transmitter;
- influence of the ionosphere;
- instability of the phase characteristic of the receiver.

Estimations [1,2] give the following values of maximal errors of the GLONASS pseudorange rate measurements :

- for a favorable session $\sigma\dot{D} = \pm 0.1$ m/s;
- for an unfavorable session $\sigma\dot{D} = \pm (0.3...0.5)$ m/s.

3. GLONASS FUTURE DEVELOPMENT

The current economic situation certainly affects GLONASS maintenance and future development. The enormous changes in Russian economy, in structure of management and production and even in structure of country gave a deep mostly negative impact on GLONASS development. This impact hits all essential elements of the system - space segment, control segment and user segment. The control segment have been dramatically reduced due to ejection of the former Soviet Republics territories. The current Russian economic difficulties also affect constellation maintenance and further development. Despite the fact that there are enough spare GLONASS satellites on the ground and launch vehicles are available even to put them into orbit, troubles with budget have slowed down the support of the constellation. However, there is relatively small percentage in comparison with the system cost; left to invest to put satellite into an orbit. Also there has been negative influence on the progress of user equipment development. Currently, due to the strong traditions of the planned economy in Russia, there are no Russian enterprises in the domestic receiver market. Russians firms are used to merely develop rather unique high-end advanced technology receivers for special orders.

Nevertheless, GLONASS has a high priority in Russia aerospace development, so its improvement is still a possibility. Despite the current difficulties, the Russian Government gives support to the GLONASS program, that is reflected particularly in the documents issued so far. Currently there are two the most important official documents :

- Russian Federation Government Decree № 237 on March 7, 1995 "About conducting work on GLONASS implementation for civilian users";
- Russian Federation Government Decree № 1435 on November 15, 1997 "On Federal support program for the use of the GLONASS global navigation satellite system for the benefits of civil users".

The main purpose of the Federal support program for the use of the GLONASS is to forge development of user navigation equipment in Russia. A specific feature of the up-to-date development stage as regards user equipment in Russia is an intent to realize integrated receivers operating via GLONASS and GPS signals at the same time. In such a situation, those enterprises were the most successful wich were able to recruit foreign partners for joint works. Examples of such developments are the following :

- 18-channel integrated GLONASS/GPS receiving measuring module ASN-22 - joint development of the Russian Institute of Radionavigation and Time (Saint-Petersburg) and DASA NFS (Germany);
- compact cheap 16-channel one-board integrated GLONASS/GPS KS-161 receiver - joint development of Kotlin Company (Saint-Petersburg) and Samsung Electronics (Korea).

Another examples of successful developments as regards integrated GLONASS/GPS receivers are presented in Table 2.

Table 2

Firm, location	Receiver type	Number of channels
RNII KP, Moscow	GROT-N	14
RIRT, St.Petersburg	ASN-21M	6
DB NAVIS,Moscow	CH 3001, 3002, 3003, 3101, 3102, 3202, 3203, 3301	14
NPO PM, Krasnoyarsk	MRK-14, 15	3+3
Kotlin, St.Petersburg	A-744	6
MDB Compass, Moscow	A-737	12
MDB Compass, Moscow	INTER-A	12
MDB Compass, Moscow	TERMINATOR	12
	SNS-2	24

The 4th version of GLONASS ICD has been prepared [2]. This version particularly carries information on GLONASS Navigation Message modernization steps, recommendations on leap second correction for GLONASS receiver and gives corrected PZ-90 parameters. The corrected version of the GLONASS navigation message should improve accuracy and integrity of navigation data and better combine GLONASS and GPS time scales.

There are other GLONASS issues that are the subject of continuous discussions and development. GLONASS will improve if the following main issues are resolved :

- protection of frequency band from the recently introduced new systems of mobile satellite communication;
- integration of international standards concerning GLONASS use;
- update of the GLONASS constellation to the new generation GLONASS-M satellites without harming the existing constellation and navigation characteristics of the system;
- improving reliability and accuracy of timing and positioning.

In addition, there are many other questions which are not expanded here, being the basis of investigations among the Russian and international organizations and commissions The main contribution to the GLONASS system development is the GLONASS-M satellite upgrade. There are two stages of GLONASS satellite upgrade which were scheduled initially [2]. The first stage (before 1999) concerned the development of the improved GLONASS satellite with 5-year active life-span. Due to the increased fuel load, the mass of satellite will increase from 1,300 kg to approximately 1,480 kg. This change will cause a modification to the Proton launch vehicle. The satellite will have a better attitude control system, thus improving the accuracy of the ephemeris calculation up to 30-40 %, and an improved, more stable cesium atomic beam frequency standard for improved time signals. A longer life-cycle will also be supported by improved spacecraft electronics and modernized batteries. The radio and laser crosslinks between satellites will support more precise ephemeris and onboard time keeping. From the outset the repopulating of the GLONASS constellation with GLONASS-M (stage 1) satellites was not planned to be completed until 2000.

The GLONASS-M (stage 2) satellite is scheduled to be used after 2000. And more realistic time frames now probably should be expand to 2005. The program of satellite Stage 2 Upgrade should include the following :

- transition to the frequency band 1,598.0625 - 1,605.3750 plus minus 0.511 MHz (channels -7 - +6) and the reduction of out-of-band interference level;
- improvements to the stability of the on-board synchronizing system that will increase the accuracy of navigation signal phase synchronization by as much as a factor of two (±7.5 ns);
- navigation signal transmission on L2 frequency for civil users in order to eliminate the ionospheric component;
- transmission of a warning signal when a satellite becomes unsuitable as a component of the navigation system within 10 s after the fault occurs.

Let's consider the first issue in detail. Each GLONASS satellite transmits two types of signal : Standard Precision (SP) and High Precision (HP). The satellite transmits both SP and HP signals at L1 frequency and HP at L2 frequency. The system uses frequency division multiple acces in the L-band :

$$L1 = 1{,}602 \text{ MHz} + n0.5625 \text{ MHz},$$
$$L2 = 1{,}246 \text{ MHz} + n0.375 \text{ MHz},$$

where n is the frequency channel number (n = 0,1,2,...24), L2/L1 = 7/9. The carrier with n = 0 isn't used for navigation, only for testing. This means that each satellite transmits the same code on its own frequency which differs from the other satellites. However, some satellites have the same frequencies, but these satellites are placed in antipodal slots of the orbit planes and they do not appear at the same time in the user's view.
The planes, slots and frequency numbers are presented below for each of the current satellites.

Table 3

Plane 1/slot	01	02	03	04	05	06	07	08
Frequency number	-	-	21	12	04	13	-	-
Plane 2/slot	09	10	11	12	13	14	15	16
Frequency number	06	09	04	22	06	-	-	22
Plane 3/slot	17	18	19	20	21	22	23	24
Frequency number	24	10	-	01	-	10	-	-

During the last international conference of the International Telecommunication Union (ITU) WRC-97 (Geneva, October 27 - November 21, 1997), an additional distribution of frequency bands assigned to aerospace satellite systems was proposed to accommodate Mobile Satellite Service (MMS) system requirements. A decision was postponed till the WRC-99. Nevertheless, pressure from the MMS community on global navigation systems is increasing. The main point about the MMS viewpoint is the misconception that GNSS is making excessive demands for protection level from MMS emissions.
The necessity for GNSS frequency band protection was emphasized during the International Conference of ICAO in Moscow on January 20-23, 1997. There were different opinions on the spectra borders which should be protected by the recommendations of ITU under Directive RM 1343. The Russian Federation position is that the frequency bands for GLONASS must be protected as follows :

- before 2005 : 1,593.0625 - 1,613.75 MHz;
- after 2005 : 1,593.0625 - 1,609.25 MHz.

It close connected to the GLONASS transitional frequency plan as it was announced in the Interface Control Document in 1995. The protection plan covers a wider band that it should under the ICD plan. Partially it connected to the delay in constellation upgrade, partially to protection from interference. Some part of GLONASS spectra, that is inside ARNSS band, became unutilized due to the frequency transaction plan. Russian officials are currently working under proposals to use these frequencies for spaced based augmentation systems worldwide. This action should also help to protect GNSS band more effectively.

Russia is participating in various international organizations like ICAO, IMO etc. in order to establish rules and regulations as well as certification of the Global Navigation Satellite Systems (GNSS). In the agreement between the Russian Federation Government and ICAO, GLONASS should be used as a main component of GNSS along with GPS. At present, working group of ICAO experts are developing standards and recommended practices (SARP) that would be necessary for using GNSS in general aviation. These SARP will include the technical characteristics and requirements for GNSS elements (including onboard GPS/GLONASS aircraft receiver) plus ground- and spaced-based augmentation systems (reference stations and the equipment for differential corrections transmission).

The Russian Federation and the European Union began to negotiate on cooperation as regards maintenance, development and use of GLONASS [3]. The Russian delegation comprises : Yu.G.Milov, Chief of Delegation, Deputy Director General of the Russian Space Agency ; V.G.Grin, Deputy Commander-in-Chief of the Strategic Missile Forces for Space Facilities; V.A.Pavlikov, Deputy Director of Department of the Russian Ministry of Foreign Affairs; V.P.Martynyuk, Chief of Scientific/Technical Office of the Russian Ministry of Transportation; V.I.Denisov, Deputy Chairman of Inter-Agency Commission "Internavigation"; A.A.Martynov, Chief of RSA Department.

As a result of negotiations, one can determine specific directions and forms for mutually beneficial cooperation in order to prepare and conclude agreement between the Russian Federation and the European Union on integration of the Russian GLONASS into the European Global Navigation System (GNSS).

One can start on the assumption that Russia will maintain and improve GLONASS, providing its main previously announced parameters over a time period no less than 15 years. A signal of standard precision will be available on the constant global base for civilian, industrial and scientific use without any direct returns; no methods for signal coding or coarsening are being planned. A signal of high precision will be available according to the order set up.

Possible cooperation directions and forms would be as follows :

- satellite navigation program coordination between the European Triple Group and RKA;
- investigations of the technical problems as regards development of promising European civil global navigation satellite system;
- more effective joint use of the Russian GLONASS by means of joint development and implementation of navigation user equipment and GLONASS/GPS monitoring stations, GLONASS-M satellite onboard equipment, joint system financing, check-out and control;
- dissemination of EGNOS using GLONASS as a GNSS-1 component onto territories of Russia and CIS;
- development of requirements and concept determination for GNSS-2;
- joint development and test of GNSS-2 main elements.

In spite of all mentioned obstacles one can be confident in GLONASS improvement and development in nearest future.

REFERENCES

1. Satellite Radionavigation Systems/Under supervision of Prof. V.S.Shebshayevich.-2nd Ed.-Moscow : Radio and Communications, 1993.
2. Vladimir Bartenev, Mikhail Krasilshikov, Mikhail Lebedev, Ivan Petrovski. GLONASS Project. Status and the Future Development // Proceedings of ION GPS -98, USA, September 15-18, 1998.
3. Negotiations between Russia and the European Union // Navigation News (Russia), Scientific & Technical Center 'Internavigation'.-1998.-№ 2.- pp.12-13.

GLOBAL POSITIONING SYSTEM (GPS) CONSTELLATION STATUS

0050

0051 ## *Constellation Status*

SLOT

PLANE

	1	2	3	4	5
A	SVN39	SVN25	SVN27	SVN19	SVN38
B	SVN22	SVN30	SVN13	SVN35	
C	SVN36	SVN33	SVN31	SVN37	SVN28 End of Life
D	SVN24	SVN15	SVN17	SVN34	
E	SVN14	SVN21	SVN40	SVN23	SVN16
F	SVN32	SVN26	SVN18	SVN29	IIR-2 SVN43

IIR-3
SVN50
(22 Apr 99)

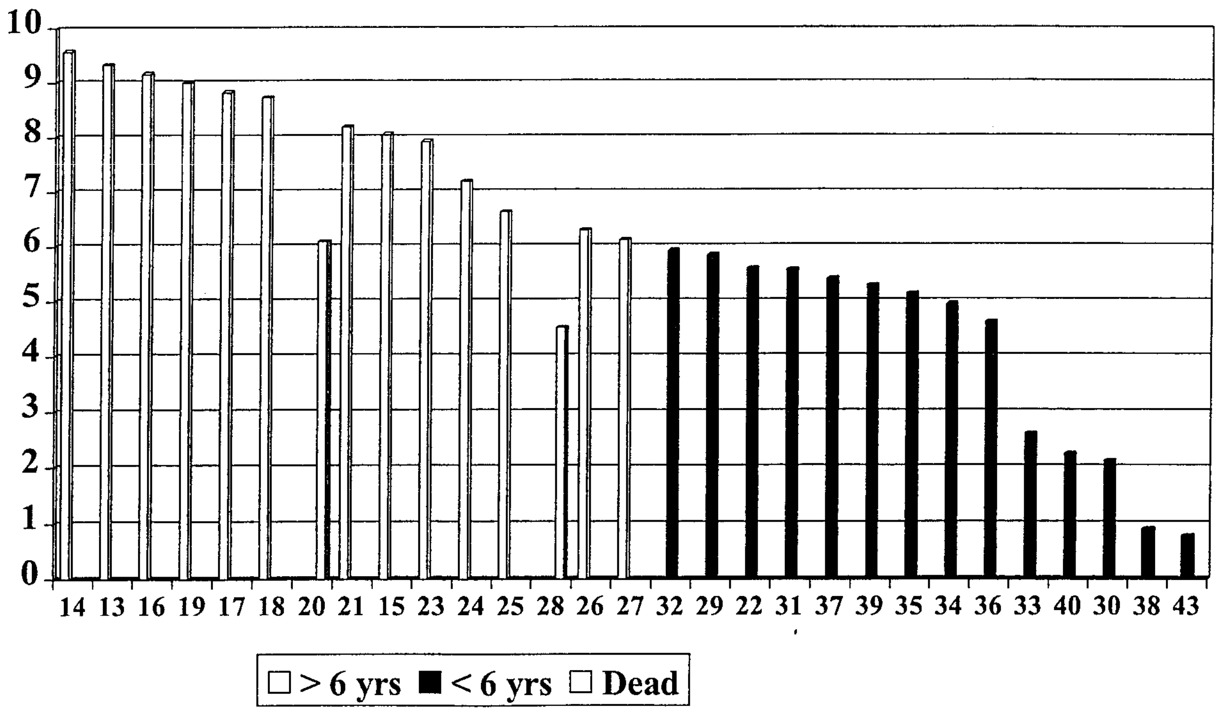
IIR-4
SVN51
(Sep 99)

27 Operational Satellites On Orbit

STATUS "GREEN"

END OF LIFE TEST

Operational Age of Satellites, Dec 98



Methods of GPS User Notification

0052

- Notice Advisory to NAVSTAR Users (NANU)
- Notice to Airmen (NOTAM)
- Broadcast Notice to Mariners (BNM)
- Satellite Navigation Message

Reporting Requirements

Previously

NO OFFICIAL DIRECTIVES FOR REPORTING AND CONTROLLING REMOVAL OF A SATELLITE FROM SERVICE

Now

2nd SPACE OPERATIONS SQUADRON HAS EXPLICIT GUIDANCE

0053

Guardian Tiger Team

- Civil Representation
  - USCG
    - NAVCEN
  - FAA
    - US NOTAM Office (USNOF)

Guardian Tiger Objectives

- Determine types and format of the information
- Determine the timing constraints
- Determine how to distribute the information
- Revalidate organizational responsibilities

Defining New Requirements

Guardian Tiger Results

- Agreed on new NANU format
- Consolidated initial NANU and NOTAM
- Defined time requirements
- Defined distribution process
- Drafted 14 AF Operating Instruction

Changes in NANU Format

- NANU Number
  - Previous: 123-97365
  - New: 1998123
- Gives end time instead of "Up to 12 Hours"
  - Previous: 365/0300 - Up to 12 hours
  - New: 365/0300 - 365/1500

New NANU Format

NOTICE ADVISORY TO NAVSTAR USERS (NANU) 1997123
SUBJ: FORECAST OUTAGE PRN08 (SVN38) JDAY 237/1230-238/0030

1. NANU TYPE: FCSTMX
   NANU NUMBER: 97123
   NANU DTG: 031234Z AUG 1997
   REFERENCE NANU NUMBER: N/A
   REFERENCE NANU DTG: N/A
   SVN: 38
   PRN: 08
   START JDAY: 237
   START TIME ZULU: 1230
   START CALENDAR DATE: 25 AUG 97
   STOP JDAY: 238
   STOP TIME ZULU: 0030
   STOP CALENDAR DATE: 26 AUG 97

2. CONDITION: GPS SATELLITE PRN08 (SVN38) WILL BE UNUSABLE ON JDAY 237 (25 AUG 97) BEGINNING 1230 ZULU UNTIL JDAY 238 (26 AUG 97) ENDING 0030 ZULU.

3. CONTACT INFORMATION HERE.

NANU Types-Forecast Outages

- **FCSTDV:** Delta-V maneuvers
- **FCSTMX:** Ion-Pumps, software testing, etc.
- **FCSTEXTD:** Extends FCST NANU until further notice
- **FCSTSUMM:** Summary of FCST outage time
- **FCSTCANC:** Cancels FCST outage - no new date
- **FCSTRESCD:** Cancels and reschedules a FCST outage

Must be sent 96 hours before the outage

NANU Types-Unscheduled Outages

0056

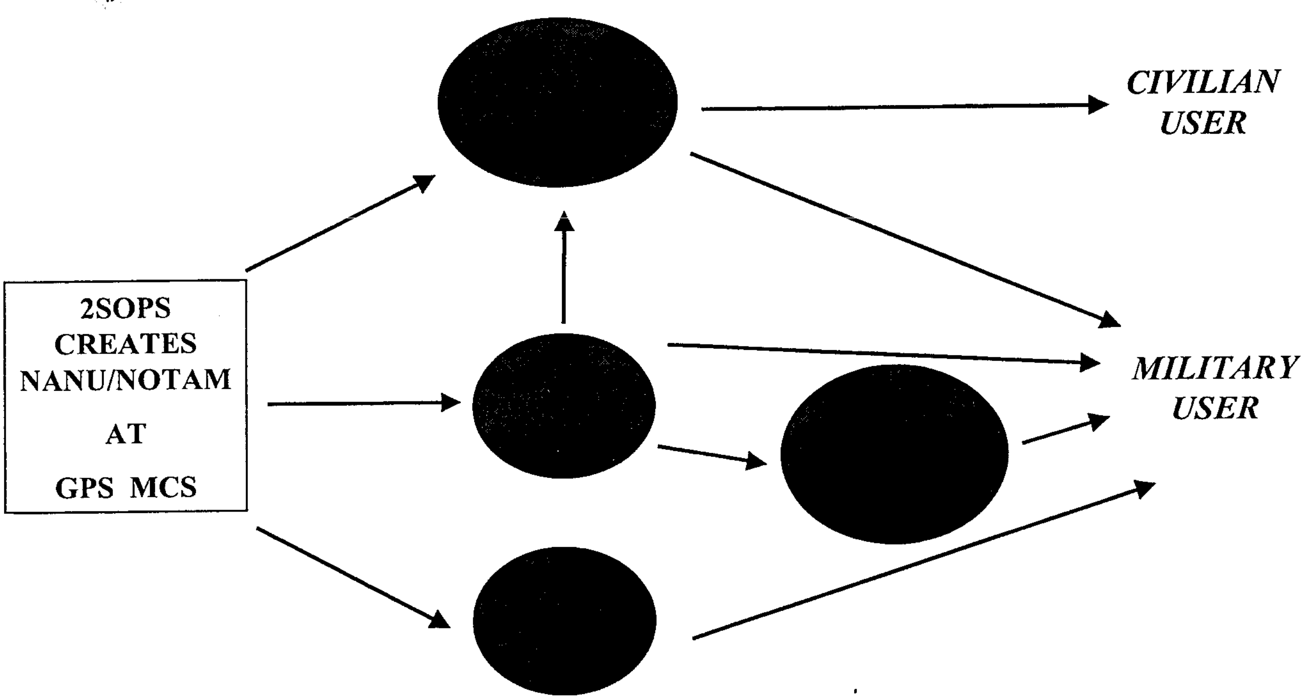
- **UNUSUFN:** Unusable until further notice
- **UNUSABLE:** Summarizes outage time for UNUSUFN
- **UNUNOREF:** Summarizes outage time with no reference NANU

Must be sent within 1 hour of the outage start time

UNCLASSIFIED

UNCLASSIFIED

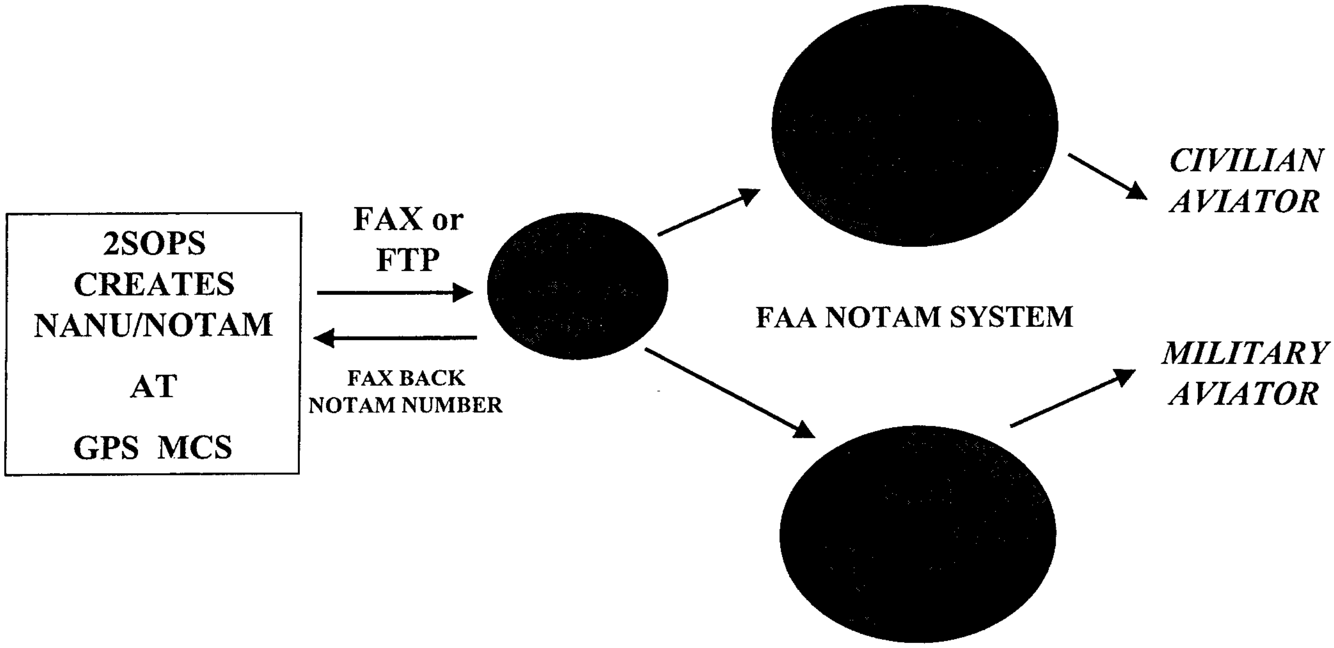
NANU Distribution Process



UNCLASSIFIED

NOTAM Distribution Process

0057



Summary

- We have a good healthy constellation
  - 27 Operational Satellites
- GPS User Support - Outage Notification
  - 2 SOPS provides outage information to the NAVCEN, USNOF, and DoD users
  - NAVCEN and USNOF distribute the information to civilian users
  - For utmost protection from imperfect data, design receiver IAW ICD-GPS-200

GPS Modernization and Operational Issues

IISC Meeting

Gavle, Sweden

December, 1998

Mr. Hank Skalski
US Department of Transportation

Overview

- What is GPS Modernization?
- System Improvements
- Operational Improvements
- Summary

What is GPS Modernization?

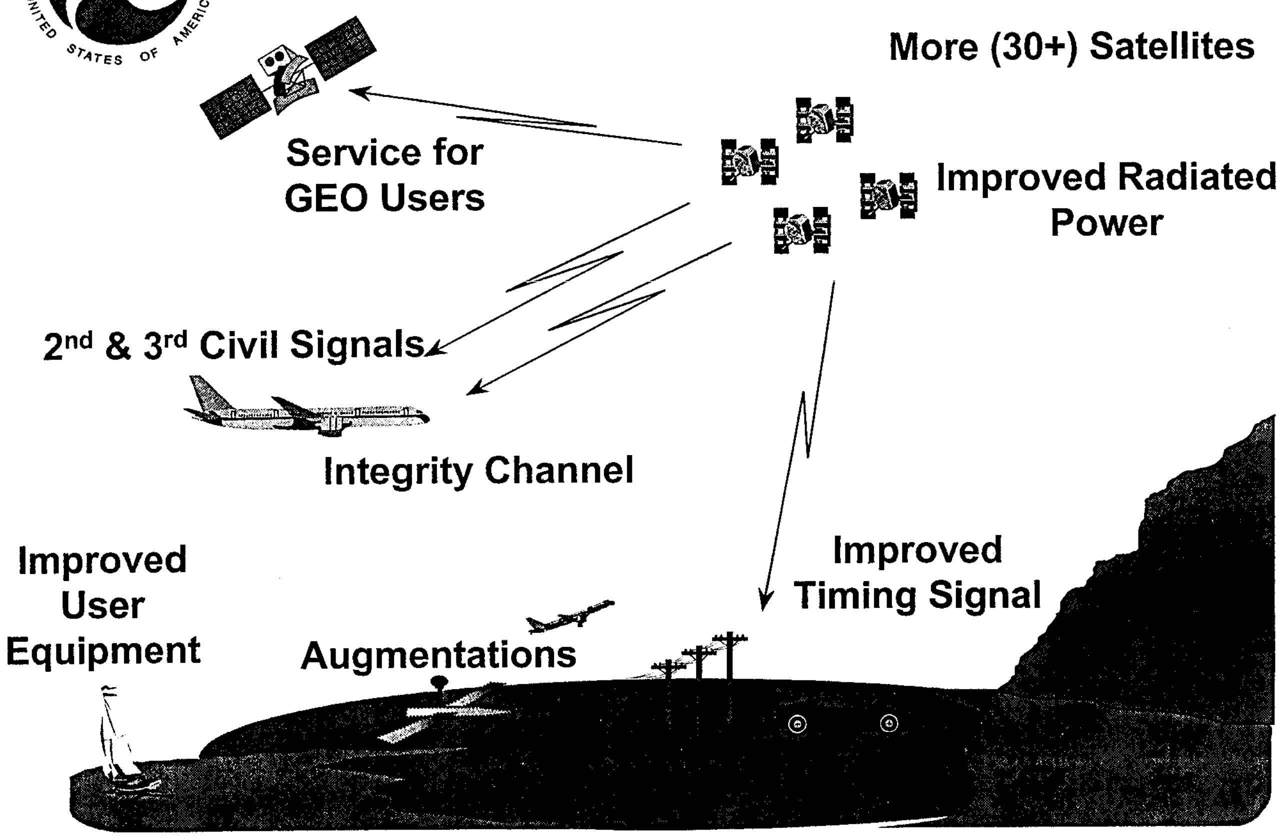
- Enhance GPS to Meet Civil Safety-of-Life and Economic Needs
  - Improve accuracy
  - Improve availability
  - Integrity
  - Improve protection from interference
  - Ensure backward compatibility with existing user equipment

What is GPS Modernization?

0060

- **Modernization has two components**
  - **System Enhancements**
  - **Operational Improvements**

System Enhancement Proposals



Modernization Analysis & Funding

0061

- Analysis of Alternatives
  - Requirements Validation
  - Cost Benefit
- Funding
  - Identify Source

Operational Improvements

- Interference Reporting and Resolution
- User Notification

GPS Interference

- **Interference happens!**
  - Intentional
    - Coordinated In-Band Test/Training Activities
    - Jamming
  - Non-Intentional
    - In-Band Test/Training Activities
    - Out-of-Band

Interference Reporting

DoD/DOT Civil Use of the GPS MOA, Annex 3: Information Coordination and Dissemination

- "...facilitate the timely reporting and resolution of a GPS PVT service operational disruption or degradation."
- "...establish a common repository for maintenance of reports and analyses related to cases of GPS PVT service operational disruption or degradation."

Reporting Responsibilities

0063

- Civil Responsibilities
  - USCG Navigation Center (NAVCEN)
    - Focal point of all civil GPS SPS interference reports, other than aviation cases
  - FAA National Maintenance Coordination Center (NMCC)
    - Aviation's single focal point for processing GPS SPS interference reports

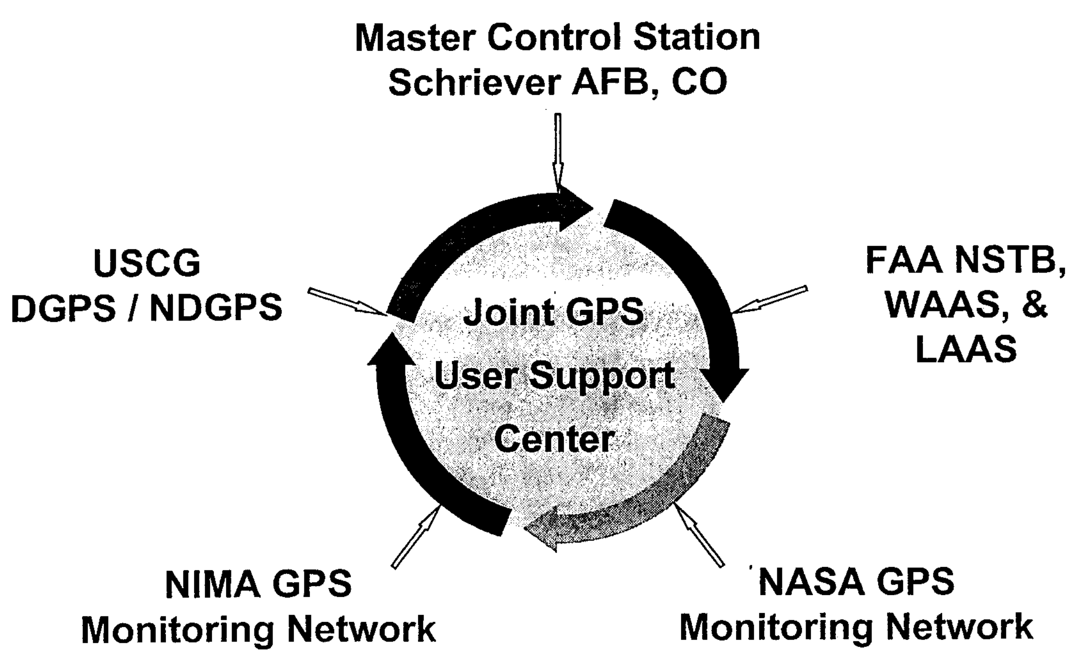
Reporting Responsibilities

- Military Responsibilities
  - US Space Command
    - DoD focal point for reporting cases of GPS PVT service operational disruption or degradation.
    - Accept and respond to GPS SPS problems reports from the NAVCEN and NMCC
    - Inform the NAVCEN and NMCC of operational changes to the GPS constellation which may impact civil use of the SPS

Bringing It Together

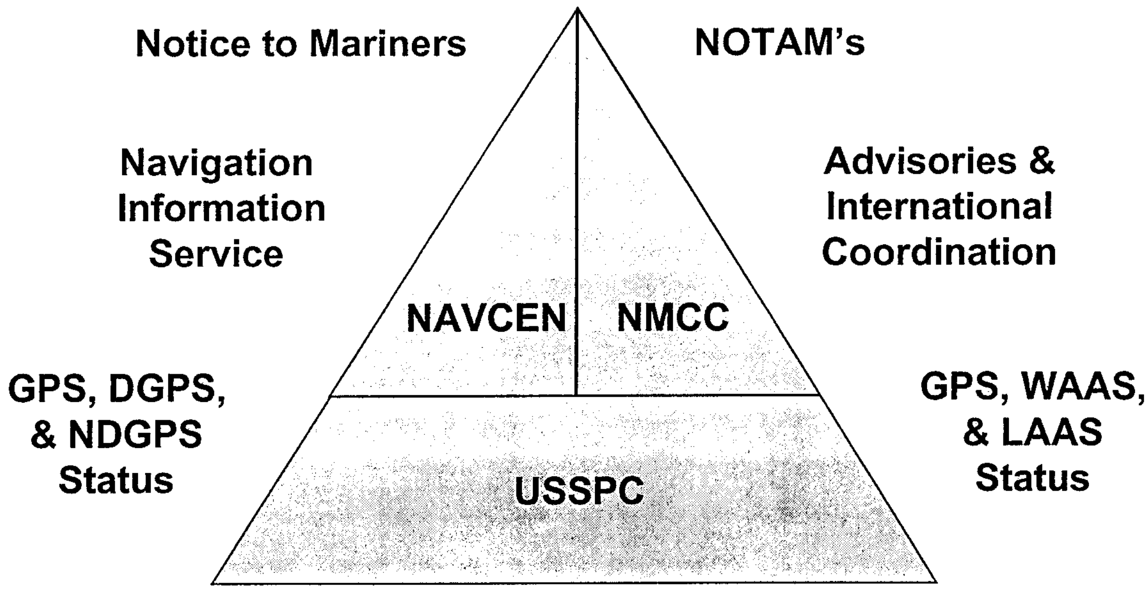
- **Joint DoD / DOT GPS User Support Center**
  - **Continuous performance monitoring**
  - **Respond to user problem reports and requests for information**
  - **Coordinate the collection, analysis, and distribution of information related to all GPS anomalies and PVT service operational disruption or degradation**

Performance Monitoring

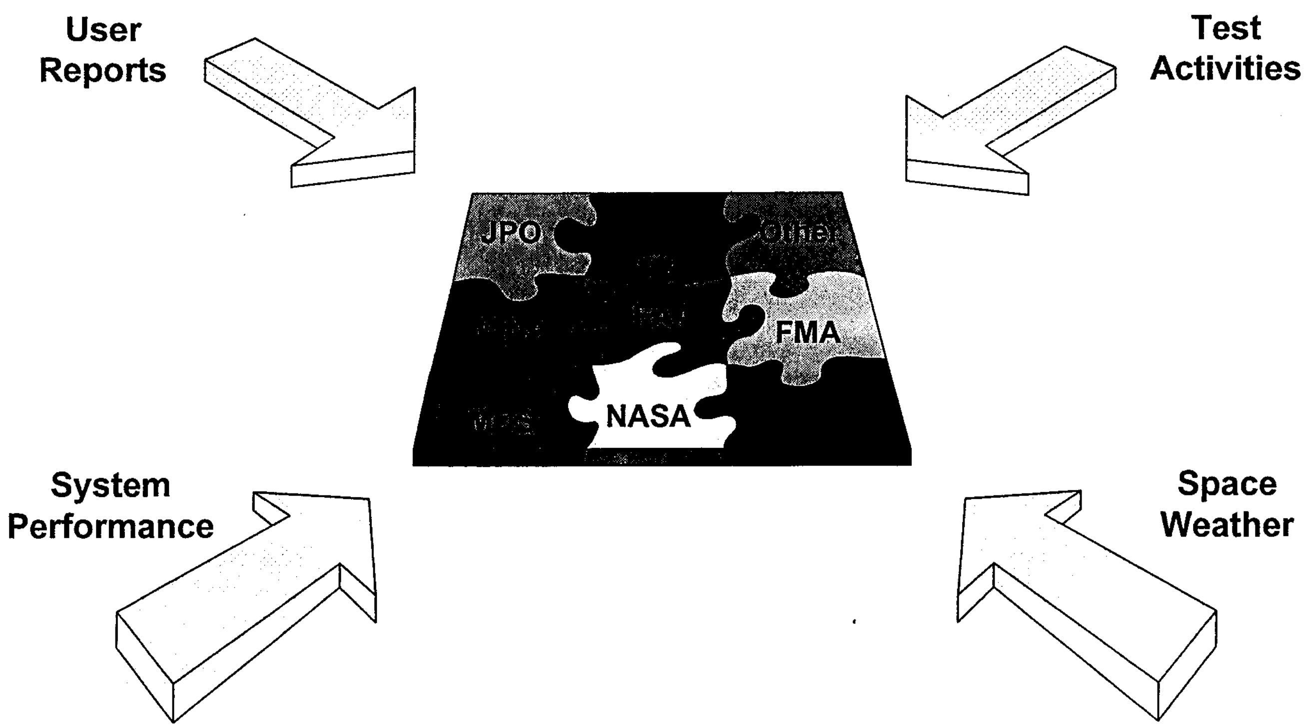


Response/Distribution To User's

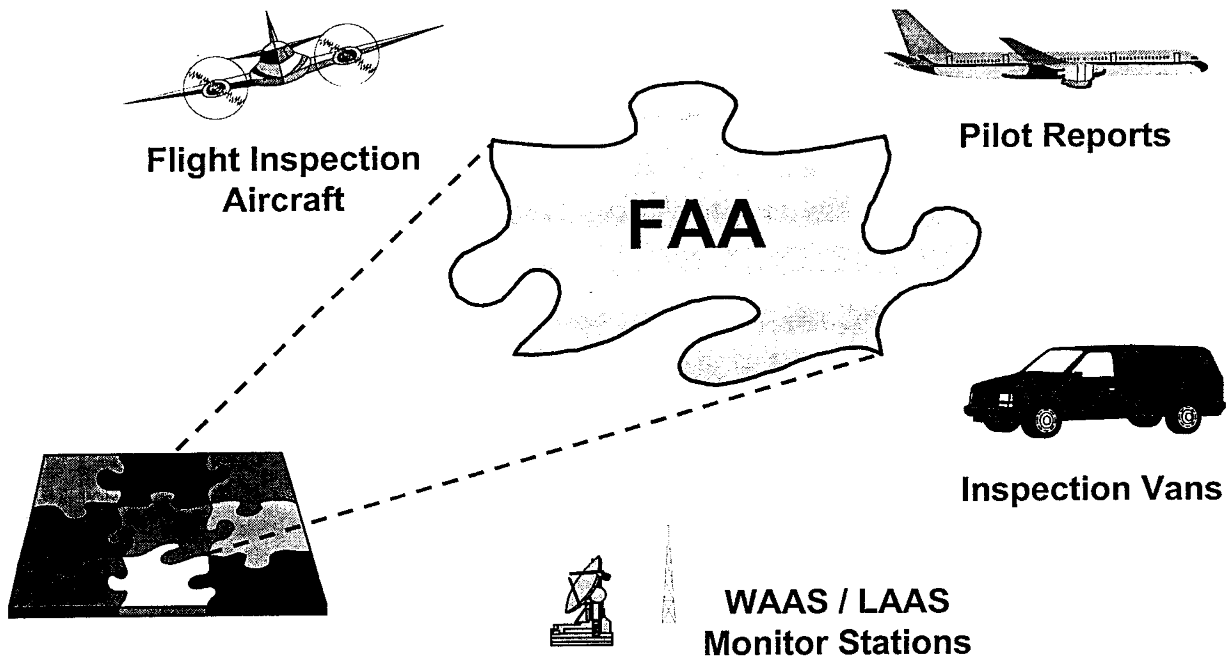
0065



Analysis



Resolution



Summary

The Global Positioning System
will be sustained and enhanced
to meet today's

Civil Safety-of-Life

and

Economic Needs

and will continue to evolve and provide a global navigation and timing service into the new millennium.

EGNOS

The European Satellite Augmentation to GPS and GLONASS

CIVIL GPS SERVICE INTERFACE COMMITTEE
International Information Sub-Comitte

Rafael Lucas (rlucas@estec.esa.nl)
ESA/Directorate of Applications/GNSS Programs

European Space Agency
GNSS-1 Project Office

3 December 98, Gavle, Sweden

PRESENTATION OUTLINE

- European Satellite Navigation Programme
- EGNOS Fundamentals
- Operational Objectives
- System Architecture
- EGNOS Test Bed
- EGNOS AOC Implementation Programme
- Summary

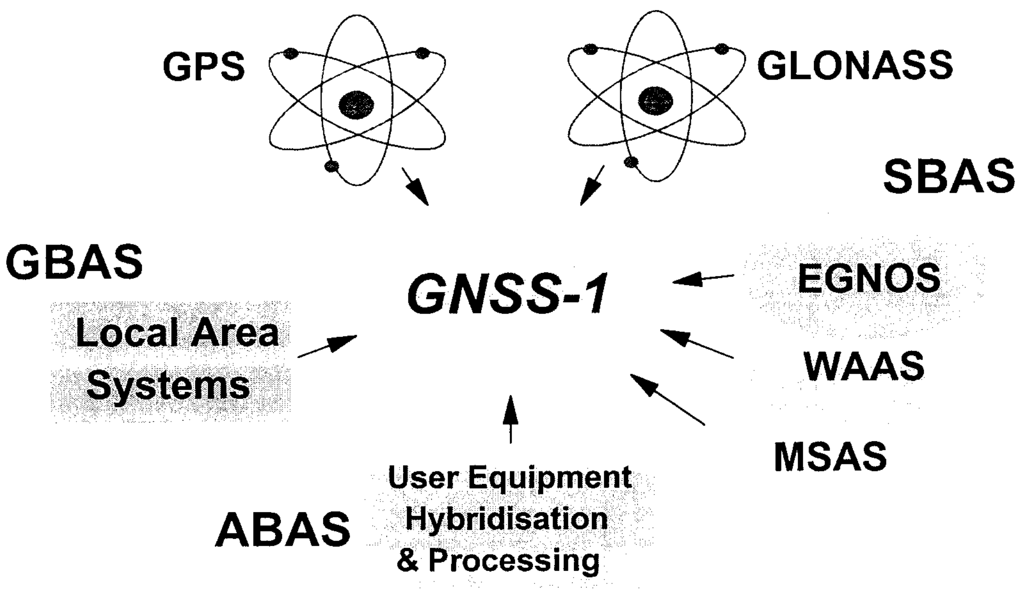
European Space Agency
GNSS-1 Project Office

European Satellite Navigation Programme

- Defined by European Tripartite Group
  - CEU, EUROCONTROL, ESA
- GNSS-1: SBAS (EGNOS), User Equip.
- GNSS-2: System definition, Technology
- Based on Inter-Regional Cooperation

European Space Agency
GNSS-1 Project Office

What is GNSS-1 ?



European Space Agency
GNSS-1 Project Office

EGNOS

European Geostationary Navigation Overlay Service

- European Satellite Based Augmentation (SBAS) to GPS and GLONASS
- Improve Accuracy, Integrity, Availability and Continuity of SatNav over ECAC
- Multimodal Mission (Aero, Maritime, Road and Rail users), driven by Aeronautical requirements

EGNOS Augmentation Service

- Satellite-based Navigation Overlay:
  - **RANGING**: GPS-like pseudoranges
  - **INTEGRITY**: broadcast of GPS and GLONASS Integrity messages (in addition to RAIM with FDE)
  - **WIDE AREA DIFFERENTIAL**: broadcast of differential corrections valid over full Service Area

EGNOS FUNDAMENTALS

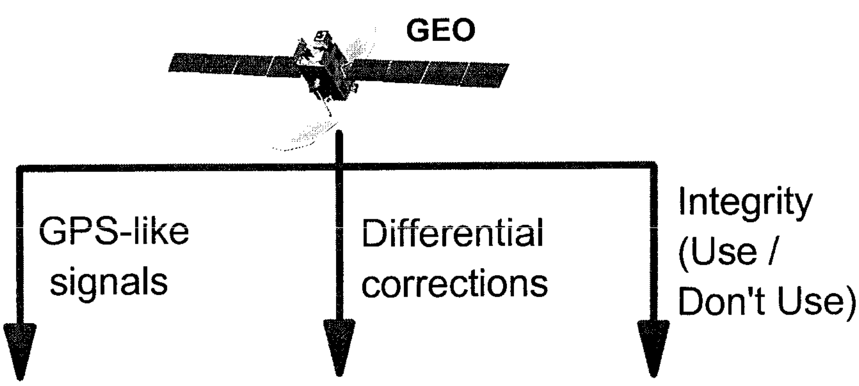
- **GROUND SEGMENT**
  - ephemeris errors
  - clock errors (SA)
  - tropospheric errors
  - ionospheric errors

  → Integrity messages (Use / Don't Use)

  → Wide Area Differential correction messages
- **SPACE SEGMENT (Signal-in-Space)**
  - additional GPS-like signals
  - GIC and WAD GEO-based data link
- **USER SEGMENT**
  - MOPS (DO229) international standard
  - GNSS Rx = GPS standard Rx + SBAS processing

European Space Agency
GNSS-1 Project Office

EGNOS ADDED VALUE



+ ACCURACY
+ AVAILABILITY
+ CONTINUITY

+ SAFETY

European Space Agency
GNSS-1 Project Office

EGNOS: Performance Objectives

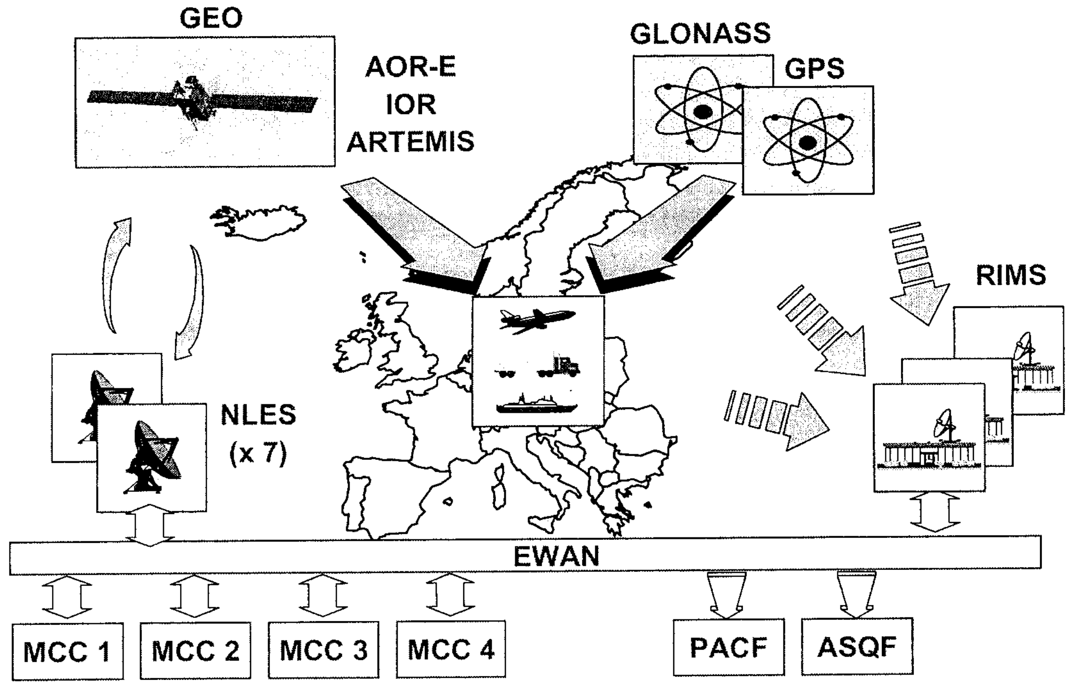
- Ranging will enhance the availability of GPS RAIM FDE for En-Route down to NPA, over full GBA
- GIC will improve the availability of NON-INTEGRITY detection for all phases of flight down to precision approach, over ECAC
- WAD will enhance ACCURACY (7-10m VNSE GPS, 4-6m VNSE GPS + GLONASS),for precision approach applications over ECAC

EGNOS System Segments

- **Ground segment:**
  - Ranging & Integrity Monitoring Stations (RIMS)
  - Mission Processing & Control Centers (MCC)
  - Navigation Land Earth Stations (NLES)
  - EGNOS Wide Area Network (EWAN)
- **Space segment :**
  - Geo satellites with navigation payloads (INMARSAT III AORE/IOR and ARTEMIS for AOC)
- **User segment :**
  - Aeronautical, maritime, land user equipment
- **Support Segment:**
  - DVP, PACF, ASQF

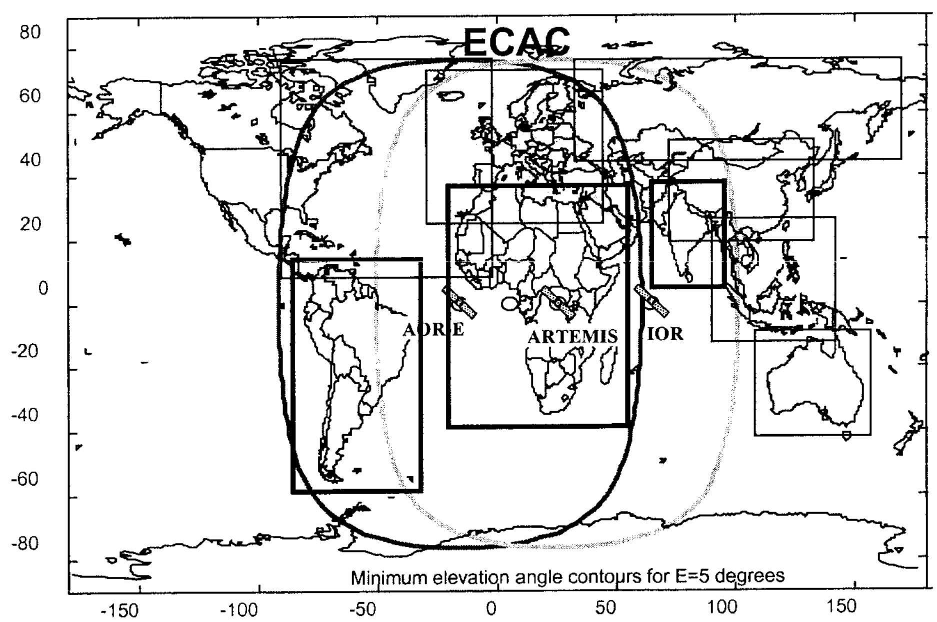
European Space Agency
GNSS-1 Project Office

EGNOS AOC Architecture

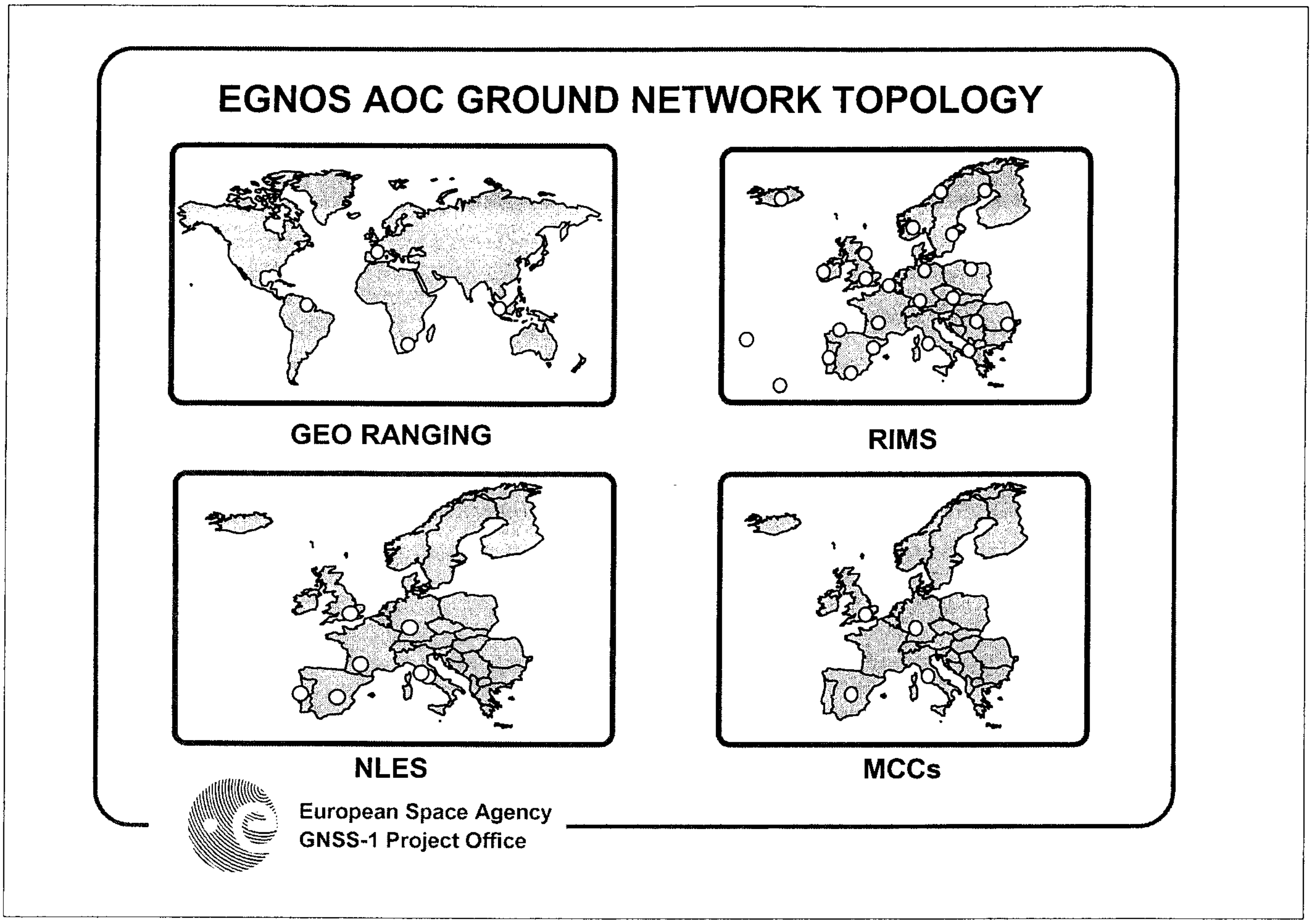


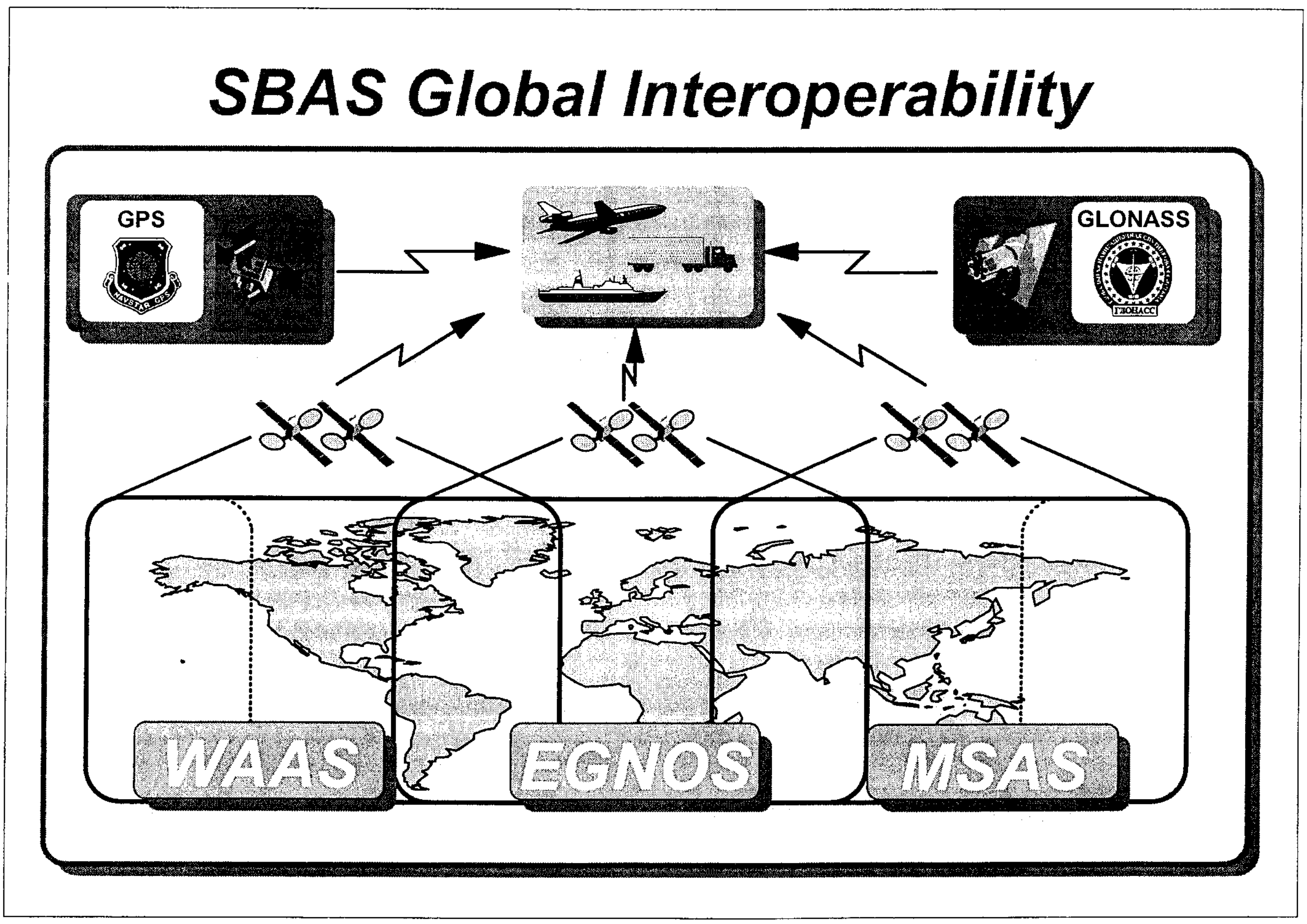
European Space Agency
GNSS-1 Project Office

EGNOS AOC : Service Broadcast Areas



European Space Agency
GNSS-1 Project Office


EGNOS AOC GROUND NETWORK TOPOLOGY
GEO RANGING
RIMS
NLES
MCCs
European Space Agency
GNSS-1 Project Office


SBAS Global Interoperability
GPS
GLONASS
WAAS
EGNOS
MSAS

GLOBAL INTEROPERABILITY

- **SBAS:** WAAS / EGNOS / MSAS
- Ensure **Seamless Service** provision
- **Optimise** use of Ground (monitors) and Space (Geo relay) **resources**
- **Standardisation**
  - Signal in Space
  - User Equipment
  - Network interfaces

EGNOS Satellite Test Bed

- **MAGNET** (CEU): available Now
  - GPS WAD demonstrations
- **EURIDIS** (CNES): Dec'98
  - GEO Ranging (AORE)
- **ESTB** (ESA/CEU/CNES/NMA/ENAV): mid'99
  - GEO Ranging (EURIDIS)
  - Integrity & WAD algorithms (SatRef host)
  - GPS & GLONASS capability
  - AORE, IOR, ARTEMIS access (Euridis,MTB)
  - **ISTB** over Latin America, Africa, India, ...

European Space Agency
GNSS-1 Project Office

EGNOS Phase CD is now ready to start

- March 98: EU Council confirm development of EGNOS as part of European strategy to develop GNSS-1 and later GNSS-2
- June 98: ETG agreement signed
- May 98: Final Industrial offer for EGNOS AOC Implementation, start of contract negotiations
- September/October 98: ARTES-9 Programme Approval by ESA (EGNOS AOC Implementation and GNSS-2 Preparatory Phase)
- November 98: Phase CD industrial contract start

European Space Agency
GNSS-1 Project Office

EGNOS Operational Milestones

TEST BED

- Ranging + GIC + WAD test signals
- development and operations support
- as from mid 1998

AOC

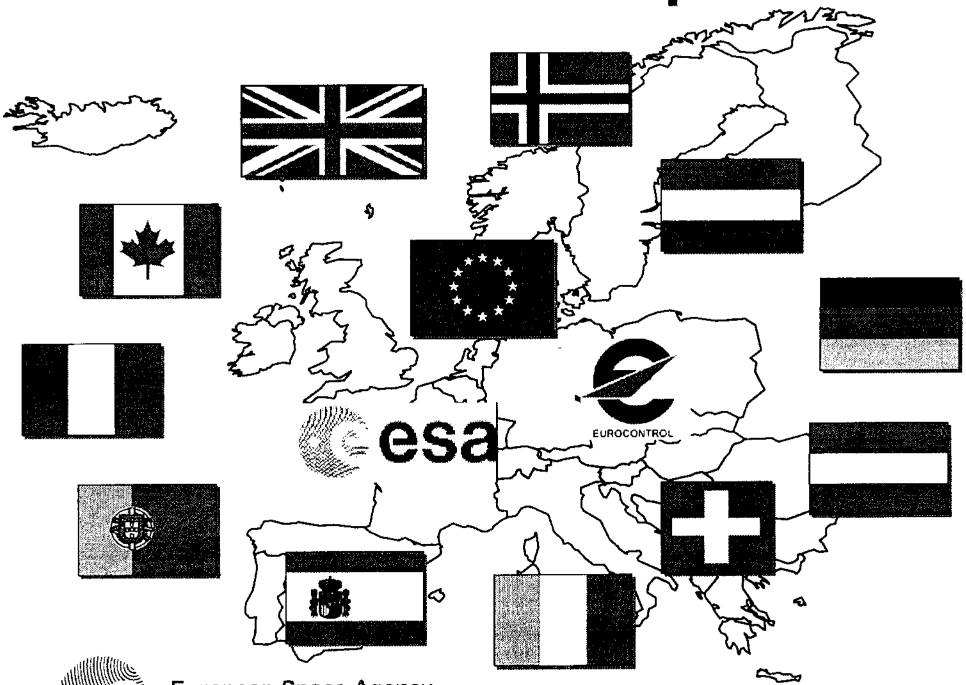
- Ranging + GIC + WAD Operational
- En-Route, NPA, IPV, CAT-I primary means
- end year 2002

FOC

- AOC + Ground / Space redundancy
- En-Route, NPA, IPV, CAT-I sole means
- year 2005 (pending programme definition)

European Space Agency
GNSS-1 Project Office

EGNOS AOC Participant States



European Space Agency
GNSS-1 Project Office

EGNOS INDUSTRIAL CONSORTIUM

ALCATEL SPACE
SEXTANT AVIONIQUE
SYSECA
SRTI

DASA, Ifen, DLR
AIRSYS-ATM
MAN
DFS

CIR
TEKELEC
OSCILLOQUARTZ

GMV
INDRA ESPACIO
SENER
AENA

EDISOFT
INESC

SEATEX
NMA

ALENIA AEROSPAZIO
LABEN
VITROCISET
TELESPAZIO
ENAV

NLR

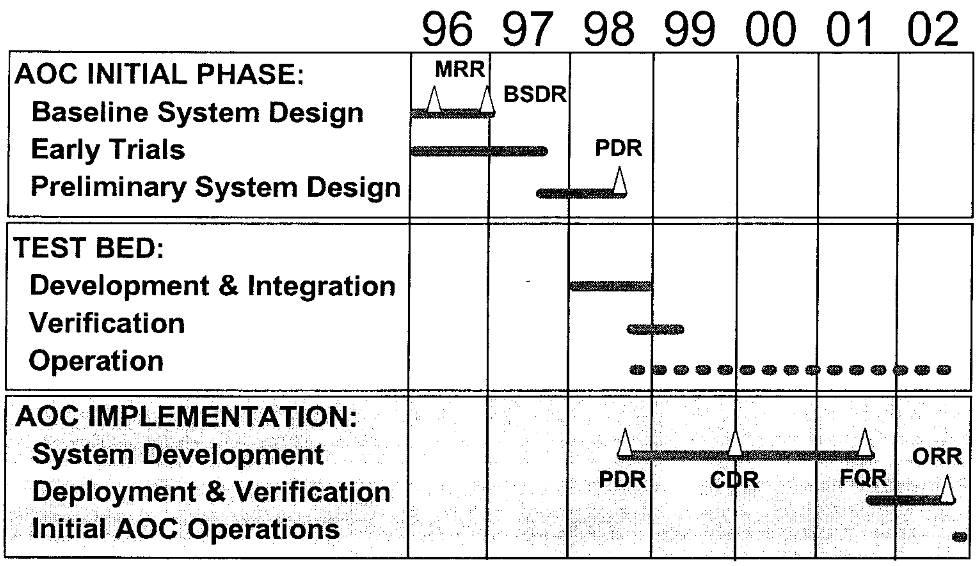
SIEMENS AUSTRIA

NOVATEL

RACAL
VEGA
MATRA MARCONI SPACE UK
LOGICA / SCIENCE SYSTEMS
AIRSYS-ATM UK
BRITISH TELECOM
NATS

European Space Agency
GNSS-1 Project Office

EGNOS AOC MASTER SCHEDULE



European Space Agency
GNSS-1 Project Office

Summary

- GPS & GLONASS alone cannot meet Civil Navigation requirements and suffer lack of civilian control
- The European Satellite Navigation Programme defined by the ETG is developing the European components of GNSS-1 and GNSS-2, to cover the needs of all modes of transport in the European Region
- For Aviation, EGNOS is being developed to meet ICAO navigation requirements for En-Route down to CAT-I, and to be interoperable with WAAS and MSAS
- **EGNOS Phase CD is now ready to start leading to AOC operational readiness by end 2002.**

European Space Agency
GNSS-1 Project Office

0078

EUROFIX

a Cheap Alternative

for

Dissemination of DGPS Corrections

Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications **Navigation Systems**
Professor Börje Forssell

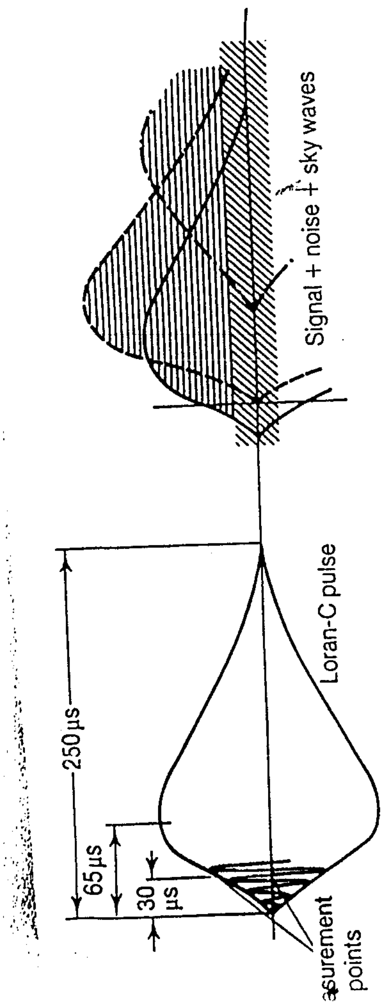
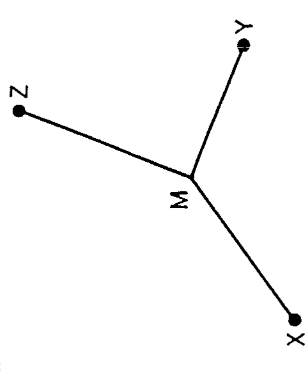


Figure 4.28 Loran-C pulse shape



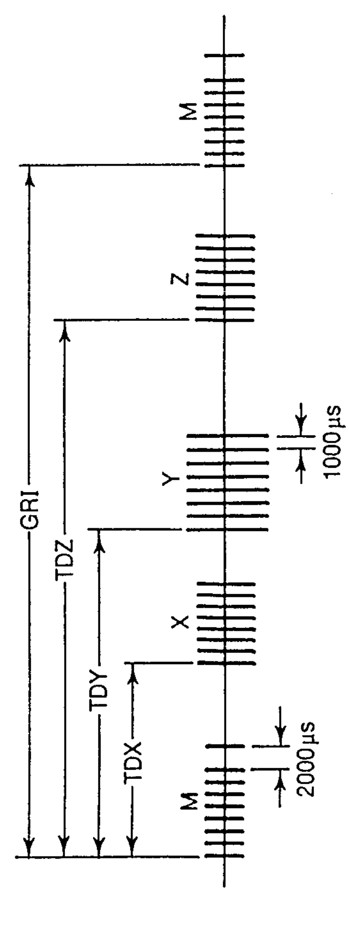


Figure 4.29 Signal format of a LORAN-C chain. Each line means a pulse of the type shown in Figure 4.28

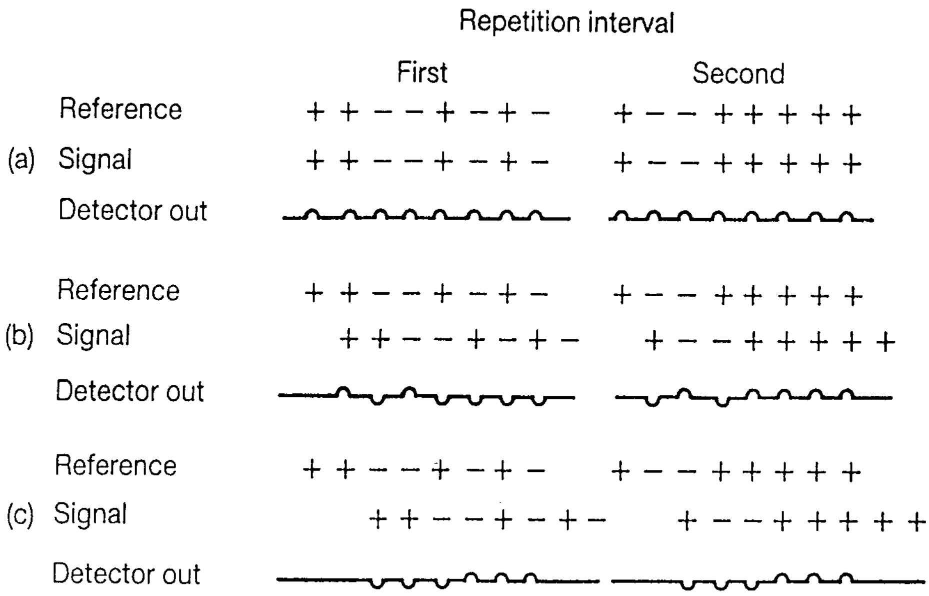


Figure 4.34 Cancellation of multihop skywave interference by phase coding of pulse groups (master signal)

Secondaries: + + + + + − − + + − + − + + − −

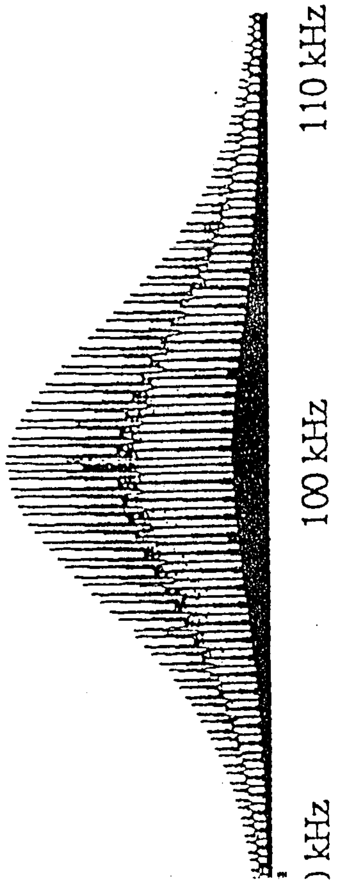


Fig. 6a *Power spectrum of Loran-C transmission*

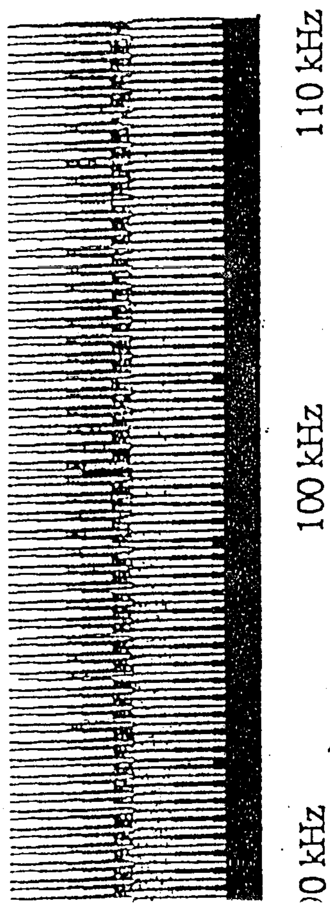


Fig. 6b *Fourier transform of receiver sampling function*

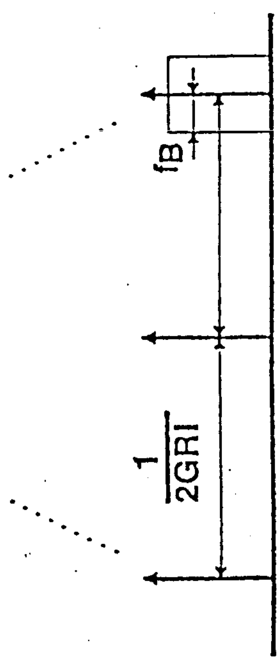
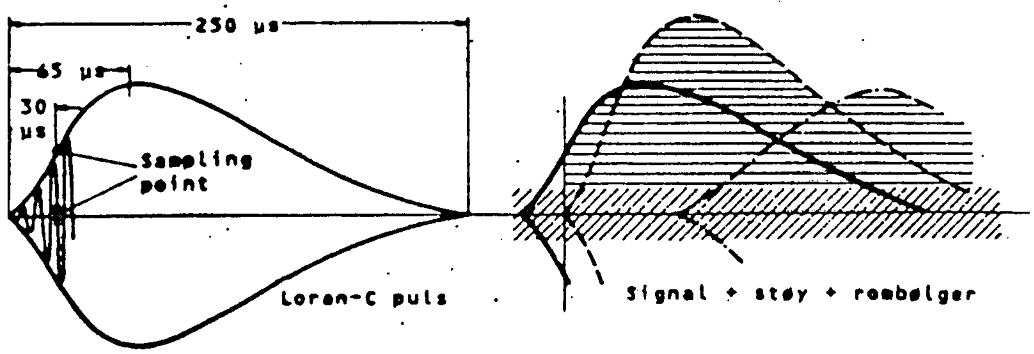
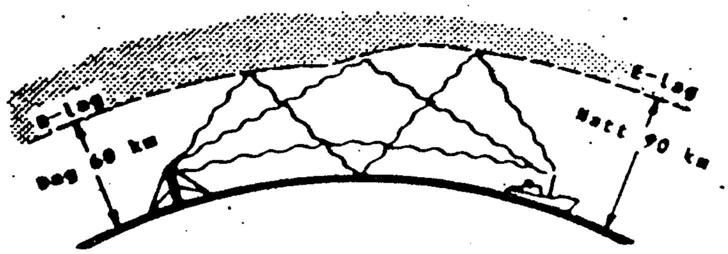


Fig. 6c *Distance between two spectral lines*



04. *Loran-C pulsform. Bare de første 30 µs er brukbart signal. Resten nødvendig for å få opp energien i samplingspunktet.*



9.02. *Signaloverføring ved jordbølge eller via rombølge i ett eller to hopp*

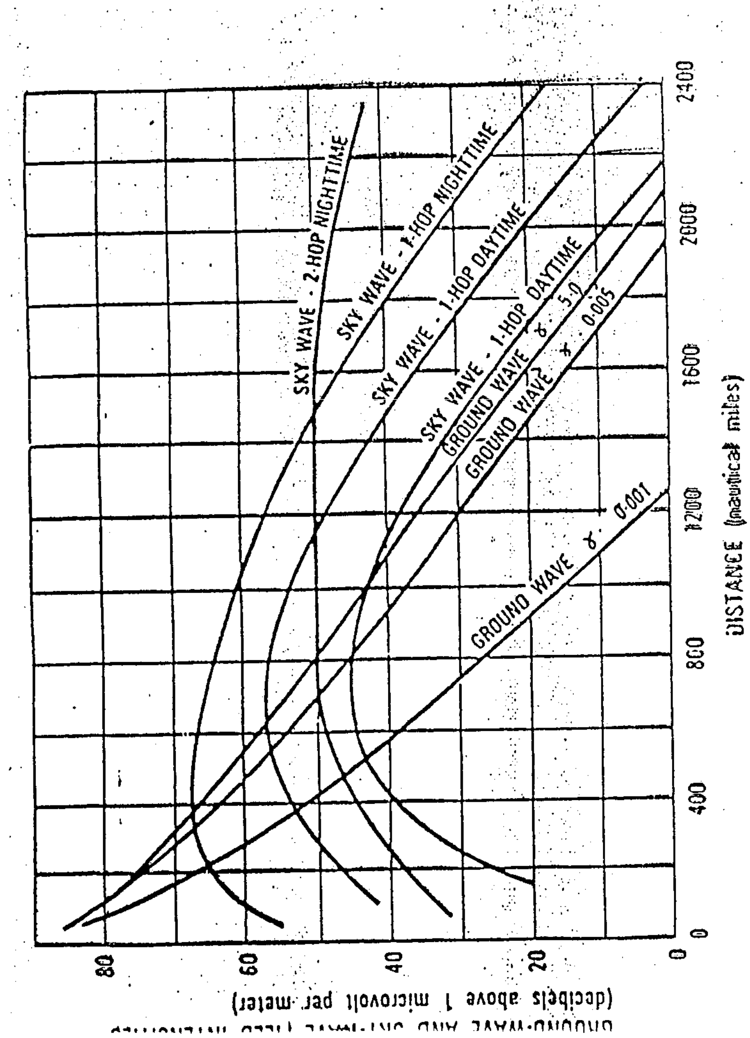


Fig. 3-4 Variation of 100 kHz ground- and sky-wave field intensities with distance for a transmitted power of 100 kW. Conductivities for ground waves are 5 mS/m (sea water), 5 µS/m (good earth) and 1 µS/m (poor earth). The conductivity for sky waves is 5 µS/m. Ionospheric height is 70 km (daytime) and 90 km (nighttime). The two 1-hop daytime sky-wave curves roughly bound the seasonal and diurnal variations. Data have been taken from [1-3].

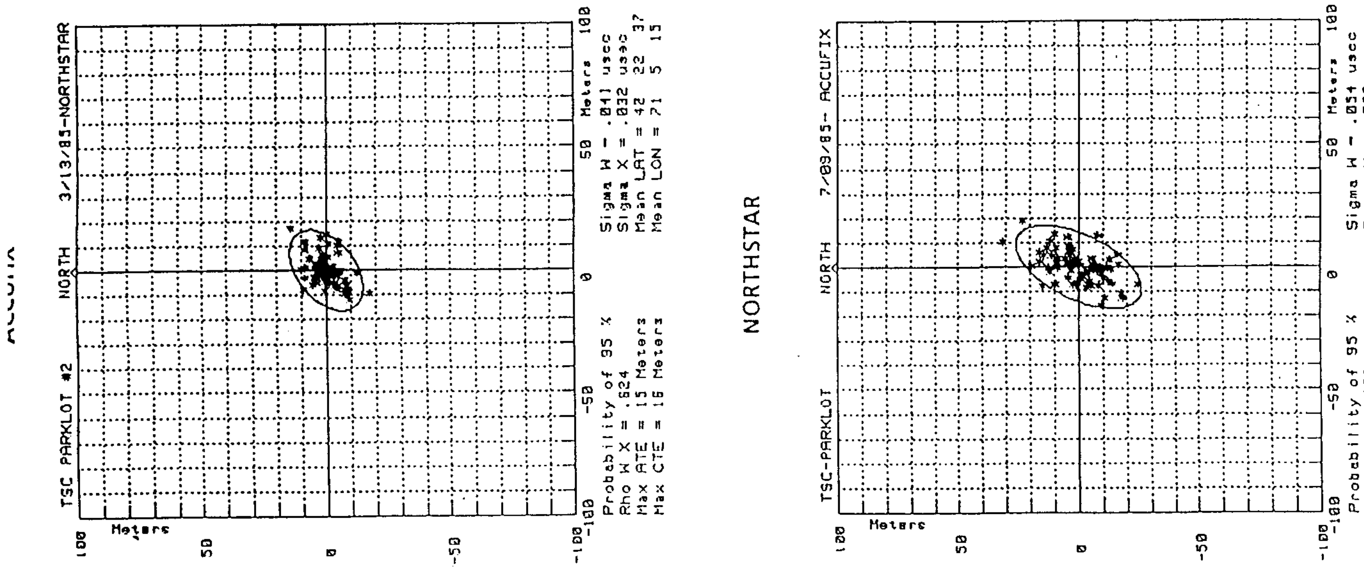


Fig. 3—Representative LORAN-C Scatter Plots at TSC

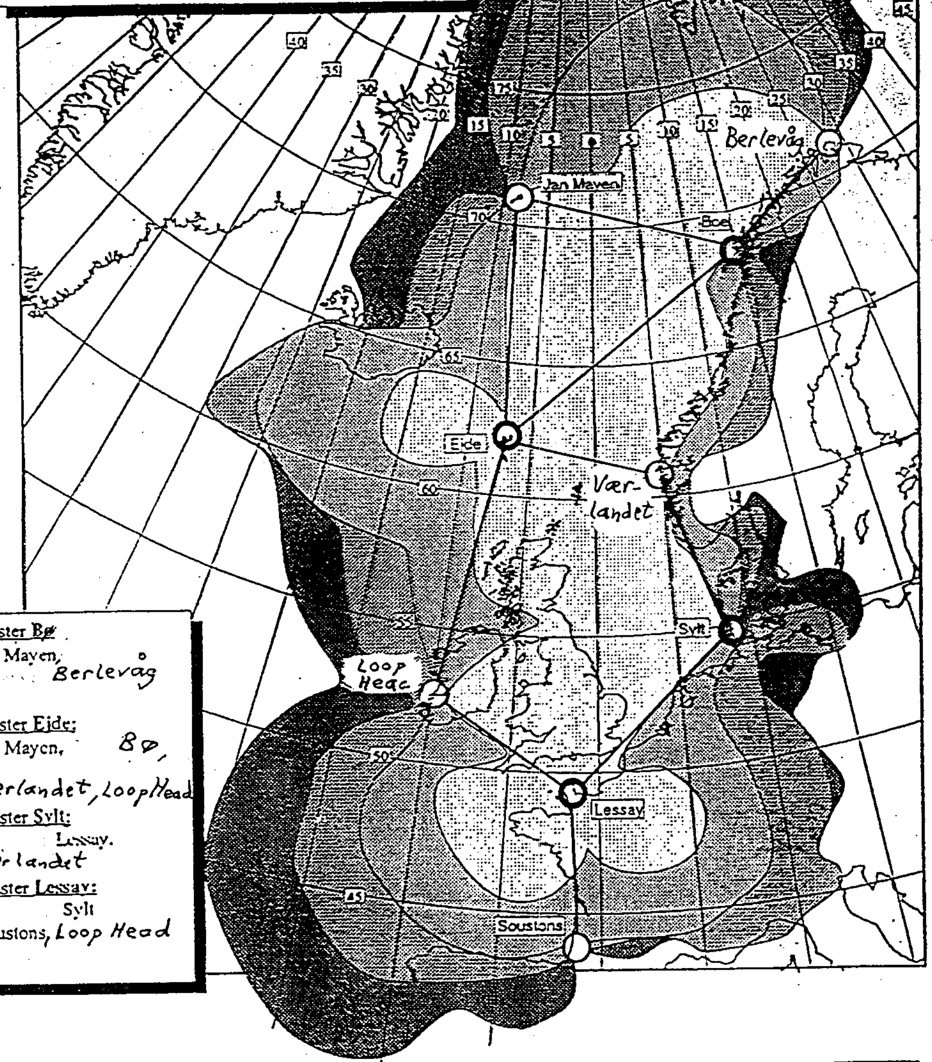
NELS

Northwest European LORAN-C System

- Denmark
- France
- Germany
- Ireland
- Netherlands
- Norway

Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

Beregnet dekning for de nye Loran-C kjedene i nordvest Europa og nordlige Atlanterhav.



Master Bø:
Jan Mayen, Berlevåg

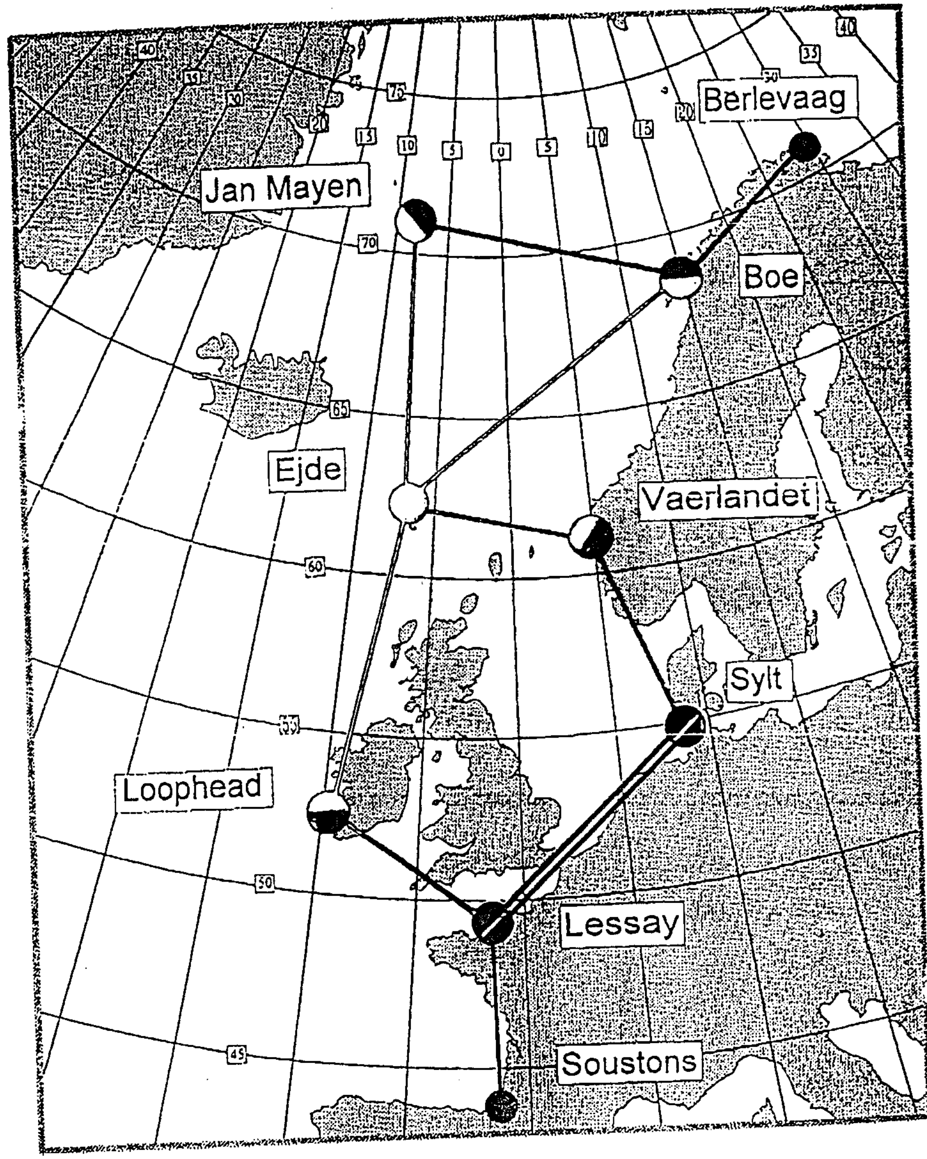
Master Ejde:
Jan Mayen, Bø,
Værlandet, Loop Head

Master Sylt:
Lessay.
Værlandet

Master Lessay:
Sylt
Soustons, Loop Head

Legend (2drms accuracy contours)

- Accuracy 200 m - 463 m
- Accuracy 50 m - 100 m
- Accuracy 100 m - 200 m
- Accuracy better than 50 m



EUROFIX

- Functions
- Development
- Tests
- Plans

Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

EUROFIX

- Data broadcast by modulation of LORAN-C signal
- proposed by the Technical University of Delft (Netherlands)
- DGPS differential and integrity broadcast
- Experimental transmissions from Sylt since 1997
- broadcast of other information is possible

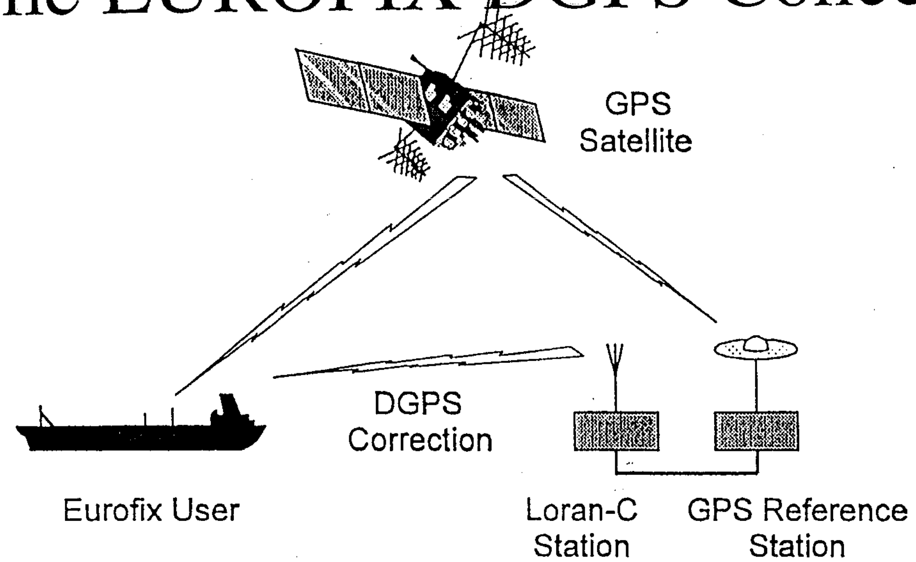
Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

What is EUROFIX?

- Provider:
  - broadcasts accurate DGPS (DGLONASS) corrections via existing LORAN-C/Chayka stations (RTCM SC-104)
  - can cover almost the entire continental Europe and North-America
- User:
  - EUROFIX has been shown to offer excellent DGPS accuracy (< 3 m) and integrity
  - networked DGPS performance with 2 or more stations received
  - DGPS can continuously calibrate LORAN-C/Chayka
  - calibrated LORAN-C bridges GPS coverage gaps

Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

The EUROFIX DGPS Concept



Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

EUROFIX is a Datalink Using LORAN-C

- Data transmission through position modulation of the last 6 (of 8) LORAN pulses by 1 μs early, prompt or 1 μs late
- fully balanced modulation through equal number of "earlies" and "lates" per GRI preserves position accuracy of LORAN-C
- negligible (0.78 dB) power loss of navigation signal
- Reed-Solomon coding used to counteract interference and atmospheric noise
- high level of integrity of messages ensured by Cyclic Redundancy Check (CRC)
- effective data rate of 30 bits/s over ranges exceeding 1000 km

Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

EUROFIX benefits

- Cost-effective DGPS correction and integrity services
- Long range (> 1000 km)
- Emergency broadcast possible
- Multiple stations for networked DGPS
- Easy integration of DGPS and LORAN-C
- Dual-rated stations allow increased data rate

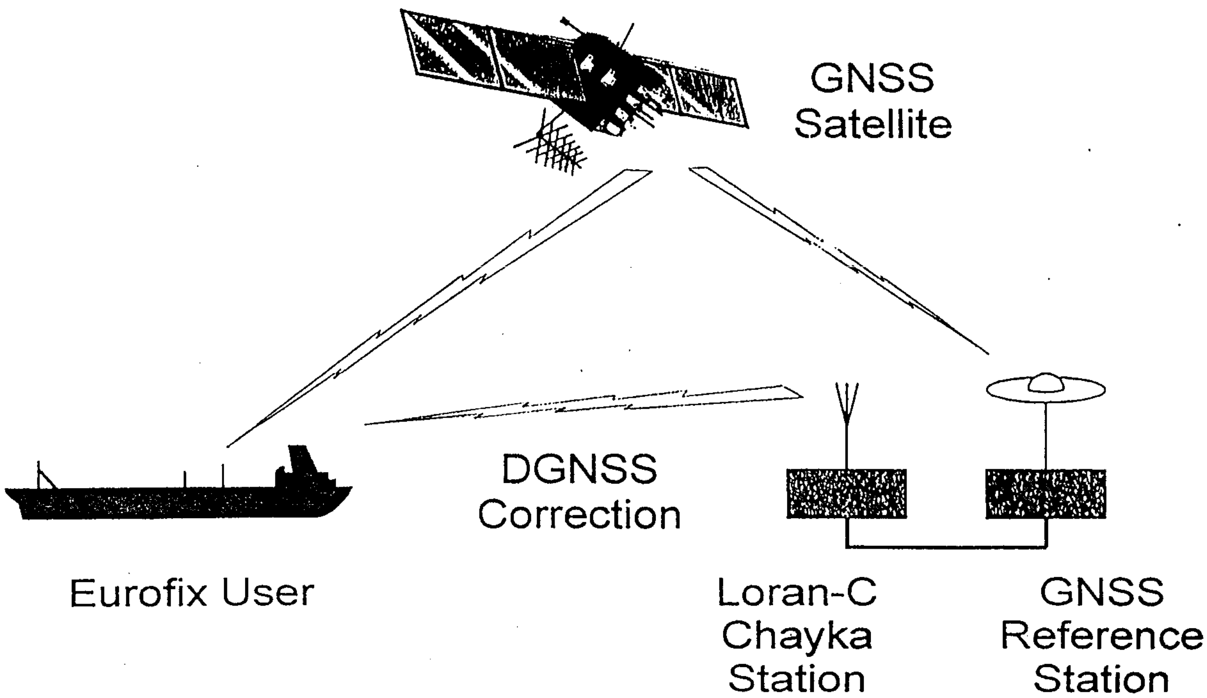
Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

EUROFIX Adds Value to LORAN-C

- LORAN-C datalink suitable for transmission of DGNSS differential correction and integrity data. Datalink bandwidth adequate for simultaneous transmission of DGPS and DGLONASS data
- Proven zero-baseline position accuracy better than 2 m
- Eurofix regional area technique expected to yield better than 5 m position accuracy
- EUROFIX coverage area much larger than with any other ground based radiobeacon system
- EUROFIX may give WAAS/EGNOS like capabilities at only fraction of WAAS/EGNOS costs

Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

The EUROFIX datalink



Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

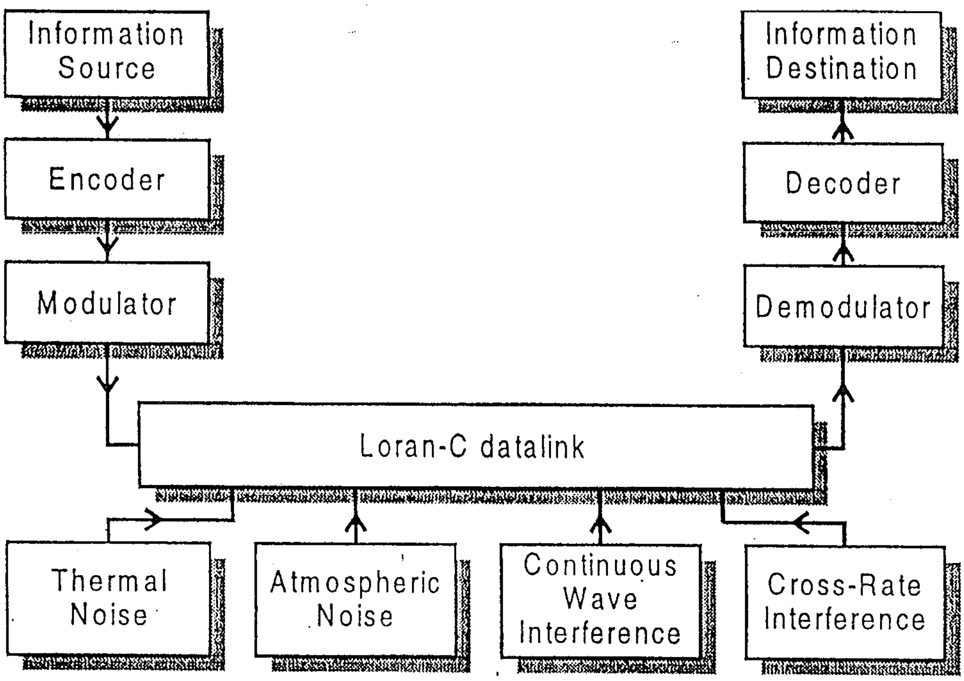
The EUROFIX datalink

EUROFIX combines:

- GNSS (GPS + GLONASS)
- LORAN-C / Chayka
- Broadcast data via LORAN-C:
  1. DGNSS corrections
  2. Integrity messages
  3. Other broadcast messages

Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

EUROFIX symbol encoding



Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

Modulation Patterns

- $3^6 = 729$ possible modulation patterns
- 141 possible balanced modulation patterns:

* * 0 0 0 0 0 0	1	0 shifts/GRI
* * 0 0 0 0 + -	30	2 shifts/GRI
* * 0 0 + + - -	90	4 shifts/GRI
* * + + + - - -	20	6 shifts/GRI
Total:	141 balanced patterns	

- 128 of 141 balanced patterns chosen to represent 7-bit symbols (1 symbol per GRI)

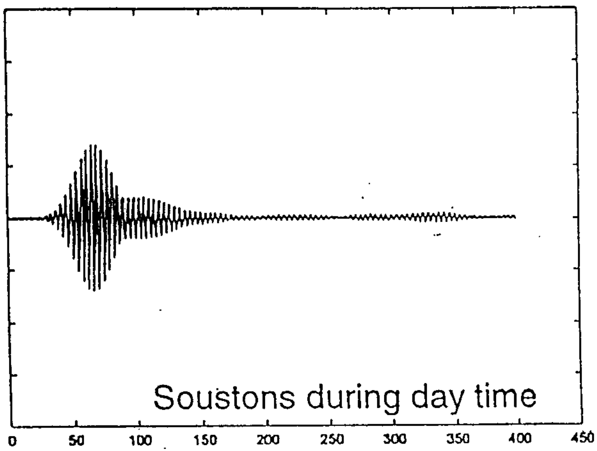
Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

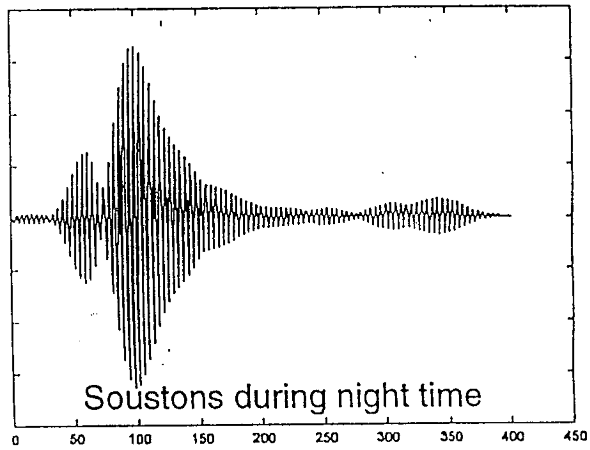
EUROFIX Symbol Encoding

6-Pulse Modulation Pattern	7-Bit Representation
* * - - 0 0 + +	1 0 0 0 0 0 0
* * - - 0 + 0 +	0 1 0 0 0 0 0
* * - - 0 + + 0	0 0 1 0 0 0 0
* * - - + 0 0 +	0 0 0 1 0 0 0
* *	.. ..

Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

Available Communication Signal Energy





- All ground and skywave energy used for communication
- Night-time skywave energy partly compensates night-time cross-rate interference

Durk van Willigen et al   **TU**Delft

Demodulation in a LORAN-C Receiver

- Quadrature bandpass samples taken over full lengths of received pulse, including skywaves
- Replica of non-modulated pulses (prompts) obtained by integrating samples of first two pulses over few seconds
- Replica forms phase and amplitude reference to detect 'early', 'late' or 'prompt' arrival of received pulses
- If sample cannot be declared 'early', 'prompt' or 'late', the detected pulse is labeled as an erasure (RASIM)*
- Even-parity check (balanced modulation)

Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

* RASIM = Receiver Autonomous Signal

Datalink Integrity

- Total datalink integrity determined by product of contributions of the following 3 mechanisms:
  - *RASIM (Receiver Autonomous Signal Integrity Monitoring) qualifies demodulated information bits*
  - *Reed-Solomon as the FEC code introduces an additional level of integrity*
  - *A 7-bit Cyclic Redundancy Check is included in the provisional data format*
- High datalink integrity essential for DGNSS and emergency Short Messaging Service applications

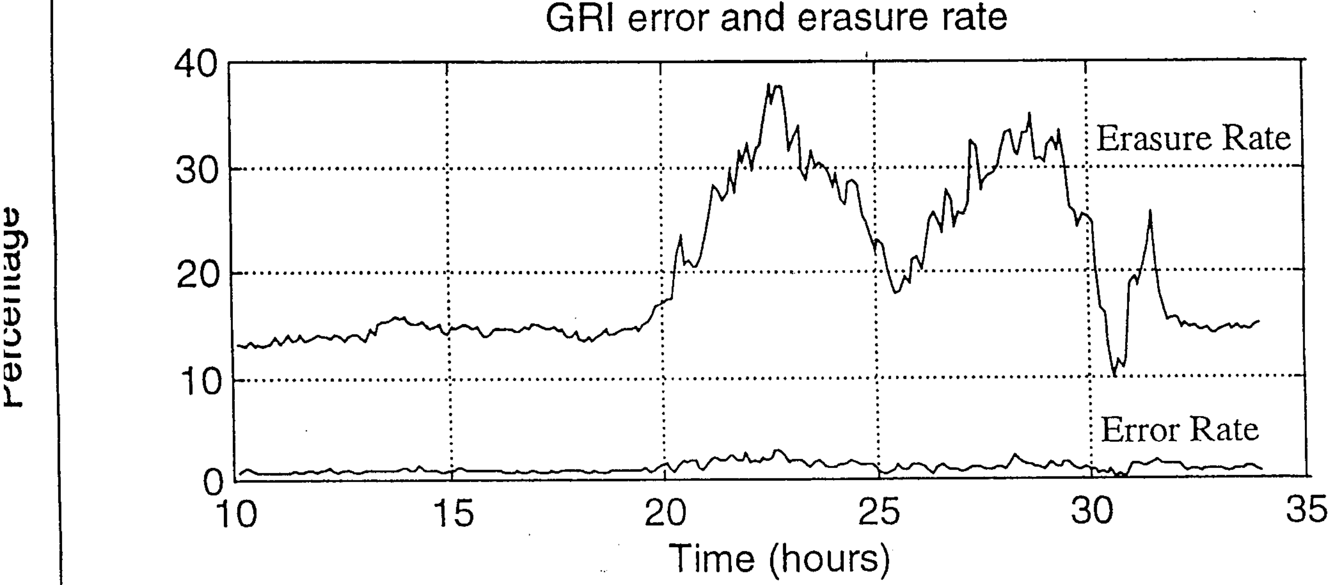
Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

Datalink Improvements

- Add Reed-Solomon Forward-Error-Correction Coding
  - *Take very special LORAN-C signal characteristics (cross-rate!) into account*
  - *Erasure rates are exceptional*
  - *Optimize coding for ranges of up to approximately 1,000 km to achieve best DGNSS navigation performance and not for highest data rate or for lowest error rate*
- Add Cyclic Redundancy Check
  - *7 Bit CRC for a 56 bit message adequate for nearly 100% message integrity*
- Reduction of effective data rate to about 30 bps

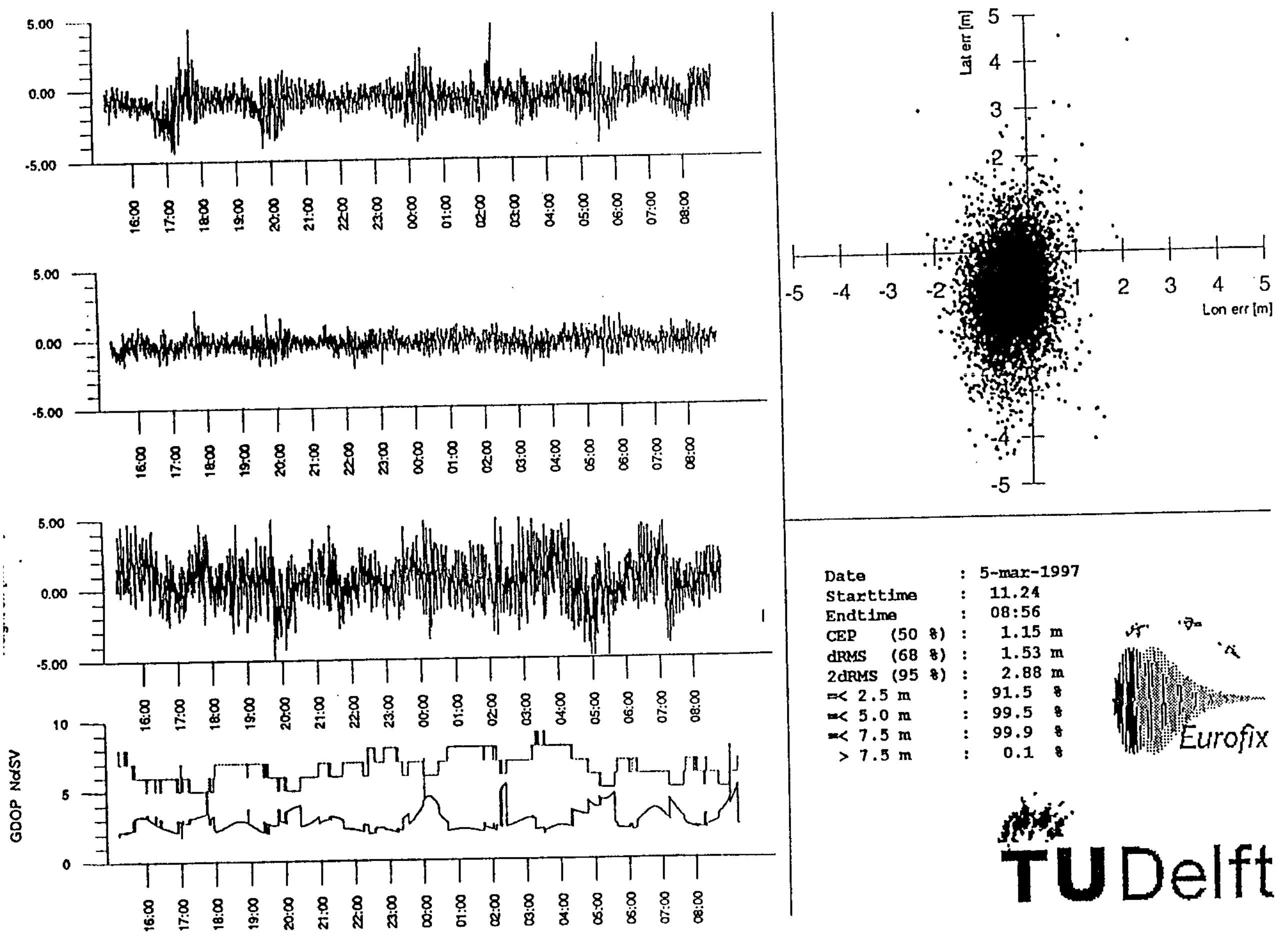
Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

Pulse Error Rates over 1,000 km Range



Soustons (1013 km, GRI 8940), run 14 September 1996

Durk van Willigen et al TUDelft



30 GRI (21 bits per second) datalink, 5/6 March 1997

Deviation between Calibrated LORAN-C and DGPS in a Dynamic Situation:

- < 10 m for 2 hours
- < 30 m for 24 hours

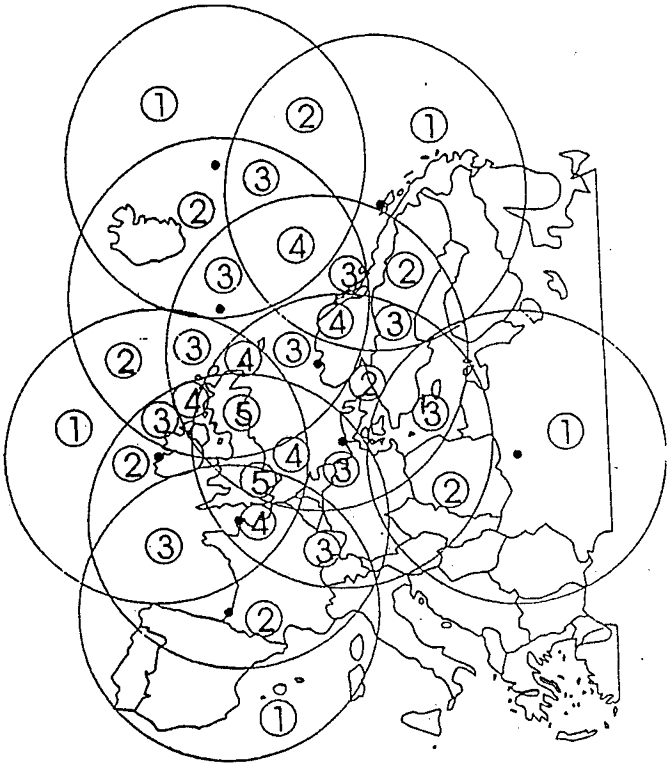
Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

EUROFIX Plans

- Step 1
  - Basic Service (Bø, Værlandet, Sylt, Lessay)
- Step 2
  - All NELS Sites
- Step 3
  - Expansion of coverage area (Mediterranean, Iberian, Chayka)

Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

Possible EUROFIX Coverage



Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

Conclusions

- Raw bit rate varies from 175 - 70 bits per second
  - *GRI ranges from 40 - 100 ms*
  - *1 Symbol of 7 bits per GRI*
- Skywave energy can be used for data demodulation
- Samples unacceptably damaged by cross-rate or atmospherics can be detected and rejected (erasures will be declared)
- Due to the signal structure of LORAN-C, pulse-errors and pulse-erasures are likely to appear in groups
- Using LORAN-C stations far away results in higher Pulse Error and Erasure Rates
  - *Soustons (1023 km): 11% avg. erasure rate, 3.7% avg. error rate*

Norwegian University of Science & Technology
Faculty of Electrical Engineering and Telecommunications
Department of Telecommunications Navigation Systems
Professor Börje Forssell

Nationwide Differential Global Positioning System (NDGPS)

Leonard W. Allen

NDGPS Project Manager

U.S. Coast Guard Navigation Center

Presented to

Senior Officer Aids To Navigation Conference

November 4, 1998

Nationwide Differential Global Positioning System (NDGPS)

Nationwide DGPS

- Leveraging DOD's $12 billion investment in GPS and the Coast Guard's investment in DGPS, the U.S. will soon blanket the nation with the most accurate and reliable navigation system the country has ever had.
- It'll be much more than a navigation system
  - Where it is currently installed, it is being used in a wide array of other applications including:
  - Surveying, Weather Modeling, Precision Farming...

Nationwide Differential Global Positioning System (NDGPS)

Need for Better Accuracy, Integrity and Availability

	GPS Standard Positioning System	GPS Precise Positioning System	Nationwide DGPS
Accuracy	100 meters	22 meters	1-3 meters real time 5 cm using post possessing
Integrity	2-4 Hours	2-4 Hours	2.5 to 5.0 Seconds
Availability	99.87%	99.87%	99.999%

Nationwide Differential Global Positioning System (NDGPS)

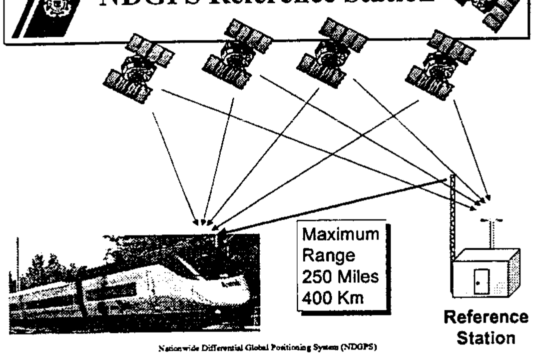
Interagency NDGPS Policy & Implementation

- NDGPS Planning Began in Jan 97
  - Executive Steering Group
  - Policy & Implementation Team

Participants	
DOT/OST	Department of Commerce
U.S. Coast Guard	Department of Interior
Federal Highways Administration	Department of Agriculture
Federal Railroad Administration	Army Corps of Engineers
Federal Aviation Administration	U.S. Air Force
Environmental Protection Agency	Various States

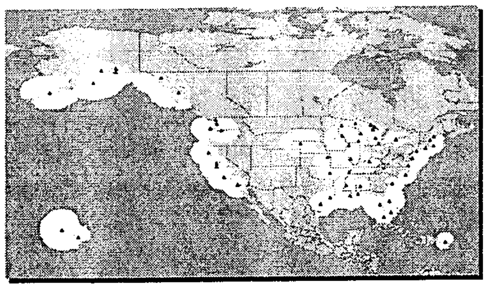
Nationwide Differential Global Positioning System (NDGPS)

NDGPS Reference Station



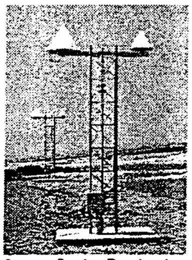
Nationwide Differential Global Positioning System (NDGPS)

Current DGPS Coverage



Nationwide Differential Global Positioning System (NDGPS)

What does NDGPS give me?
System Characteristics


Reference Station Receive Antennas

- Accuracy
  - 0.5 meter near the reference station
  - Add 1 meter/150 Km
  - Accuracy with Post Processing is 5 cm
- Integrity
  - 5 seconds at 100 bps
  - 2.5 seconds at 200 bps

Nationwide Differential Global Positioning System (NDGPS)

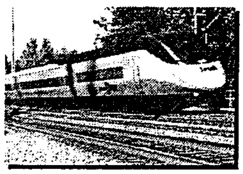
International Standard

- NDGPS is designed to an international, non-proprietary standard
  - Compliant with RTCM SC-104 and ITU-R M.823
- Signal is free to any user
- Currently used in 31 countries
- Many other countries are planning systems
- Resulting in a seamless international navigation system

Nationwide Differential Global Positioning System (NDGPS)

NDGPS Requirements
Positive Train Control

- DGPS use in the Positive Train Control will
  - Prevent accidents, saving over $60 million per year
  - Reduce fuel consumption by better pacing trains
  - Increase rail line capacity through closer train spacing, reducing the need for additional capital investment in plant and equipment



Nationwide Differential Global Positioning System (NDGPS)

Nationwide DGPS
Intelligent Transportation System

- An integrated vehicle safety system consisting of DGPS, map matching & communication links will:
  - Automatically notify emergency personnel when an air bag is deployed, allowing for faster response to the exact location, thus saving some of the 41,000 people who die on U.S. roads each year.
  - Automatically reroute traffic around an accident, preventing multi-car pile-ups & improving traffic flow.
  - Plot cost effective trips, thus saving both time and fuel.

Nationwide Differential Global Positioning System (NDGPS)

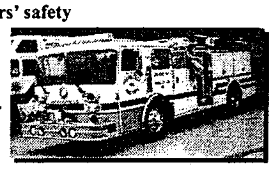
Nationwide DGPS
Other Federal Agencies

- 24 Federal Agencies have Public Safety needs
- EPA - Locate 1.4 million hazardous waste sites
- DOI (National Park Service) -
  - Search and Rescue, fire fighting and oil spills
- DOE - Continuously monitor shipments of radioactive materials
- DOJ - Locate FBI & DEA personnel in danger & track vehicle location
- DOA - Fire fighting and resource management
- Bureau of Land Management - mapping natural resources and tracking fire fighting equipment
- USPS - tracking over 80,000 postal carriers

Nationwide Differential Global Positioning System (NDGPS)

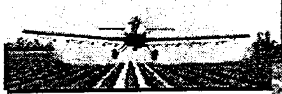
Nationwide DGPS
State & Local Governments

- Many State and Local Governments need DGPS to:
  - Mapping transportation infrastructure
  - Police, fire & ambulance 911 emergency response
  - Monitoring police officers' safety
  - Location of fire hydrants in snow
  - Monitoring contaminated well water
  - Natural Resource Management

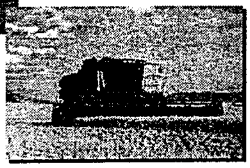


Nationwide Differential Global Positioning System (NDGPS)

Benefits to Agriculture



NDGPS used in Precision Farming saves $5 to $14 per acre.

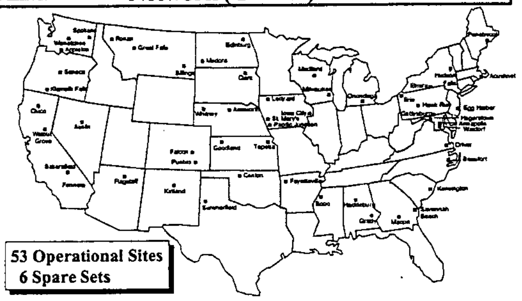


Map Soil quality

Reduce use of pesticides and fertilizers

Monitoring crop yield

Air Force Ground Wave Emergency Network (GWEN) Sites



Implementation

The GWEN Opportunity

- Ground Wave Emergency Network (GWEN)
  - Air Force is decommissioning the GWEN system
  - DOT is converting the GWEN sites into DGPS sites
  - One of the largest Defense to Civil conversions in history

	GWENs Current Location	Moved GWENs CONUS	New Sites CONUS	Moved GWENs Alaska	Total
Number of Sites	32	14	7	14	67

Public Law 105-66

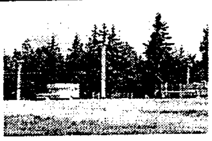
Section 346

- Reuse Air Force Ground Wave Emergency Network (GWEN) Equipment and Sites to augment installation of NDGPS
- Integrate NDGPS with:
  - Coast Guard's DGPS for operational control
  - National Geodetic Survey's Continuously Operated Reference Stations (CORS) service for surveying applications
  - National Oceanic and Atmospheric Administration's Precipitable Water Vapor System for weather modeling
- Ensure that the service is provided free of any user fees
- Continually upgrade the system
- Sponsor new applications

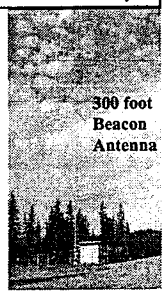
Public Law
Bill Clinton

Converted GWEN to NDGPS

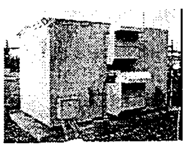
Appleton, WA



Reference & Integrity Antennas *Two sets of each*



300 foot Beacon Antenna

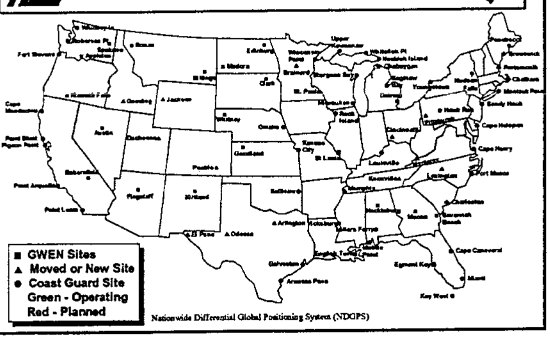


DGPS Equipment Shelter

There is a similar shelter for the 25KW generator

Nationwide DGPS

Single Coverage



Nationwide DGPS

Double Coverage

Nationwide Differential Global Positioning System (NDGPS)

Cost and Benefits

You would think that a nationwide system like this would cost billions to build, but the use of a proven design and commercial equipment will allow us to build the system for a modest cost of $30.3 million.

15 Year Life Cycle

Cost	$68.6 M
Benefits	10,400.0 M

Benefits to Cost ratio:

152 : 1

Nationwide Differential Global Positioning System (NDGPS)

Who will do what?

Teamwork

- Air Force - Transfer GWEN equipment
- ACOE & States - Acquire & Prepare sites
- Coast Guard - Installations, Operations, Maintenance & Planned Improvements
- FHWA - Environmental Assessment
  - Document System Performance
- FRA - Project Sponsor (funding)
- NOAA - Integrated Precipitable Water Vapor
  - Monitor Reference Stations (CORS)

Nationwide Differential Global Positioning System (NDGPS)

Nationwide Differential Global Positioning System (NDGPS)

Leonard W. Allen

GPS Branch Chief

NDGPS Project Manager

United States Coast Guard

Phone: (703) 313-5888
Fax: (703) 313-5805
LAllen@navcen.uscg.mil

USCG Navigation Center
7323 Telegraph Road
Alexandria, VA 22315-3940

Nationwide Differential Global Positioning System (NDGPS)

Scandinavian GNSS Industry Council

GPS rådet SKANDINAVISKA

Scandinavian GNSS Industry Council (SGIC) - an association of companies promoting and producing products and system for satellite positioning and navigation.

In Swedish, SGIC is called the "Skandinaviska GPS-rådet"

1

Background

GPS rådet SKANDINAVISKA

The development of new GPS based products to improve the effectiveness of:

•Passenger & goods transportation on land , at sea, in the air
•Leisure activities
•Forest Industry
•Land Surveying
•Positioning as part of GIS for property registration
•Agriculture
•CAES, Computer Aided Earthmoving Systems

2

GPS rådet
SKANDINAVISKA

The Need

Widespread and disparate use of GPS requires appropriate industrial support , which, in turn, must demonstrate growth in order to attract investment.

To achieve this, the industry needs to address following:
•Stability
•Competition
•Co-operation
•Influence

3

GPS rådet
SKANDINAVISKA

Objectives

SGIC will promote commercial development of GPS and communicate to Industry, User groups and Authorities.

4

GPS rådet SKANDINAVISKA

Positive effects on Society with the use of GPS based system

•Environment	Transport and Agriculture
•Employment	New IT industry
•Economy	Healthy enterprise
	Positive economical effects

5

GPS rådet SKANDINAVISKA

Advantage of a national GNSS industry

Competens, service and development within the country

6

GPS rådet SKANDINAVISKA

Achieving the Objectives

The objectives are achieved by:
•SGIC Internet Website for external and internal information

•Arranging seminars, conferences and workshops

•Attending international exhibitions and conferences of commercial interest on behalf of membership.

•Distributing collected industrial, technical and commercial information to members

•Co-operating with organisations with complementary objectives

7

GPS rådet SKANDINAVISKA

Objectives with SGIC website

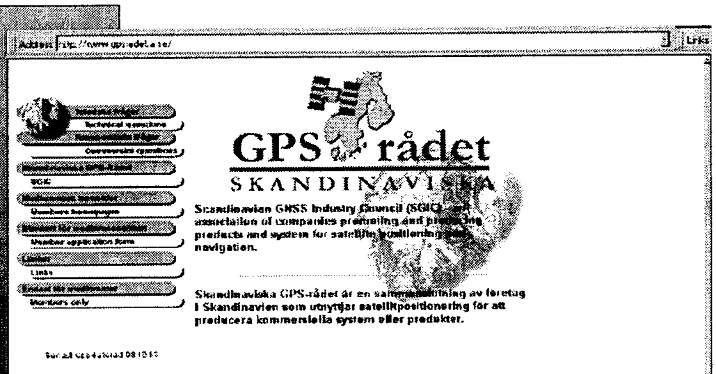
•Showplace for our members products and services

•Meeting place for producers and potential customers

•Information source for the GPS system and it´s augmentation

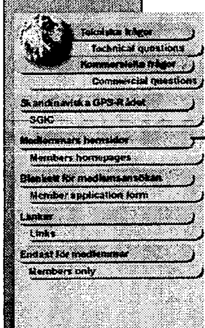
8

SGIC website: www.gpsradet.a.se



9

SGIC website: www.gpsradet.a.se/ membershomesites

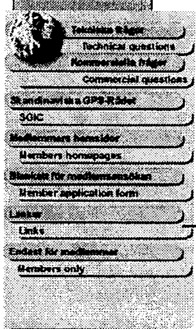


- ACTE NC Sweden AB
- Adveto AB
- Ag Com AB
- AM-TELE Mätinstrument AB
- B & M Systemutveckling AB
- C A Clase
- Celsius Aerotech AB
- City Navigator AB
- Communicator Teleplan AB
- ESRI Sweden AB
- FURUNO Sverige AB
- GP&C Sweden AB
- KGK Fordonssystem AB
- Leica AB
- Metimur AB
- Metron AB
- Navigation Technologies Sweden AB
- NOAB
- AB NYGE Aero
- Orbit Communications
- Pentax Scandinavia AB
- Saab Dynamics AB
- Saab Survey Systems AB
- Saab Training Systems AB
- Silva Sweden AB
- Spectra Precision AB
- Sportmanship Marin AB
- TeraCom
- Y-DAB i Härnösand AB

10

GPS rådet SKANDINAVISKA

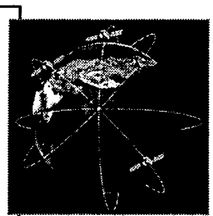
SGIC website: www.gpsradet.a.se/links



Companies:
- Ashtech
- Trimble
- Navsys Corporation

Authorities - Government agencies
- Coordinational Scientific Information Center (CSIC), Russia
- DGXII at the European Commission
- Lantmäteriverket - National Land Survey, Sweden
- Luftfartsverket - Civil Aviation Administration, Sweden
- US Coast Guard Navigation Center
- Statens Kartverk - National Mapping Authority, Norway
- Department of Transportation, USA
- NAVSTAR GPS Operations
- Sveriges Provnings- och forskningsinstitut - Swedish National Testing and Research Institute

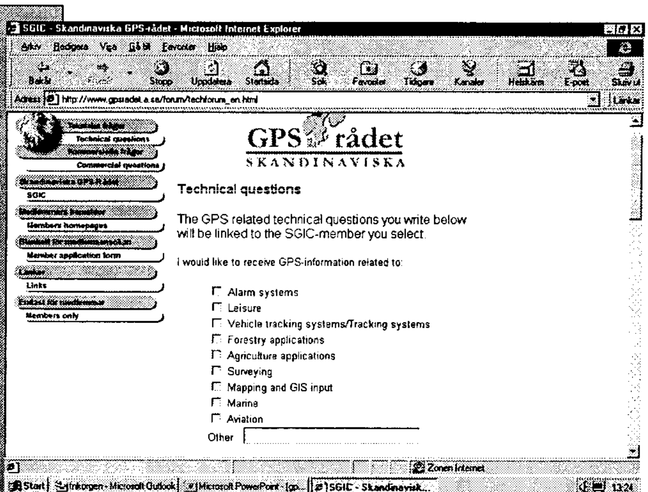
Information and Services
- GPS/GLONASS Satellite Postitions
- GPS World Magazine
- Swedish Space Corporation
- Institute of Navigation
- Fachinformationszentrum, Germany
- Global Information Inc, Japan
- Navtech Seminars and GPS Supply, USA
- Utvecklingsrådet för Landskapsinformation - Development Council for Land Information, Sweden



11

GPS rådet SKANDINAVISKA

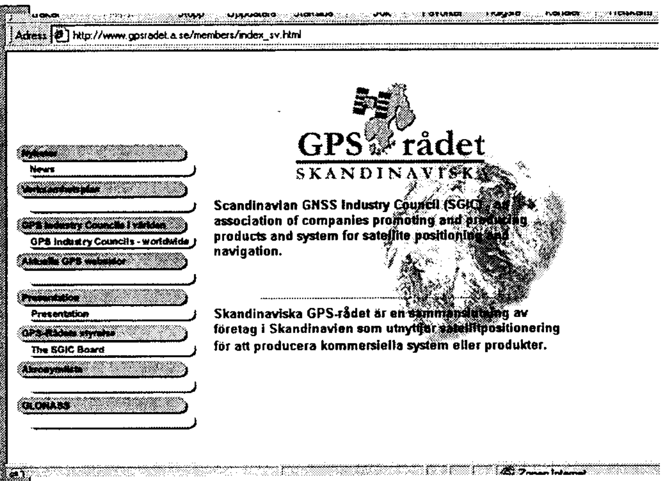
SGIC website



12

SGIC website:
www.gpsradet.a.se/members

GPS rådet
SKANDINAVISKA



13

GPS rådet
SKANDINAVISKA

Relations with Other Organisations

Amongst others in Sweden are the:
•SSFF "Svenska Sällskapet för Fotogtammetri & Fjärranalys
•SKMF "Sveriges Komunala Mätningsteknikers Förening"
•KS "Kartografiska Sällskapet"
•RNN "Radionavigation Board of Sweden"
•NNF "Nordisk Navigations Forum"
•MBK "Mätning Beräkning Kartering"

Global contacts
CGSIC, US GPS Industry Council, Japan GPS Council

14

GPS rådet
SKANDINAVISKA

Membership

SGIC membership is open to:

Commercial companies and agencies whose activities include research, development and sale of products with GPS or other similar technologies are.

Educational institutions which represent, use, prepare or operate services connected to GPS/GNSS

15

GPS rådet
SKANDINAVISKA

Financing

The work of SGIC is financed from membership subscriptions, and from such profits that may accrue from conferences, exhibitions, seminars and other future activities.

16

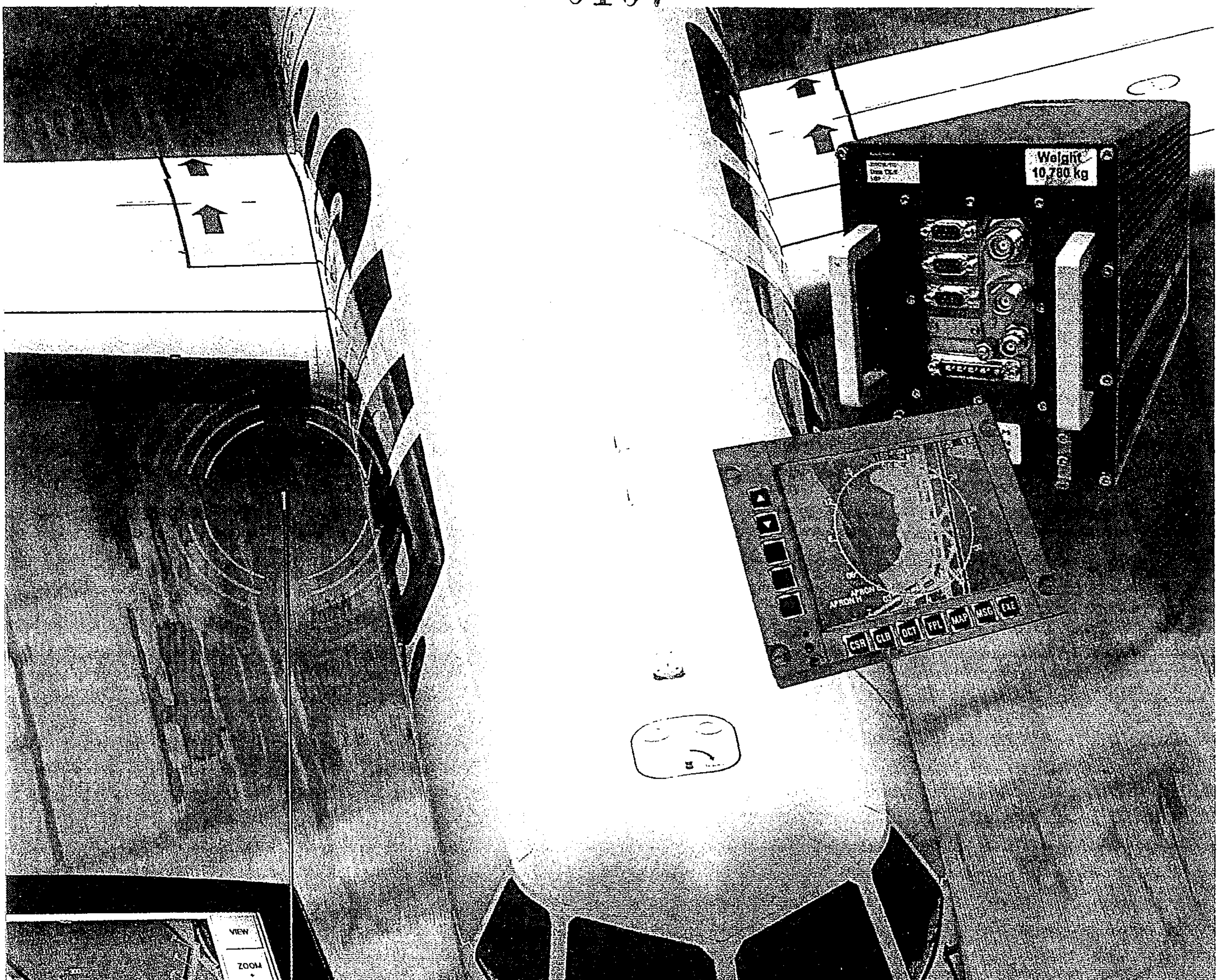
GPS rådet
SKANDINAVISKA

Membership

- The annual Membership Subscriprion is SEK 5.000:-
- Applications and other enquiries should be addressed to any member of the SGIC Board
- Internet adress: www.gpsradet.a.se

17

0107



SAAB AEROSPACE

LINCS is a data link system designed for radio transmission of position data, text and other data among a large community of users. When a user transmits his position and receives positions from other users within the 200 n.m. radio range, LINCS is in the ADS-B mode. By using text messages between aircraft and/or between aircraft and ground control, the user can get pre-departure clearance, weather information, etc. The accurate position information can be used for conflict avoidance, significantly enhancing flight safety.

Based on the 1 m accuracy of differential GPS positioning, LINCS supports both ADS-B and ADS-C. It also offers extensive additional functionality, permitting:

- Flight plan loading in any phase of flight
- Service monitoring (e.g. flight information, traffic information, etc.)
- Airport ground-vehicle movement monitoring
- Mixed vehicle/aircraft ground traffic management
- Transmission/reception of ATC messages by text
- Taxiing and docking guidance in adverse weather conditions
- Runway-incursion prevention
- Situation awareness/conflict avoidance
- Accurate ETO/ETA-4-D
- Reduced separation
- Search and rescue management

LINCS T3L/M

The LINCS T3L/M Airborne Transponder is designed for use in harsh military environments as well as civil aviation applications. Designed around the standard STD-32 Bus, its highly flexible design facilitates adaptation to the configuration requirements of various applications. The LINCS T3L/M Airborne Transponder complies with ARINC 404A.

The extruded aluminum case meets stringent mechanical and thermal requirements. The front cover is easily custom-configured with, e.g., selectable standard connectors such as D-sub or MIL-type circular. The back cover is used as a heatsink for the transceiver. Mounting attachments conform to ARINC 404A.

Inside the shock- and vibration-resistant enclosure are a heavy-duty power supply, dual transceivers, one Intel 486TM processor, a GPS multichannel receiver with high position update rate, low latency and multipath mitigation. All printed circuit cards are interconnected via a low-noise backplane with the STD-32 Bus.

The main features of the LINCS T3L/M Airborne Transponder design are durability, flexible configuration and robustness, with software implemented in the Ada programming language and certifiable to RTCA/DO-178B, level A.

The LINCS T3L/M Airborne Transponder is certified for non-essential use in civil aviation.

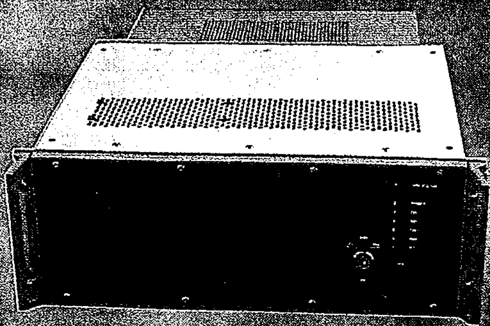
LINCS T3L/F

The LINCS T3L/F Base Station Transponder is designed for differential GPS signal corrections that are transmitted over the data link. As a base station, it controls all transponder-equipped vehicles within radio range. It is designed for use in military environments as well as civil aviation applications.

The LINCS T3L/F Base Station Transponder is housed in a 19" (4U) rack-mountable, rugged enclosure, equipped with a high-performance backplane for the STD-32 Bus system designed for operating in harsh and electrically noisy environments. Inside the shock- and vibration-resistant enclosure there is a heavy-duty power supply (rear-mounted IEC input socket accepts low or high AC inputs on a fuse-protected line), dual transceivers, one Intel 486TM processor and a GPS multichannel reference station receiver with high position update rate, low latency and multipath mitigation. All printed circuit cards are interconnected via a low-noise backplane with the STD-32 Bus. This flexible design facilitates adaptation to the configuration requirements of various applications.

The LINCS T3L/F Base Station Transponder software is implemented in the Ada programming language and is certifiable to RTCA/DO-178B, level A.

The LINCS T3L/F Base Station Transponder is CE-certified.



Technical Data LINCS T3L/M

HxWxD
193,5x157,2x364 mm (ARINC 404A)

Weight
≤10 kg

Power input
19-32 V DC or
115 V AC/400 Hz
appr. 4 A @ 28 V DC

Connectors
GPS antenna: TNC female 50-Ohm
Transceiver antenna VHF 1 and 2: Triax type 50-Ohm
Comp. link, config. link: D-sub, 9-plugs, RS 232
ASCII link: D-sub, 9-plugs, RS 232
Power supply: D-sub, 5-plugs

GPS receiver
Ashtech G12 all-in-view 12-channel, 10 Hz position update
Reacquisition time: <2 s

Transceiver
(Complies with I-ETS 300 113 Packet Radio Standard)
Frequency: VHF 112-140 MHz (or 136-174 MHz)
Modulation: FM/GMSK
Data rate: 9600 bps
Power output: programmable 1-25 W
No. of channels/transceiver: 16
Bandwidth: 25 kHz
Refresh rate: dynamically controlled

Operating environment
Complies with RTCA-DO160D

Technical Data LINCS T3L/F

HxWxD
176,3x482,6x500 mm (19" rack standard)

Weight
≤20 kg

Power input
100-240 V AC, 50/60 Hz

Connectors
GPS antenna: TNC female 50-Ohm
Transceiver antenna VHF 1 and 2: Triax type 50-Ohm
Comp. link, config. link: D-sub, 9-plugs, RS 232
ASCII link: D-sub, 9-plugs, RS 232
Power supply: D-sub, 5-plugs

GPS receiver
Ashtech G12 all-in-view 12-channel reference receiver, 2 Hz position update
Reacquisition time: <2 s

Transceiver
(Complies with I-ETS 300 113 Packet Radio Standard)
Frequency: VHF 112-140 MHz (or 136-174 MHz)
Modulation: FM/GMSK
Data rate: 9600 bps
Power output: programmable 1-25 W
No. of channels/transceiver: 16
Bandwidth: 25 kHz
Refresh rate: dynamically controlled

Operating environment
Temperature: 0°C to +60°C

SAAB
Saab Dynamics AB

SE-581 88 Linköping
Sweden
Telephone +46 13 18 60 00
Telefax +46 13 18 60 06
www.saab.se/dynamics


NINS/NILS
An autonomous navigation
and landing system
SAAB
AEROSPACE

The navigation and landing supervisor for the 21st century

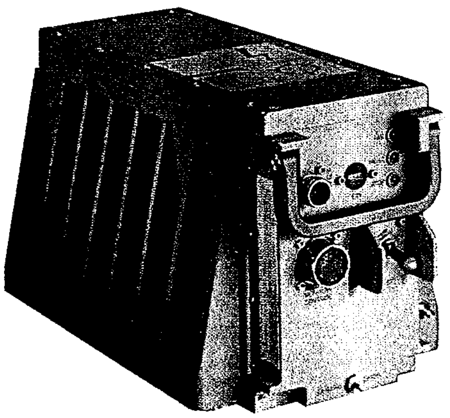
Saab NINS is a total navigation solution including modular hardware and software based on digital geographical databases.

The system offers an alternative navigation solution that is fully real-time and independent of ground- or space-based equipment. The software package can be integrated both with aircraft and cruise missiles, with selected hardware and software features as an "add-on" package for existing platforms or in new designs where the full benefit of Saab NINS can be utilized.

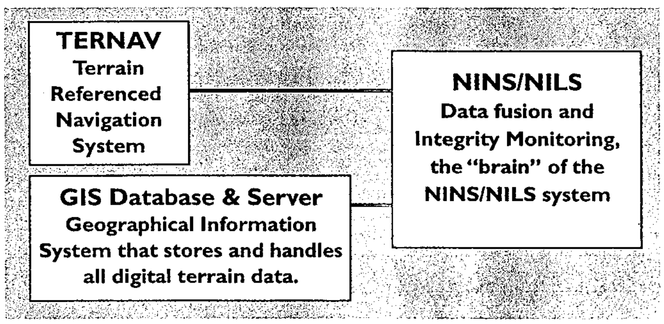
Key features of the system include

- high position and velocity accuracy
- fully autonomous operation
- awareness of surrounding terrain

Saab NILS is a landing system that takes full advantage of the NINS concept by creating a glidepath based on NINS navigation information. Only onboard sensors are utilized, which reduces cost and increases flexibility, e.g. for operations from austere or dispersed bases with no ground equipment.



NINS/NILS hardware based on PowerPC processors and MIL-STD-1553B communications with the inertial navigation system (INS), the air data computer (ADC) and the radar altimeter (RA).



The **NINS/NILS** system computer.

System overview

Saab **TERNAV** is a non-linear terrain-referenced navigation algorithm that has been developed over 20 years and achieves military GPS performance in the envelope. The system is operational in Swedish Air Force AJS 37 Viggens and in full-scale development for deployment in the JAS 39 Gripen.

A high-precision continuous position fix can be derived from the basic sensor data (INS, ADC and RA) and from the GIS database.

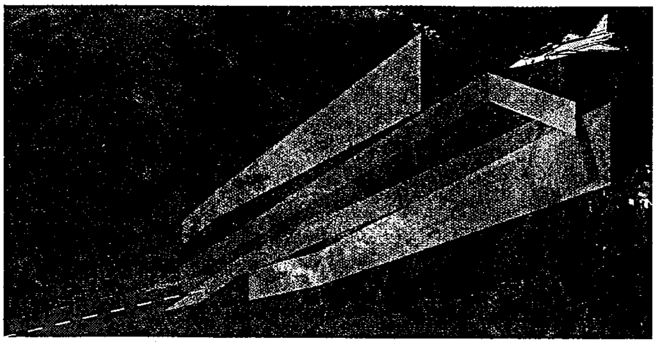
The GIS Database & Server is where all terrain databases, including those for landing, are stored and prepared for real-time access. TERNAV is one application that uses GIS, along with others such as passive terrain-following and ground-proximity warning.

The Data Fusion function handles all incoming and outgoing data streams from sensors and system functions. It is the decision-maker in the system and feeds data to all the other functions as well as to the cockpit displays.

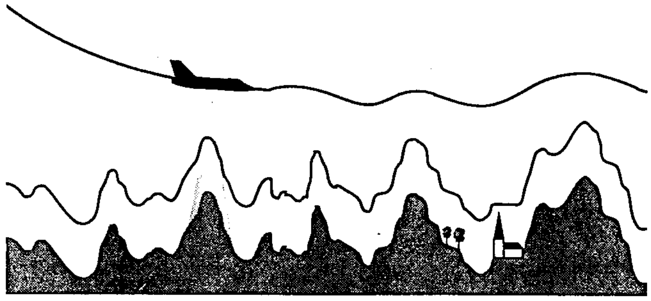
At its heart is a Kalman filter for optimal processing of all incoming data streams. The filter utilizes all navigation information in the system to estimate the position, velocity and attitude of the platform.

The pilot's standard cockpit displays show information output from the Data Fusion function, including navigation and approach information, ground-proximity warnings, etc.

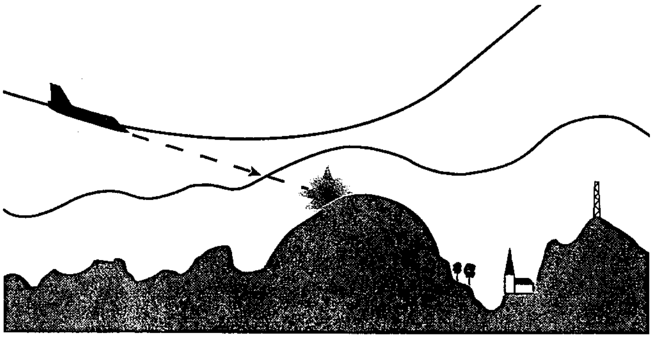
Integrity Monitoring is a diagnostic system for failure detection and exclusion of failed-sensor signals. With support sensors (e.g. GPS), it is possible to achieve integrity monitoring at an even higher level, allowing for graceful degradation while still supporting many system functions.



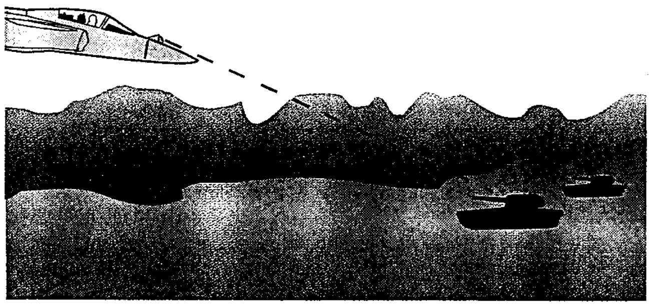
NILS generates glidepath information only from onboard sensors, allowing aircraft such as the Gripen to use austere or dispersed bases without requiring any inputs from ground-based equipment.



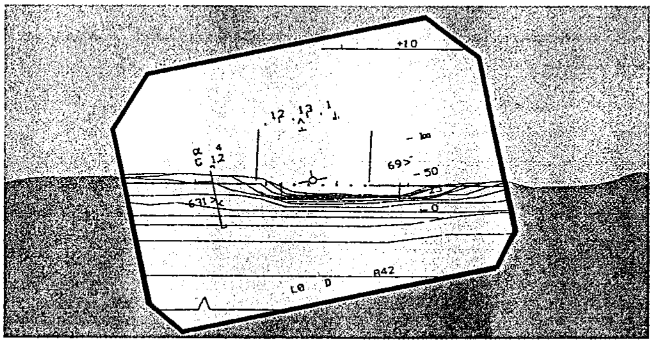
Combining the GIS Database, predictive algorithms and NINS, the system allows for passive, unjammable terrain-following and navigation. Figure shows a descending flight path and predictive terrain-following (blue), a pre-set safety height (red) and the underlying digital terrain database (green).



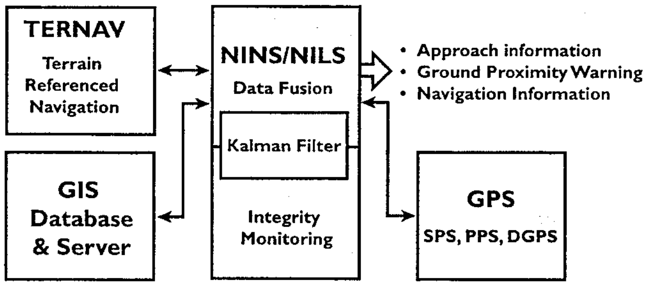
Ground-proximity warning is based on a concept similar to passive terrain-following, with a pre-set safety height and warning functions when the predictive algorithm detects ground. Obstacle warning is included in the system.



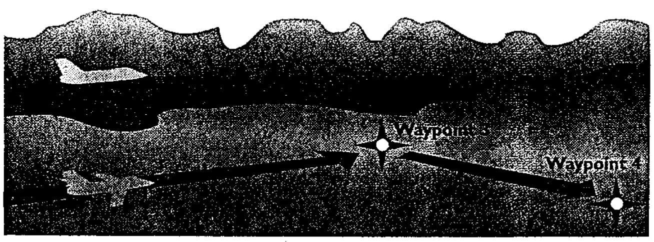
Passive target-ranging. With NINS navigation accuracy and a ground target in the field of view of IR-OTIS, precision passive targeting is possible for improved weapon-aiming or surveillance.



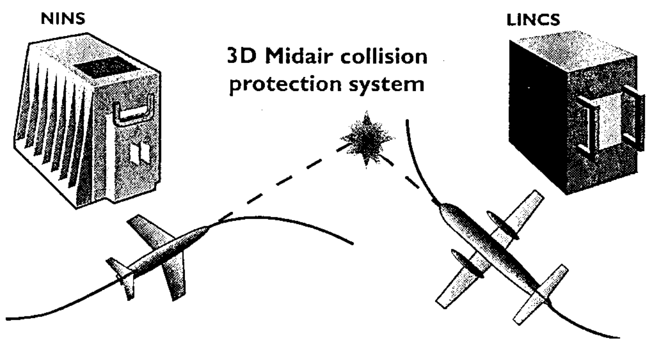
Synthetic terrain presentation in the HUD. At low altitude, in adverse weather or at night, displays that include a synthetic terrain presentation give enhanced situation awareness. Horizontal, cross-track "terrain-lines" move with the aircraft, perfectly matching real terrain as a result of NINS performance.



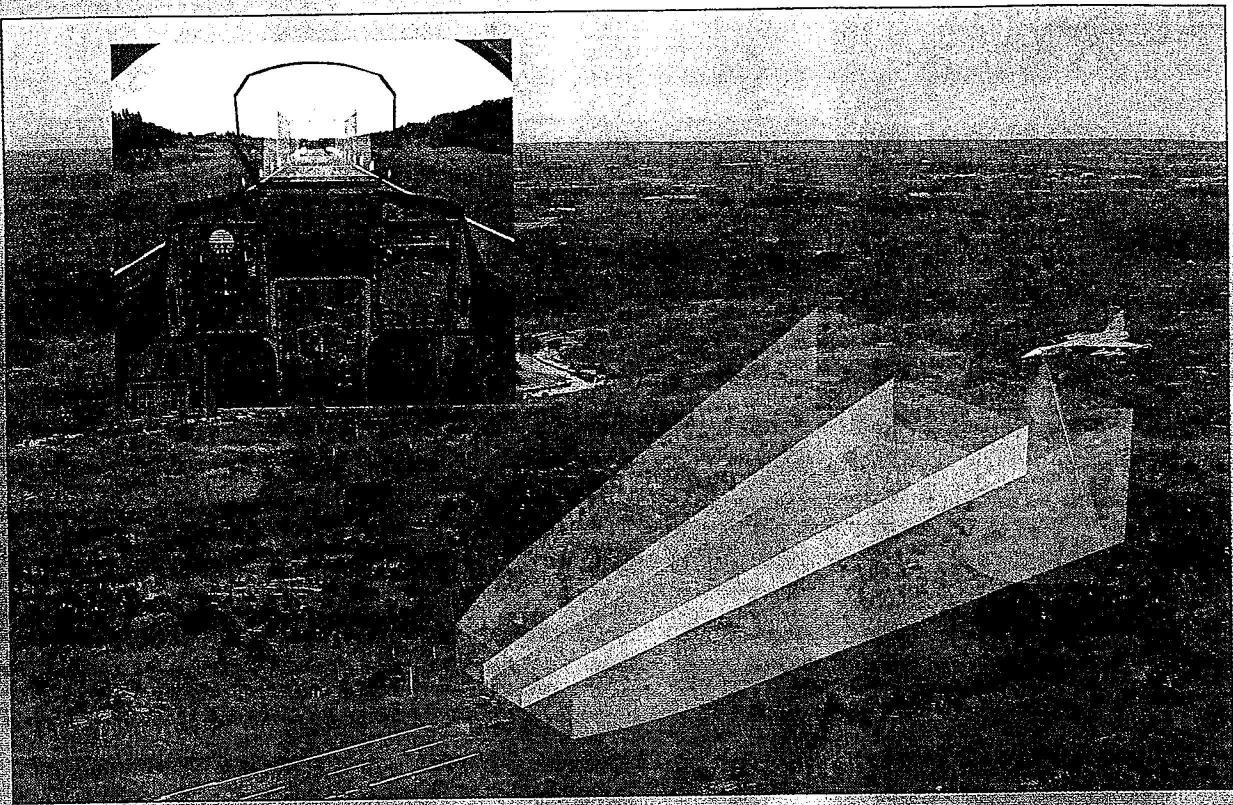
Integrity Monitoring is a software diagnostic system for failure detection and exclusion of failed-sensor signals. With GPS, integrity monitoring is possible at an even higher level, allowing for graceful degradation.



NINS improves random route navigation capability, offering more freedom in the selection of waypoints, better waypoint precision and therefore higher weapon delivery accuracy.



By combining the ground-proximity warning and terrain-following predictive algorithms in NINS with GPS-derived data from aircraft equipped with LINCS, a high-performance 3D airborne collision-avoidance algorithm can provide protection even in high maneuvering situations. Core system functions were flight-tested in February 1998.



Saab NINS/NILS main characteristics

Saab NINS is a total navigation solution including modular hardware and software based on digital geographical databases. Main characteristics are:

- Utilizes existing inertial or Doppler navigation system, radar or laser altimeter and air data system
- High real-time position and velocity accuracy, plus error awareness
- Surrounding-terrain awareness

Saab NILS is a landing system that takes full advantage of the NINS concept, creating a glidepath based on NINS data. Main characteristics are:

- Utilizes existing digital or analog instruments to create glideslopes similar to ILS
- Curved-approach capability
- Utilizes only onboard sensors, reducing cost and increasing flexibility

Options

Ground-proximity warning
Terrain-following
Input to virtual reality in the HUD
Passive target-ranging
Integrity monitoring with GPS
Mid-air proximity warning with LINCS

Specification

Performance (dependent on sensors and terrain characteristics):

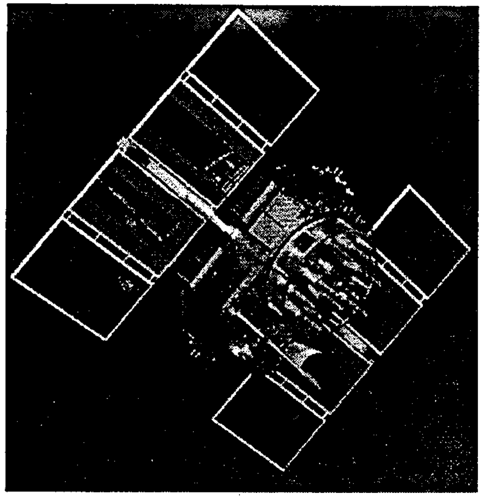
- Horizontal position error: 5-50 m, CEP 50%
- Vertical position error: 2-4 m (1-sigma)
- Horizontal velocity error: 0.05-0.5 m/s CEP 50%
- Vertical velocity error: 0.02-0.2 m/s (1-sigma)
- 3 min over water with negligible performance degradation

Performance at the high end of these accuracies has been demonstrated regularly with a 1 n.m./h INS and "standard" RA and ADC systems over 90% of Swedish terrain.

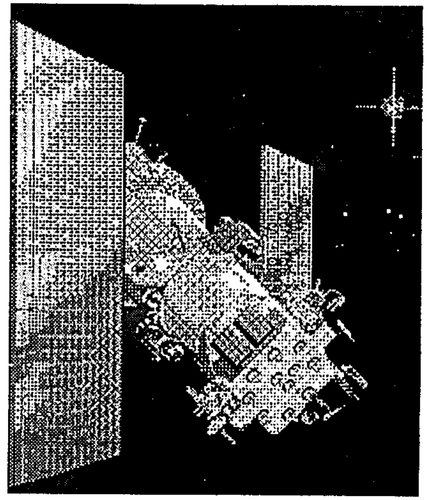
SAAB AEROSPACE
SAAB
Saab Dynamics AB

SE-581 88 Linköping
Sweden
Telephone +46 13 18 60 00
Telefax +46 13 18 60 06
www.saab.se/dynamics

SEATEX



A Combined GPS/GLONASS Position Reference System for DP Operations



SEATEX AS

A COMPANY IN THE NAVIA GROUP

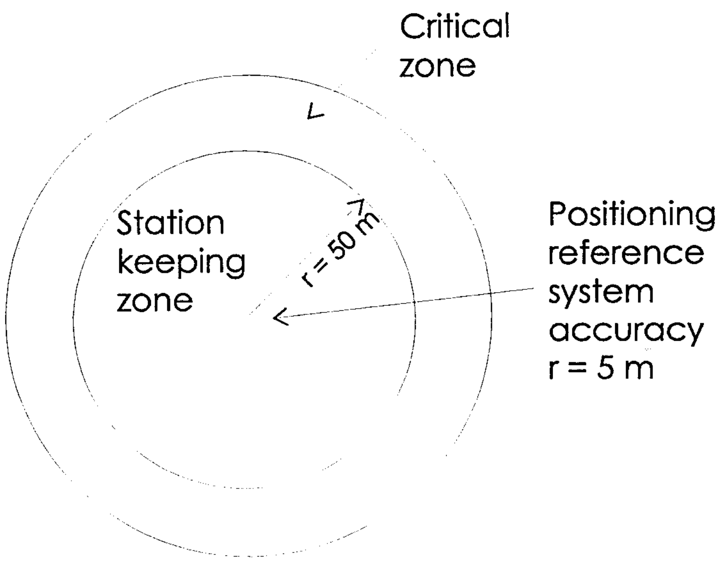
POSITIONING REFERENCE REQUIREMENTS

SEATEX

- IMO, *GUIDELINES FOR VESSELS WITH DYNAMIC POSITION SYSTEMS*
  - **Minimum 3 position reference systems, not all of same type but based on different principles suitable for operating conditions**
- Other requirements to be considered
  - **Accuracy**
  - **Availability**
  - **Integrity**
  - **Continuity**

SEATEX

Accuracy Requirements



SEATEX

GPS GLONASS

GPS

- American
- 24 satellites
- Operational (1993)
- Accuracy 100 m (95% prob), GPS
- 1 - 5 m (95% prob), DGPS

GLONASS

- Russian
- 24 satellites (14 operational)
- Operational (1996)*
- Accuracy 57 - 70 m (99.7% prob), GLONASS
- 1 - 5 m (95% prob), DGLONASS

GPS, GLONASS and GPS/GLONASS

SEATEX

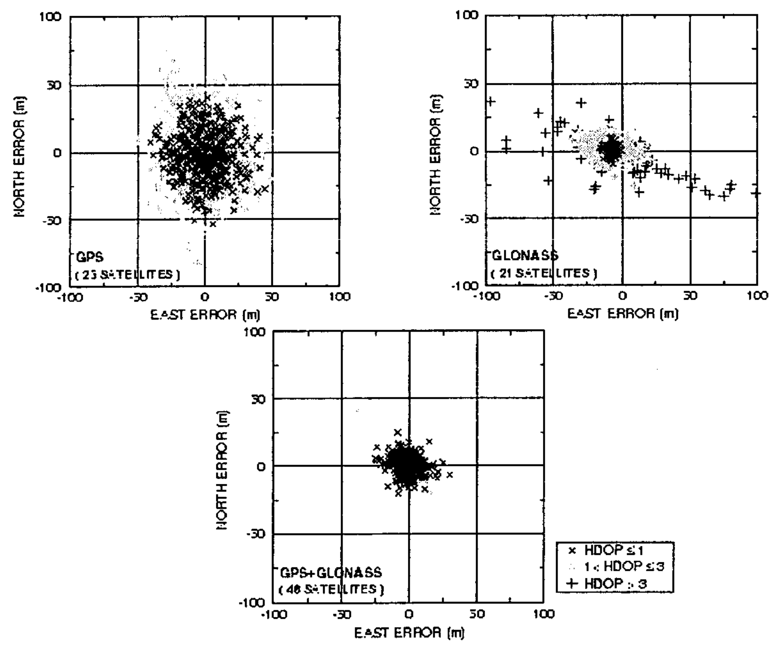


Figure 3. GPS & GLONASS Position Estimates (1-minute samples, 1 September 1996).

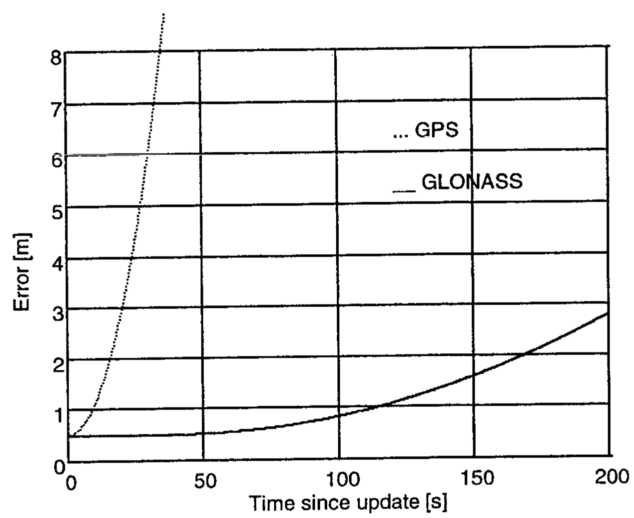
Integrated DGPS/GLONASS

SEATEX

- The integrated system inherits al advantages from GPS and GLONASS
- The integrated system has twice as many satellites available
- The integrity capacity increases to 100%
- The system is robust against loss of differential corrections. The combined accuracy is < 16m 95% even without the differential corrections
- Blocking by structures is less of a problem due to the large amount of available satellites
- Availability increases to close to 100%

SEATEX

Errors in DGPS and DGLONASS as a function of age of corrections



SEATEX

Critical parameters

- The main error source for the integrated DGPS/DGLONASS system will be on board the vessel
- The installation has to be subject to thorough planning to maximise the availability of the system

SEATEX

Installation considerations

- The GPS and GLONASS antennas should be well separated in different masts if possible
- The GPS and GLONASS antennas should have a free view of the horizon in all directions
- The antenna cabling should be separated for the different antennas
- The antennas or antenna cables should not be exposed to the Inmarsat transmission beam, at least not simultaneously
- Separate UPS supplies for the GPS and GLONASS parts

TSW - 981130.gggevle98co.ppt

SEATEX AS
A COMPANY IN THE NAVIA GROUP

SEATEX

Installation considerations

- The satellite communication antennas should have a clear view of the horizon
- The electronic system should be mounted with good ventilation in a clean environment and not exposed to other heat transmitting sources

TSW - 981130.gggevle98co.ppt

SEATEX

Reliability of DP Operations Sea Trials

Storegga Nov-1998

TSW - 981130.gggevle98co.ppt

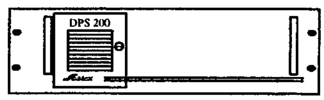
GPS/GLONASS products in the deep water technology program

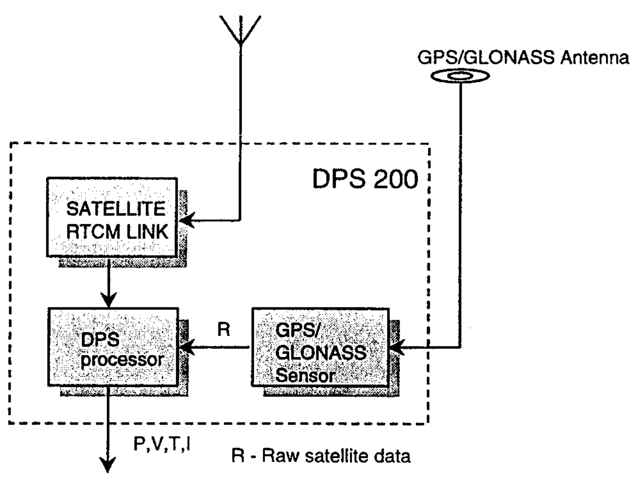
SEATEX

- GLONASS Reference Station
- GLONASS Integrity Monitor Station
- Differential GPS/GLONASS mobile system

DPS 200, DGPS/DGLONASS, Single Configuration

SEATEX

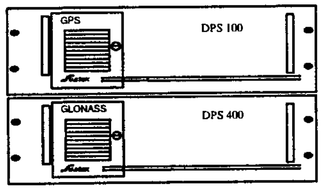




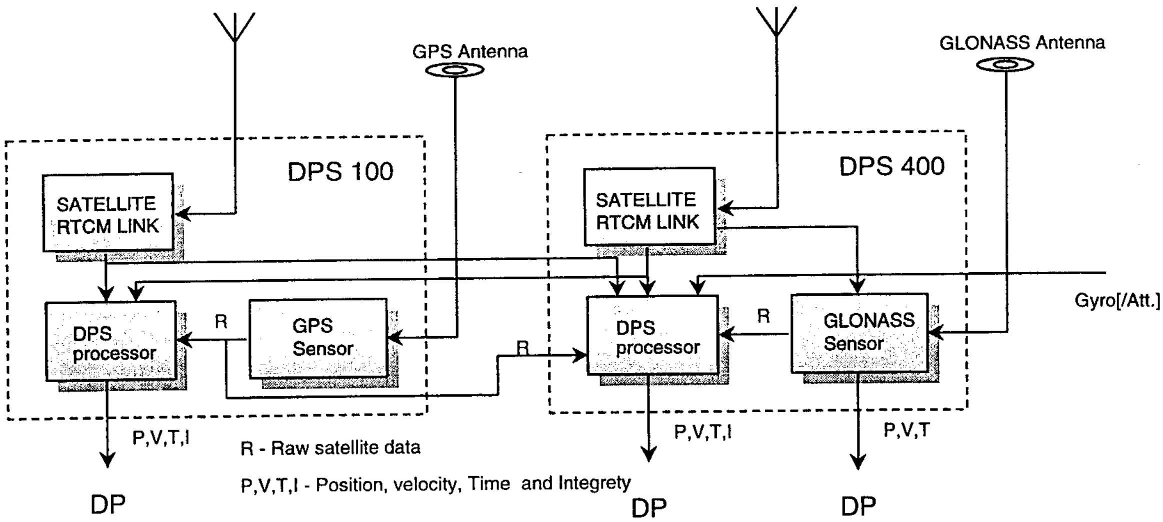
TSW - 981130.gggevle98co.ppt

SEATEX AS
A COMPANY IN THE NAVIA GROUP

DPS 400, DGPS/DGLONASS, Dual Configuration

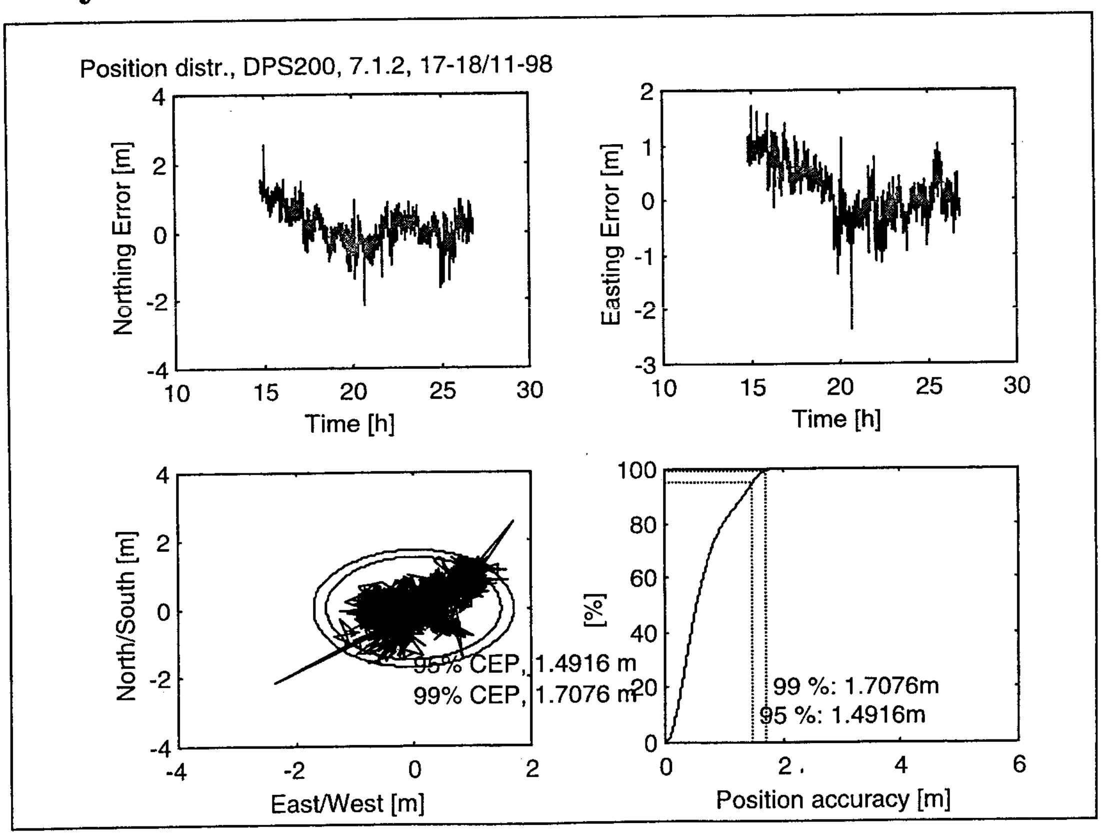


SEATEX



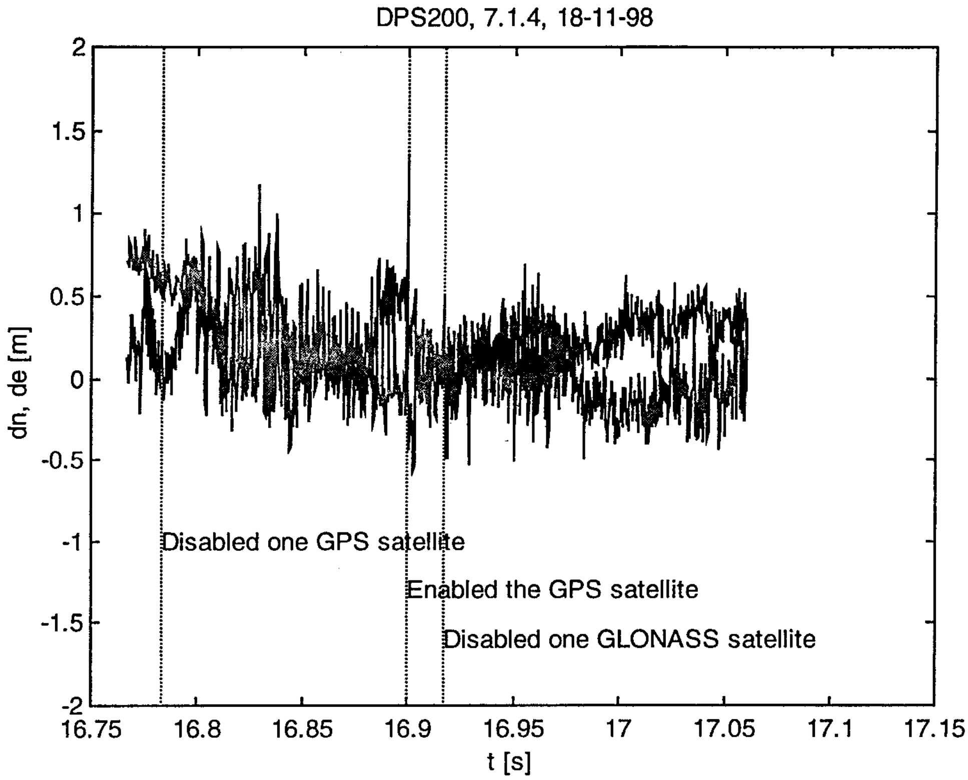
Dynamic Accuracy Test

SEATEX



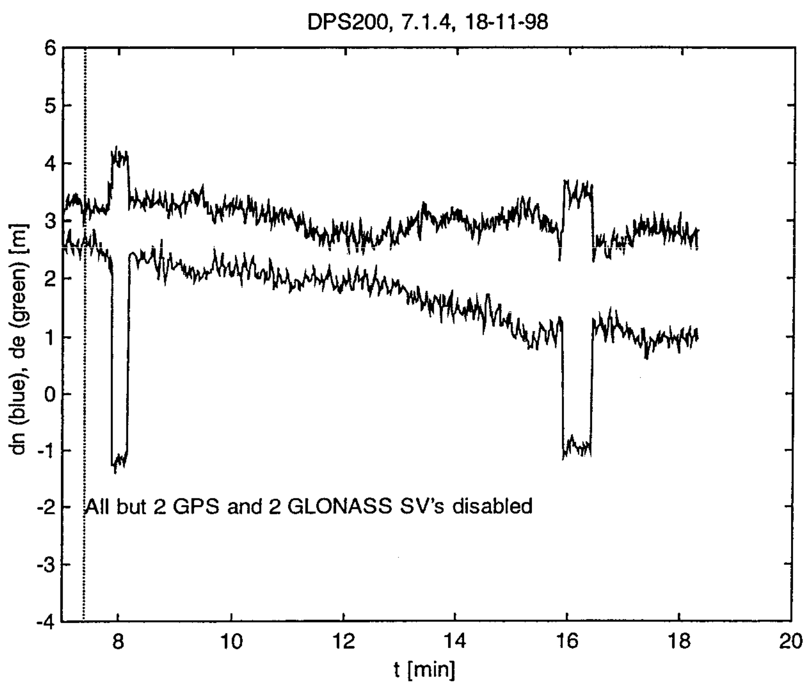
Loss of Satellites

SEATEX



Loss of satellites

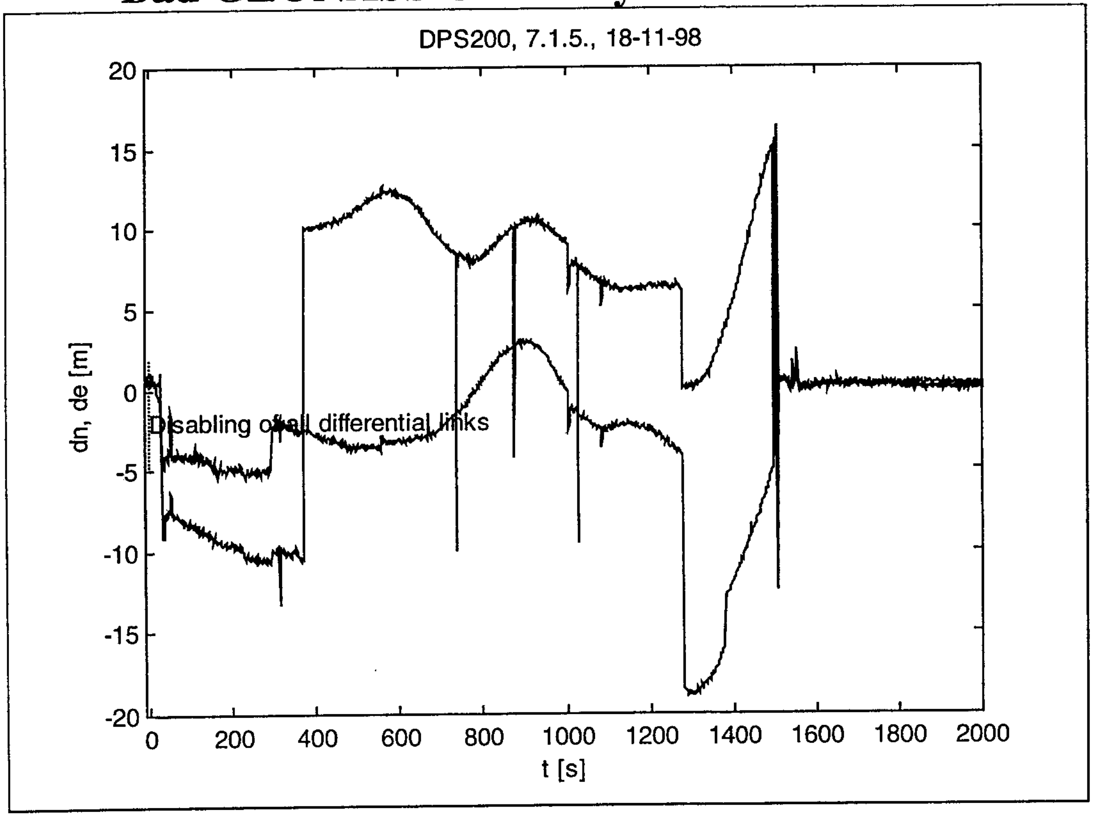
SEATEX



0124

Loss of Differential Correction Signal. Bad GLONASS Geometry.

SEATEX



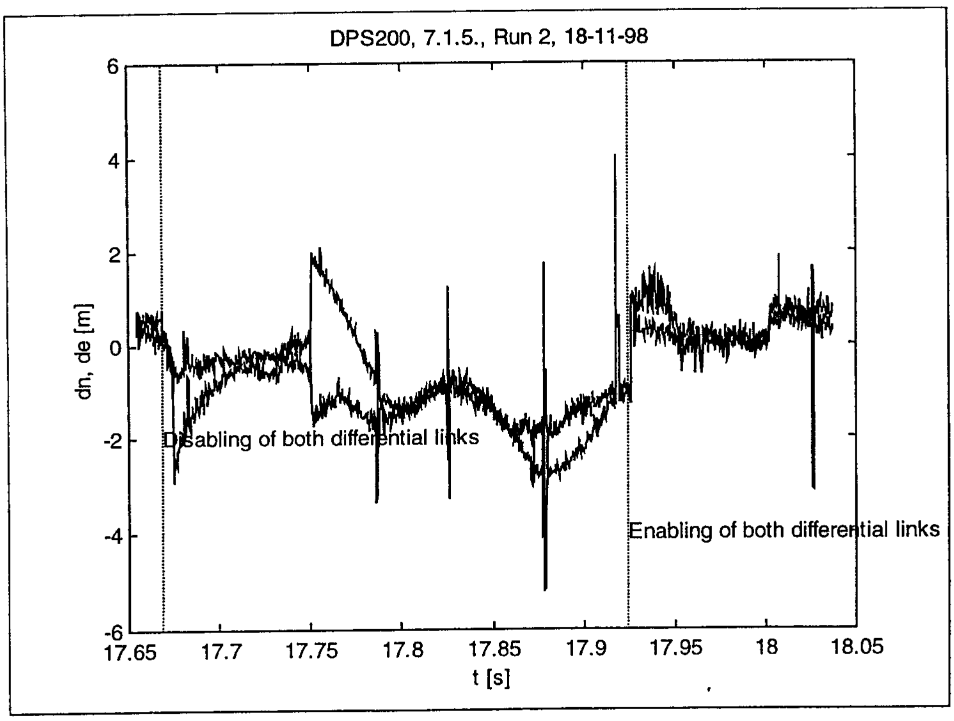
SEATEX AS

A COMPANY IN THE NAVIA GROUP

TSW - 981130gggevle98co.ppt

Loss of Differential Correction Signal. Good GLONASS Geometry.

SEATEX



SEATEX AS

A COMPANY IN THE NAVIA GROUP

TSW - 981130gggevle98co.ppt

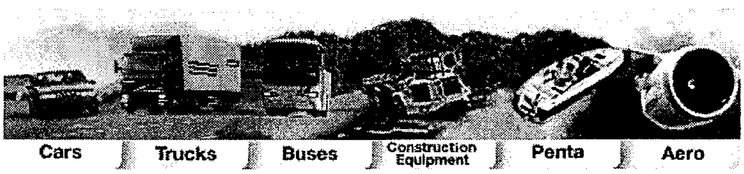
Volvo Technological Development Corporation

GPS applications at Volvo

Sven Jonsson
Volvo Technological Development

VOLVO

Volvo Technological Development Corporation



[redacted]

[redacted]

[redacted]

Traffic & Transport

[redacted]

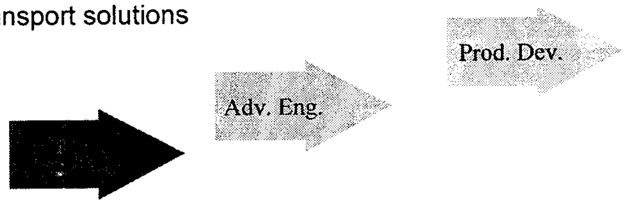
VOLVO

Volvo Technological Development Corporation

Traffic & Transport Competence Areas

- Traffic Information
- Route Guidance
- Fleet Management
- Traveler Information
- Personal Security
- In-vehicle multimedia
- Transport solutions

- Digital Maps
- Mobile Communication
- Standardization
- In-vehicle hardware



VOLVO

Volvo Technological Development Corporation

Key issues in fleet management

- Where are the vehicles?
- What's the status of current tasks?
- How well are they doing it?

Improved productivity and cost efficiency!

VOLVO

Volvo Technological Development Corporation

Dynafleet Info System

A tool for more efficient transports

Message and order management

On-board Mapping

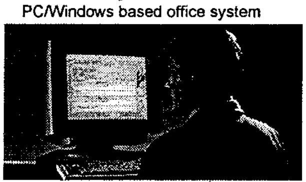
Positioning (GPS)

Traffic Information (FM/RDS radio)

Vehicle/driver information
- -engine data
- -tachograph data
- -weight data

Driver
Embedded on-board system

Dispatcher
PC/Windows based office system



Message and order management

Positioning of vehicles

Report module
- -Driver
- -Vehicle
- -Order

External system (Invoice etc.)

Communication

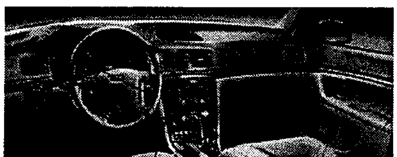
GSM/SMS | Inmarsat/C

Volvo Action Service Europe (Gent)

VOLVO

Volvo Technological Development Corporation

On-board navigation



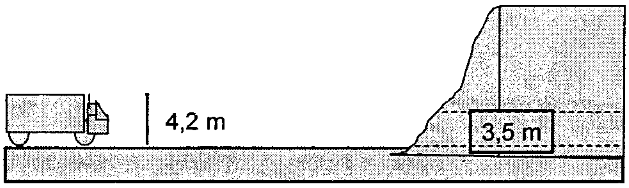
Integrated GSM phone (S80)

RTI - On-board navigation systems (CD-based)
(How do I get from A to B?)
Positioning using GPS, gyro and map matching

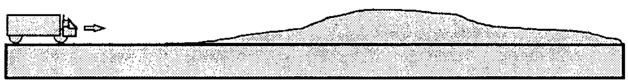
VOLVO

Volvo Technological Development Corporation

Preview (Future)



Slopes & fuel consumption



Volvo Technological Development Corporation

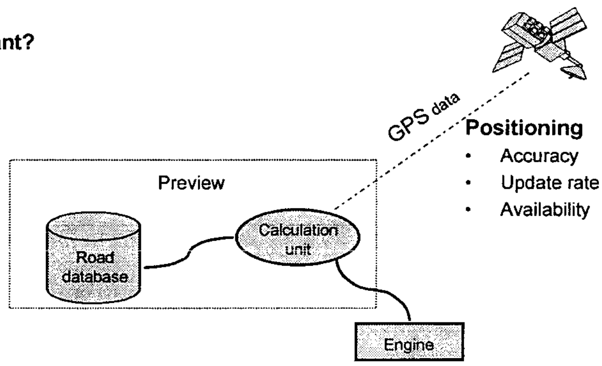
Preview Overview

Which information is relevant?

•Low bridges
•Weak roads
•Narrow roads
•Slopes
•Sharp curves

Database Requirements

- Accuracy
- Performance
- Content
  - Three-dimensional road data
  - Information about restrictions in vehicle configuration



Volvo Technological Development Corporation

A pleasure to drive and own

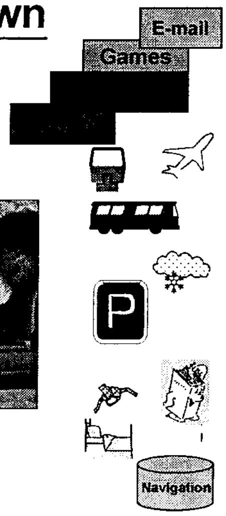
Mobile Internet Access (in-vehicle)

•Dial-up access to traveler services on the internet, no need for on-board databases.

•Low cost on-board terminal, **"pay as you use"**

•Your physical location will not limit your ability to stay in touch - mobile office with e-mail messaging

•Games and entertainment



Enhanced traveling convenience and flexibility!

VOLVO

Integrity Monitoring System (IMoS)

A suite of Windows NT programs for the purpose of integrity monitoring, data storage and data distribution for permanent DGPS or Geodetic reference station networks using TCP/IP protocol.

Scalable parallel computing architecture supporting 2 to 1024 reference stations (once per second).

Software is receiver independent and supports world wide distribution of receivers via Internet.

Defining terms in IMoS

Virtual Integrity Monitoring:
(Replaces the need to purchase a GPS receiver from the manufacturer by creating reference-integrity receiver pairs with software).

GPS Internet node:
(Establish GPS Reference stations as real-time internet nodes (with TCP/IP address) for data access, distribution and integrity monitoring)

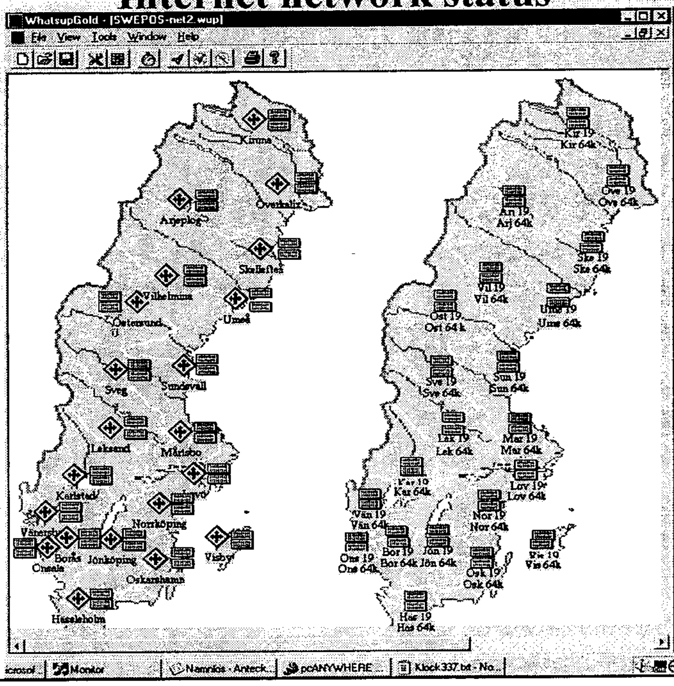
Virtual Reference Station

- Reference Stations are used to check each other's integrity.
- Traditional Requirement for a separate IM GPS receiver is driven by manufacturers
- Using Virtual Reference Station demonstrates accuries closer to those experienced by users.
- Saves Hardware costs: One Pentium II can handle 64 Stations.

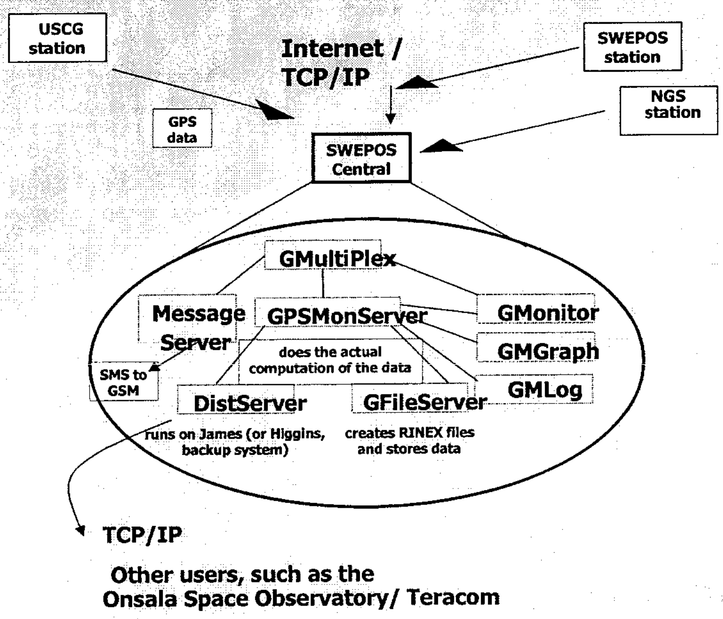
Internet as Telecom backbone

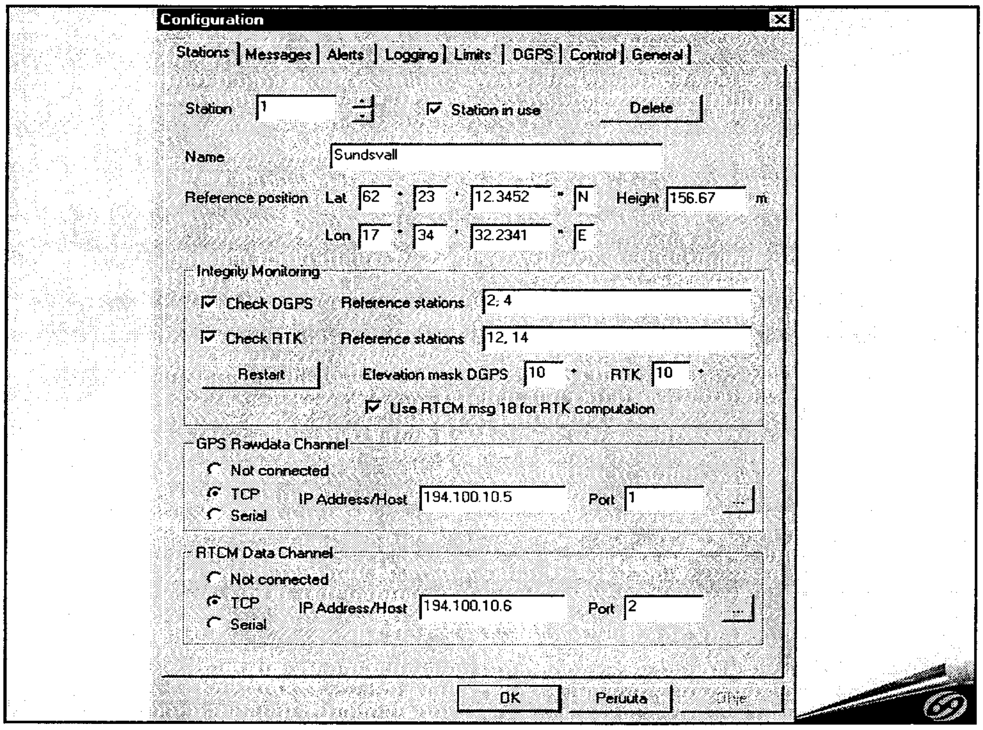
- Fault Tolerant
- Automatic Rerouting
- Inexpensive
- Near real-time
- Equipment readily available

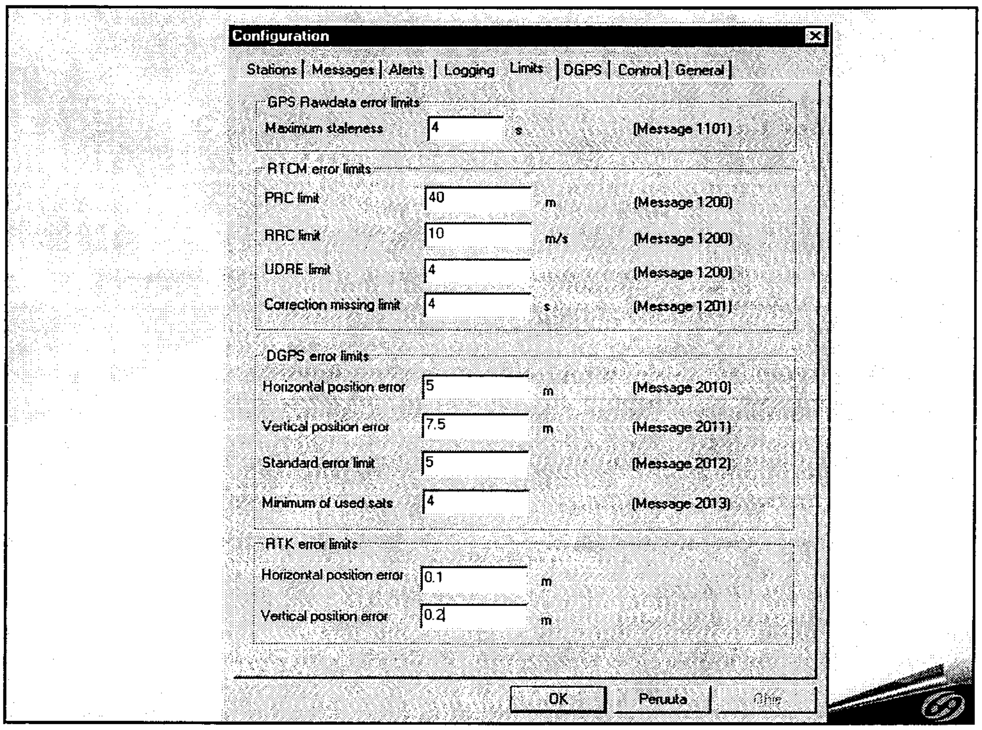
Internet network status

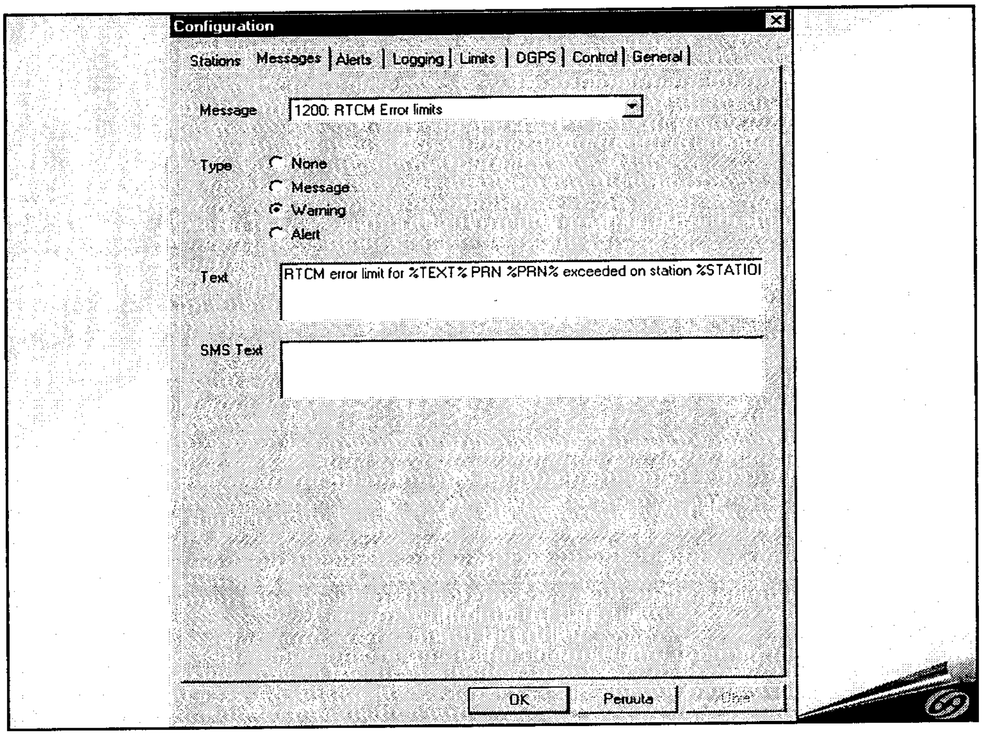


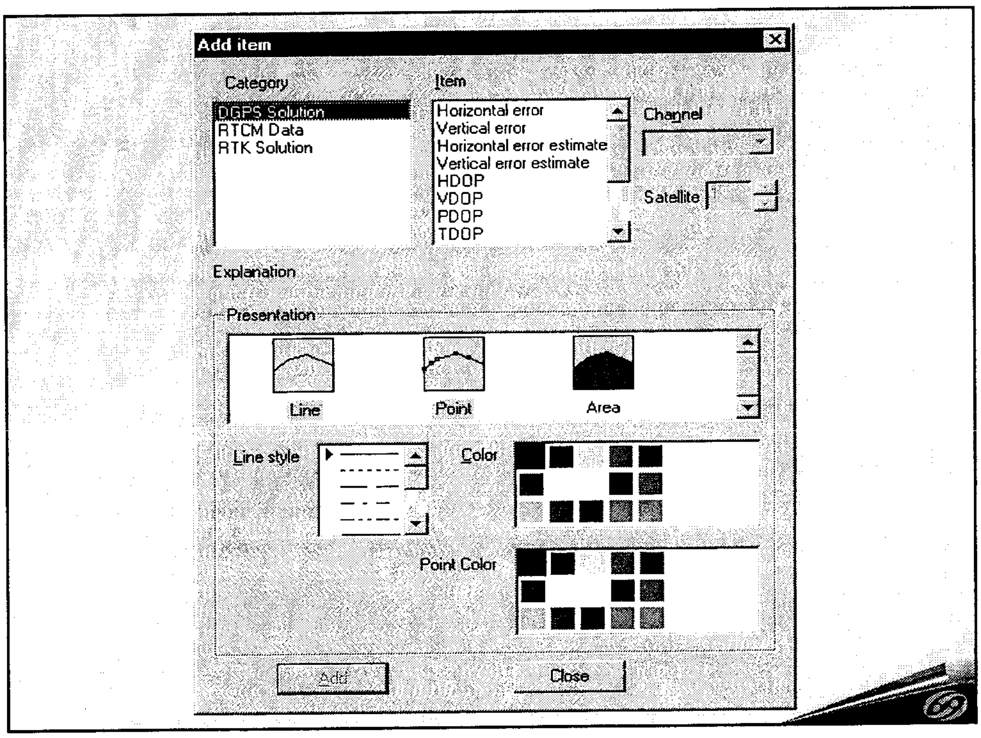
The flow of GPS data from SWEPOS stations to the different parts of IMoS.



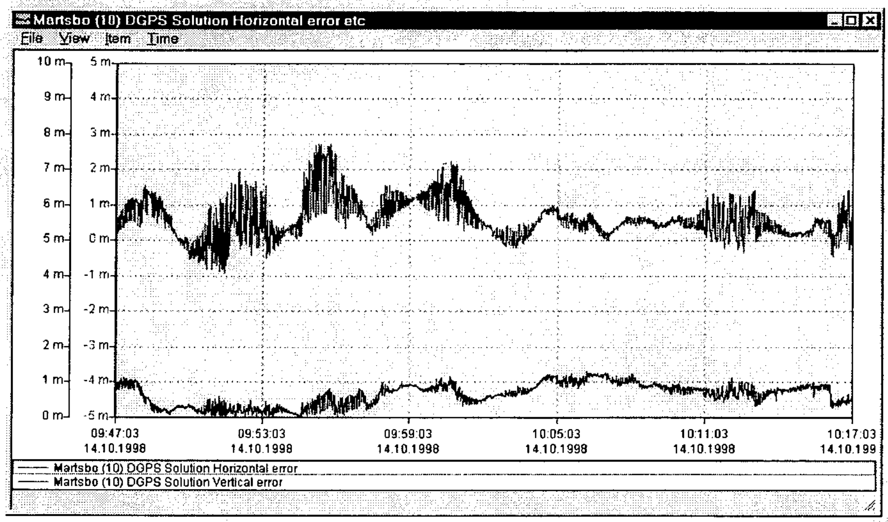

Configuration
Stations | Messages | Alerts | Logging | Limits | DGPS | Control | General
Station 1
Station in use
Delete
Name Sundsvall
Reference position Lat 62 ° 23 ' 12.3452 " N Height 156.67 m
Lon 17 ° 34 ' 32.2341 " E
Integrity Monitoring
Check DGPS Reference stations 2, 4
Check RTK Reference stations 12, 14
Restart
Elevation mask DGPS 10 ° RTK 10 °
Use RTCM msg 18 for RTK computation
GPS Rawdata Channel
Not connected
TCP IP Address/Host 194.100.10.5 Port 1
Serial
RTCM Data Channel
Not connected
TCP IP Address/Host 194.100.10.6 Port 2
Serial
OK
Peruuta


Configuration
Stations | Messages | Alerts | Logging | Limits | DGPS | Control | General
GPS Rawdata error limits
Maximum staleness 4 s (Message 1101)
RTCM error limits
PRC limit 40 m (Message 1200)
RRC limit 10 m/s (Message 1200)
UDRE limit 4 (Message 1200)
Correction missing limit 4 s (Message 1201)
DGPS error limits
Horizontal position error 5 m (Message 2010)
Vertical position error 7.5 m (Message 2011)
Standard error limit 5 (Message 2012)
Minimum of used sats 4 (Message 2013)
RTK error limits
Horizontal position error 0.1 m
Vertical position error 0.2 m
OK
Peruuta

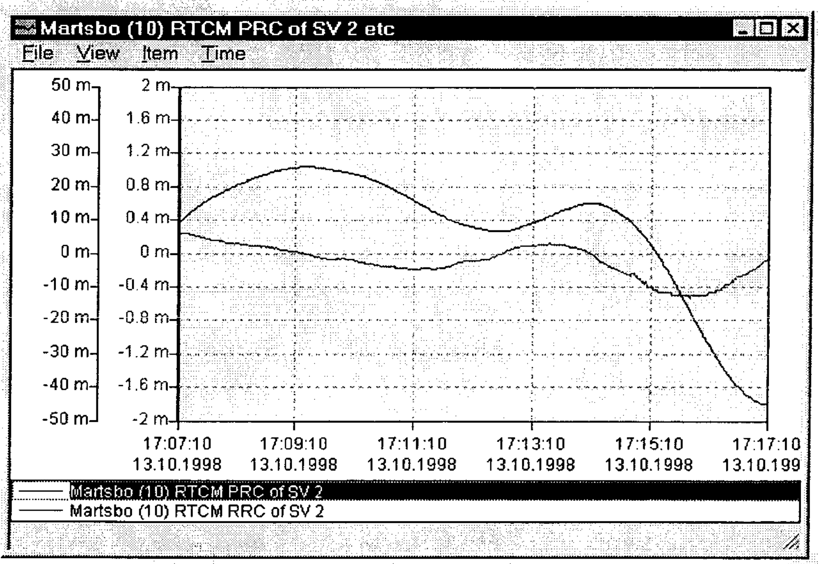

Configuration
Stations
Messages
Alerts
Logging
Limits
DGPS
Control
General
Message
1200: RTCM Error limits
Type
None
Message
Warning
Alert
Text
RTCM error limit for %TEXT% PRN %PRN% exceeded on station %STATIOI
SMS Text
OK
Peruuta


Add item
Category
DGPS Solution
RTCM Data
RTK Solution
Item
Horizontal error
Vertical error
Horizontal error estimate
Vertical error estimate
HDOP
VDOP
PDOP
TDOP
Channel
Satellite
Explanation
Presentation
Line
Point
Area
Line style
Color
Point Color
Add
Close

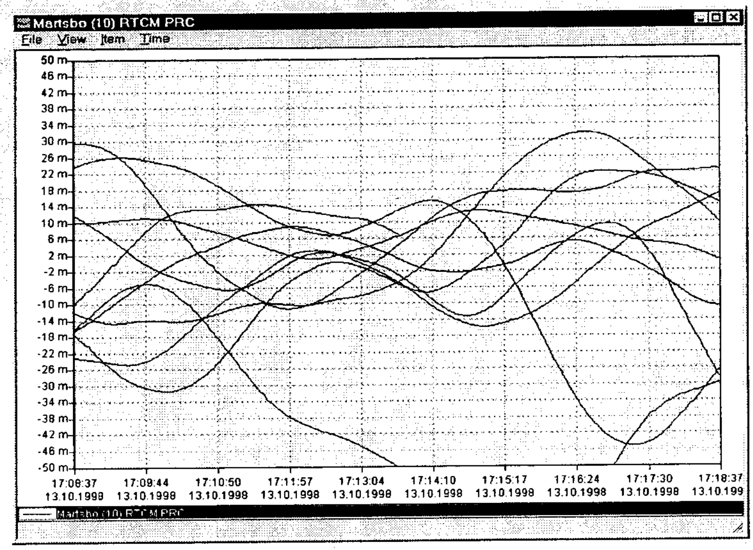
Horizontal/vertical error over 24 hour period



PRC/RRC short term variation (SV 2)



PRC variation over time (all SVs)



0137

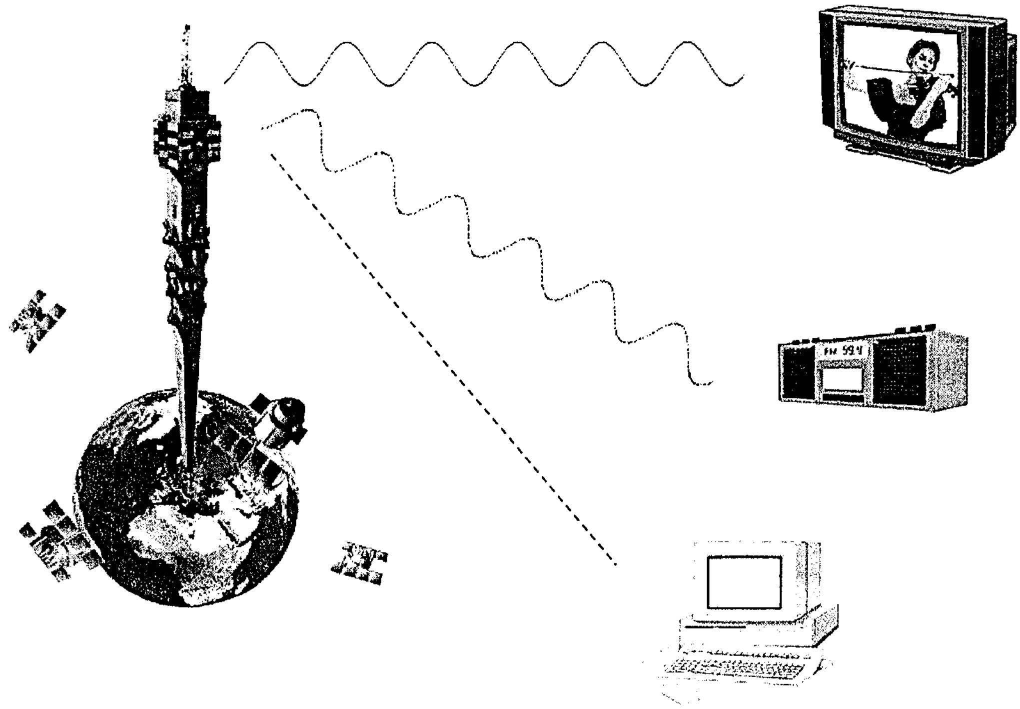
IISC-meeting

1998-12-03

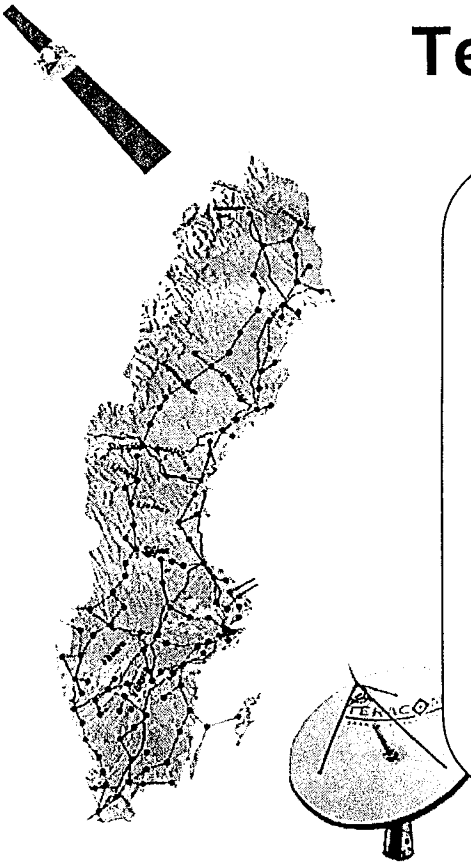
Nation-wide DGPS and RTK services using the FM radio network

Peter Ericson
Teracom AB
Phone: +46(0)920-23 96 05
Email:pet@teracom.se
www.teracom.se

TERACOM

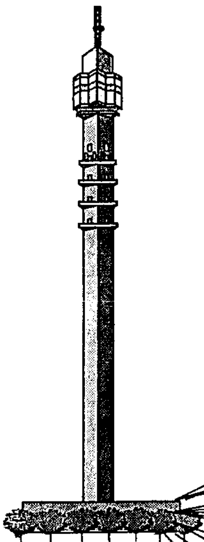


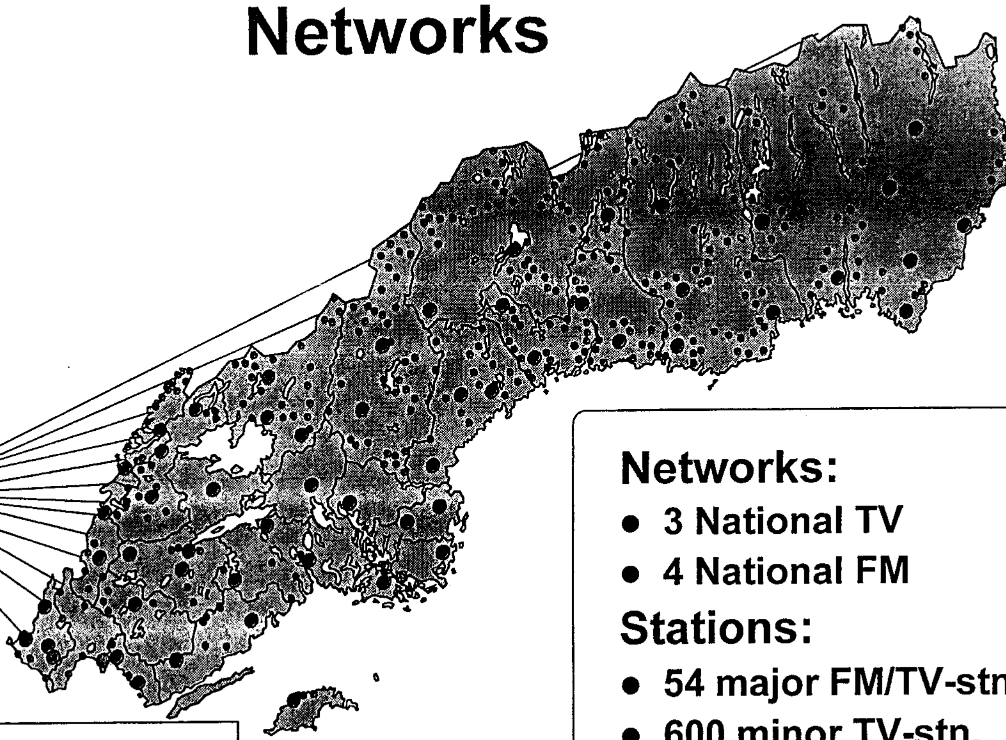
Teracom today



- 54 large FM/TV -stations
- About 600 small FM/TV -stations
- National radio broadcasting network
- Satellites: Sirius 1, Sirius 2 and Sirius 3
- Sales: ~ 1.2 miljards
- Employees: ~740

Networks





- Major FM/TV-stations
- Minor stations for TV and FM
- AM-stations

Networks:

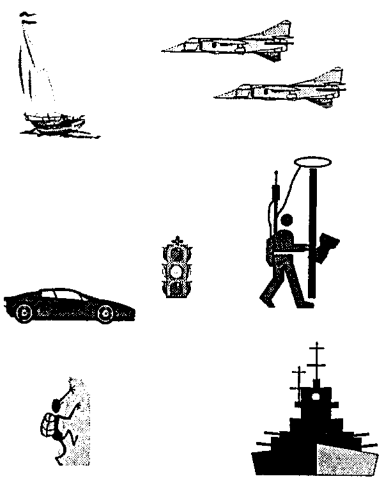
- 3 National TV
- 4 National FM

Stations:

- 54 major FM/TV-stn.
- 600 minor TV-stn.
- 100 minor FM-stn.

- Differential GPS via FM RDS
- Started Dec -1994
- Subscription based service
- Two levels of accuracy:
  - Premium, 2 m
  - Basic, 10 m
- Teracoms role as Service Provider:
  - Broadcast
  - Supervision
  - Quality controll
- Customer support
- Subscription management

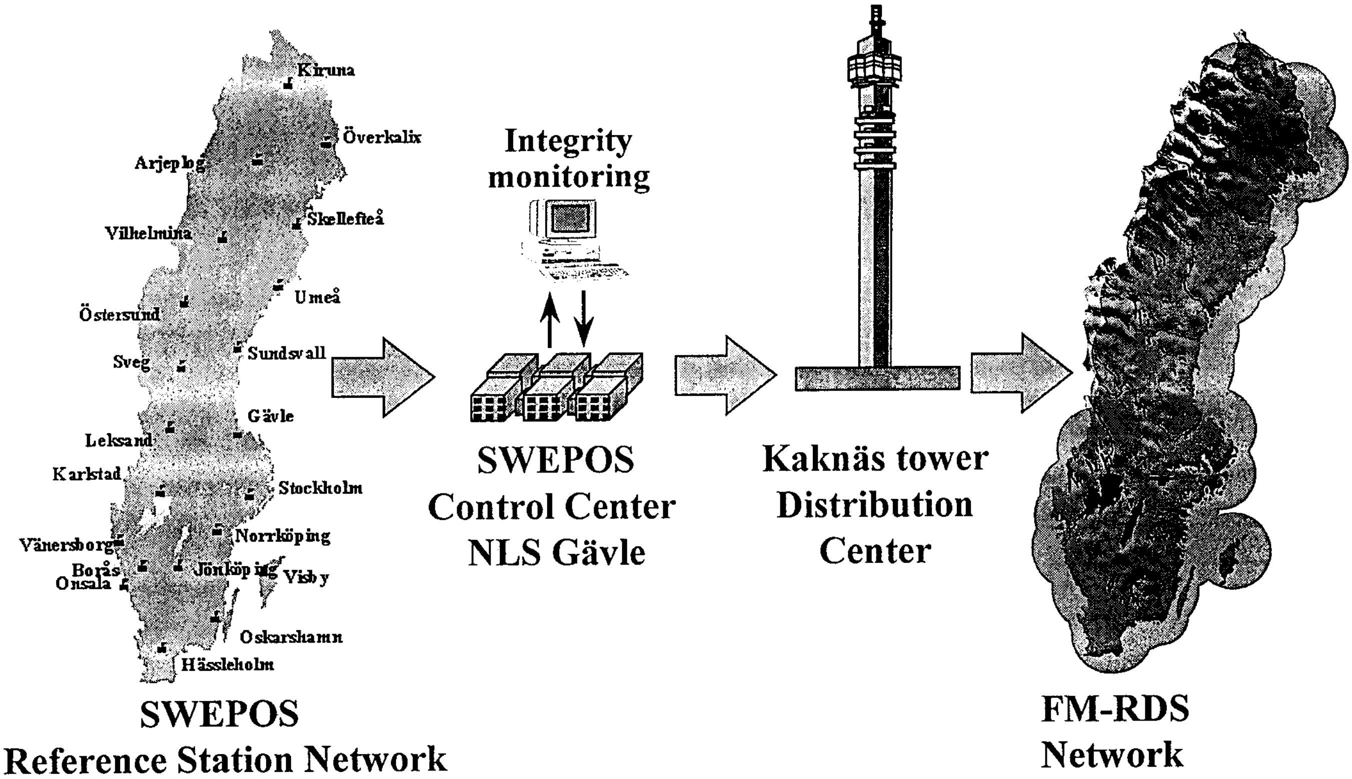
Users



- Marine
- Aviation
- Mobile, car and traffic
- Survey and mapping (GIS)
- Personal Alarms and security applications
- Applications for the total defense

0140

Distribution



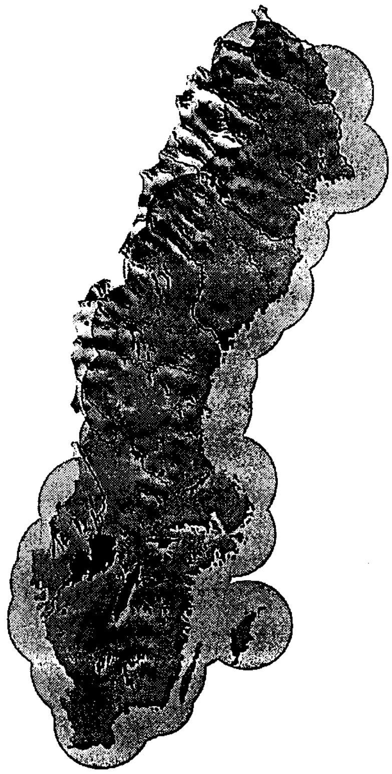
Radio Data System, RDS

- FM subcarrier at 57 kHz
- Data transfer speed: 1187,5 bit/s
- Global standard.
- Primarily used for program related information
- Channel suitable for mobile data reception
- Reaches >99,9% of the Swedish population

0141

Coverage

- 2 FM Networks
  P3 : 54 major + 82 small FM-stn.
  P4 : 54 major + 114 small FM-stn.
- Coverage >99.9% (population)
- Sea coverage ~ 100 km
- FM in stereo = Epos coverage

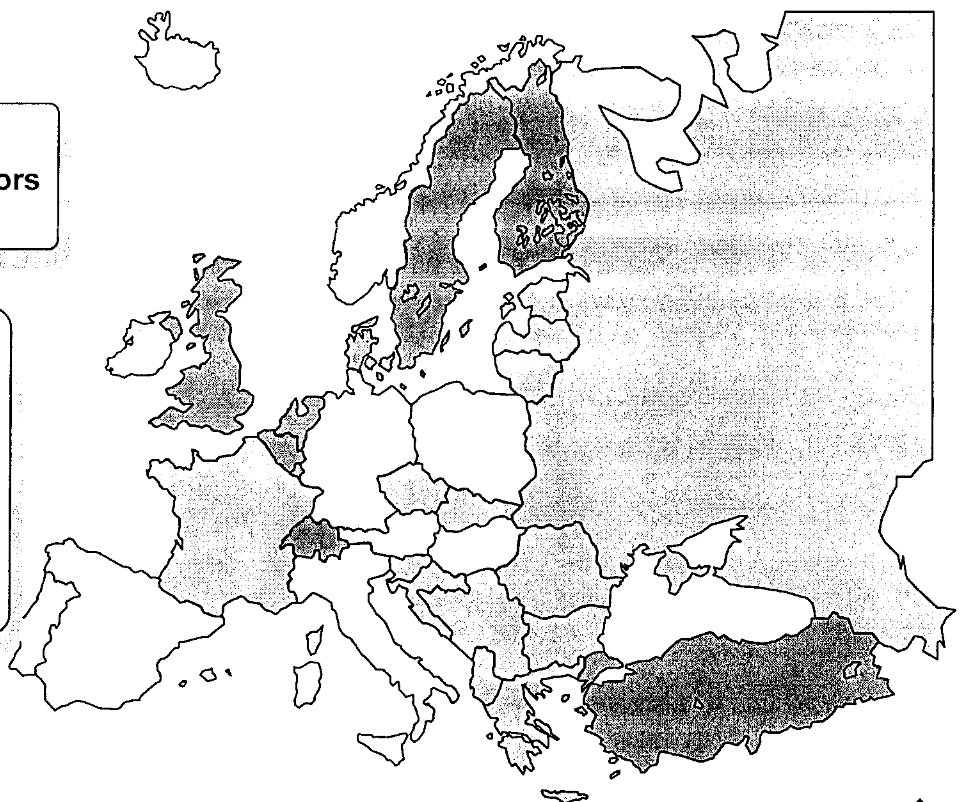


DGPS via RDS in Europe

- Operational
- Contracted Operators
- Trials / Evaluation

Outside Europe

- USA
- Canada
- Australia
- Singapore
- Taiwan



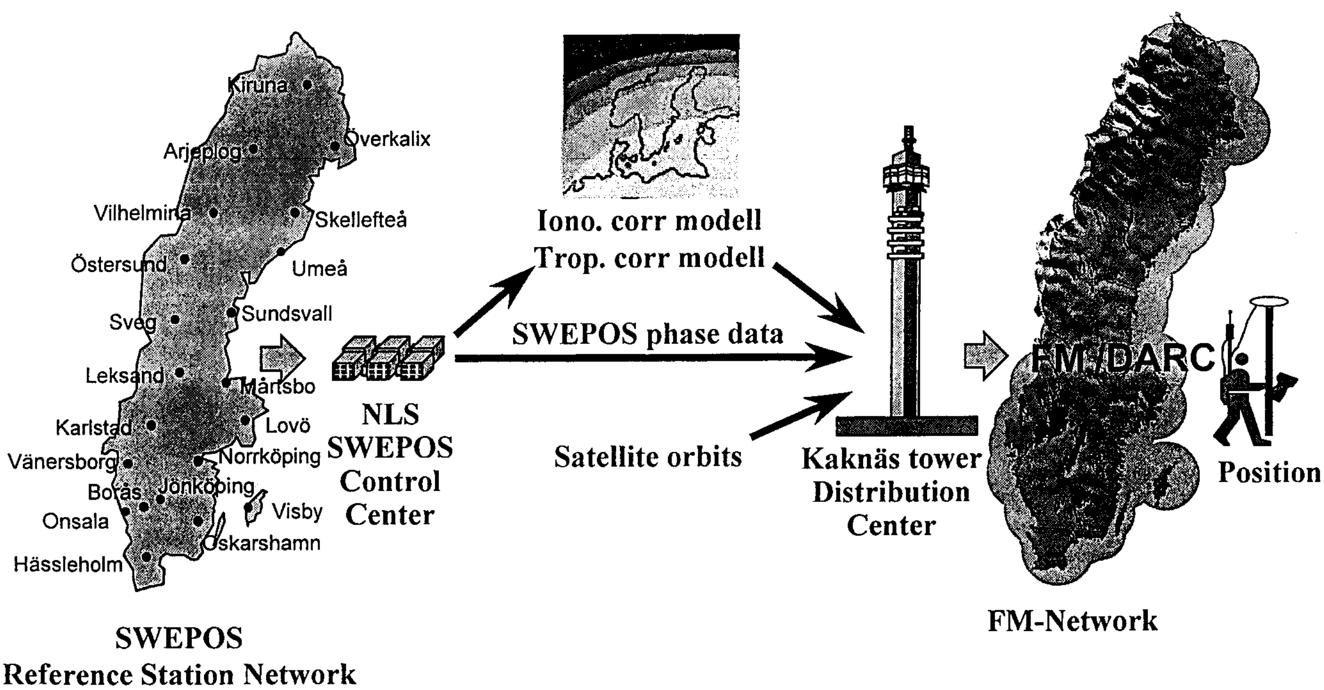
The Ciceron project

Project parts:

- SWEPOS
- Modelling of errors
- The DARC channel

LANTMÄTERIVERKET TERACOM

Distribution



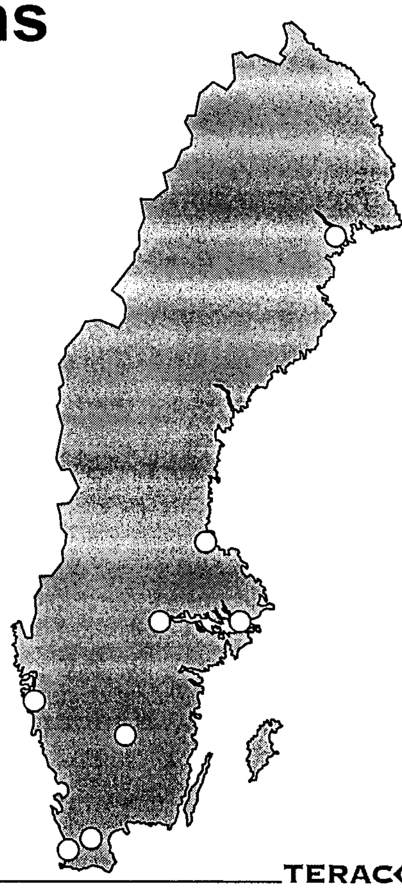
Test plattforms

Test areas:

- Luleå, Gävle, Göteborg
- Malmö, Hörby, Jönköping, Stockholm, Västerås

Test pilotes

- Customers
- Retailers, manufactures



Test plattforms => RTK Service

A Ciceron (RTK) service

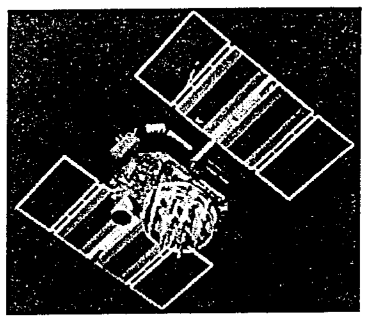
- Based upon our existing test plattform.
- Experience from test pilotes
- Start of service 99-04-01 ?

Global Positioning System

- A basic utility
- A powerful addition to other technologies
- A productivity booster
- An infrastructure manager

GPS at a glance

- 24 satellites
- 18000 kilometers above Earth
- Maintained by U.S. DOD
- Guaranteed by PDD & Law
- Available everywhere for free



Global Navigation Satellite Services & Mobile Satellite Services

- GPS and MSS are Synergistic
- GNSS & MSS are Fundamentally Different
- Cannot Share the Same Frequency Band
- GNSS Augmentations Are Key to Safety
- Big Incentive to Work Together

Global Navigation Satellite Services & Mobile Satellite Services

- GNSS & MSS Are Synergistic

Share Customers & Platforms

GPS Adds Value for Safety & Commerce

Inmarsat-C / GPS - IMO Requirement

GPS Stabilizes Globalstar Satellites

Global Navigation Satellite Services & Mobile Satellite Services

- **GNSS & MSS Are Different**

  GNSS is FREE

  MSS is Fee/Service

  GNSS is Low Power & One (1) Way

  MSS is Focused Power & Two (2) Way

  GNSS is Safety of Life Driven

  MSS is Commercially Driven

Global Navigation Satellite Services & Mobile Satellite Services

- **GNSS & MSS Cannot Share Same Band**

  Bit Rates are Vastly Different

  Link Margins Fundamentally Different

  Cannot Segment Since Sharing is not Feasible

  GNSS Has Safety of Life Requirements

  Pseudolites Required for Availability

Global Navigation Satellite Services & Mobile Satellite Services

- Band Segmentation Would Affect Safety

Sharing 1559-1567 MHz Not Feasible

Cannot Segment 1559-1563 MHz

Frequency Needed for Augmentations

OOBE Would Affect GPS & Pseudolites

Global Navigation Satellite Services & Mobile Satellite Services

- GNSS Augmentations Key to Safety

Regional Control of Integration

Integrity Monitoring key to Safety

Added Accuracy via Differential

Added Availability via Pseudolites

Value Added

Global Navigation Satellite Services & Mobile Satellite Services

- Safety of Life Requirements

  Signal Fault Monitoring

  Immediate Notification

  Signal Parameter Records

Conclusions

- GPS Evolving by Customer Demand
- GPS Will Fully Use Its Spectrum
- Free GPS adds Value for MSS Customers
- Free GPS Lowers Costs for MSS
- Everyone Wins by Working Together

  example: Solidaridad Satcom & GNSS

GNSS Gävle '98

History & Present status of radio beacon DGNSS in Finland

by
Rolf Bäckström
Finnish Maritime Administration
Finland

Finnish Maritime Administration

Finnish Maritime Administration

FMA DGPS office

Rolf Bäckström

- Radio engineering degree in 1968
- Employed by the Finnish Maritime Administration since 1968
- Head of FMA radionavigation office
- Representing Finland in EU on issues involving radionavigation matters

2

Finnish Maritime Administration

FMA DGPS office

A brief DGPS history I

- In 1985 DGNSS was demonstrated by the USCG to the late IALA Systems WG, as a potential candidate for buoy positioning
- The potential of DGNSS as a navigational aid in our confined waters was immediately realised - in spite of a stiff resistance from colleagues from the navigation fraternity
- 1986 the DGNSS project was inserted in the FMA 5 year budget plan

3

Finnish Maritime Administration

FMA DGPS office

A brief DGPS history II

- In 1986 the IALA System WG undertook the task of defining a specification for DGNSS
- The shuttle disaster in 1988 introduced an unexpected delay of several years
- The 23th of March 1991 the first Finnish DGNSS station was put into operation and the 27th the first Swedish one - the first *public* DGNSS stations in the world!

4

Finnish Maritime Administration

FMA DGPS office

A not so brief DGPS history III

- In 1996 the latest DGPS station, Turku, was taken into operation
- In 1998 the Finnish DGPS system was declared operational
- Six more stations are planned

5

Finnish Maritime Administration

FMA DGPS office

Radionavigation ⇔ Positioning

- A marine radio navigation service
  - a global standard - follows IMO regulations
  - is featured with a reliable and standardised integrity monitoring and reporting system
  - the operator assumes a rather extensive judicial and financial liability
  - normally supplied by a governmental agency or on a contract with a governmental agency
- A radio positioning service appears equal, but falls short because of the issues above

6

Finnish Maritime Administration

FMA DGPS office

Finnish DGPS station list

Station name	Ref.st. I.D.	Tx Stn I.D.	Position	Range [km]	Freq. [kHz]
Mäntyluoto	601	401	61N36 21E28	250	298,0
Outokumpu	603	403	62N41 29E01	70	293,5
Porkkala	600	400	59N58 24E23	250	285,0
Puumala	602	402	61N24 28E14	70	301,5
Ristna	840	530	58N56 22E04	200	307,0
Turku	604	404	60N26 22E13	200	304,0

Note. All frequencies will be changed because of a European re-allocation.

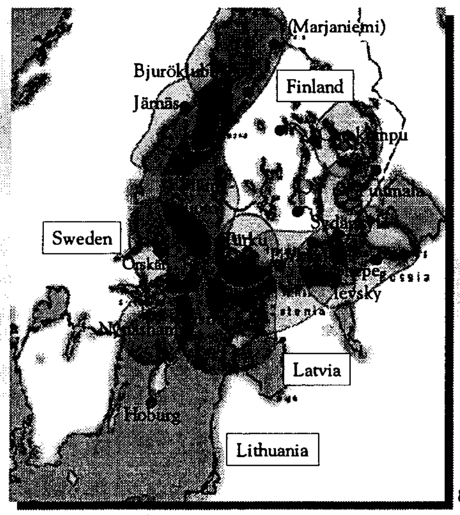
7

Finnish Maritime Administration

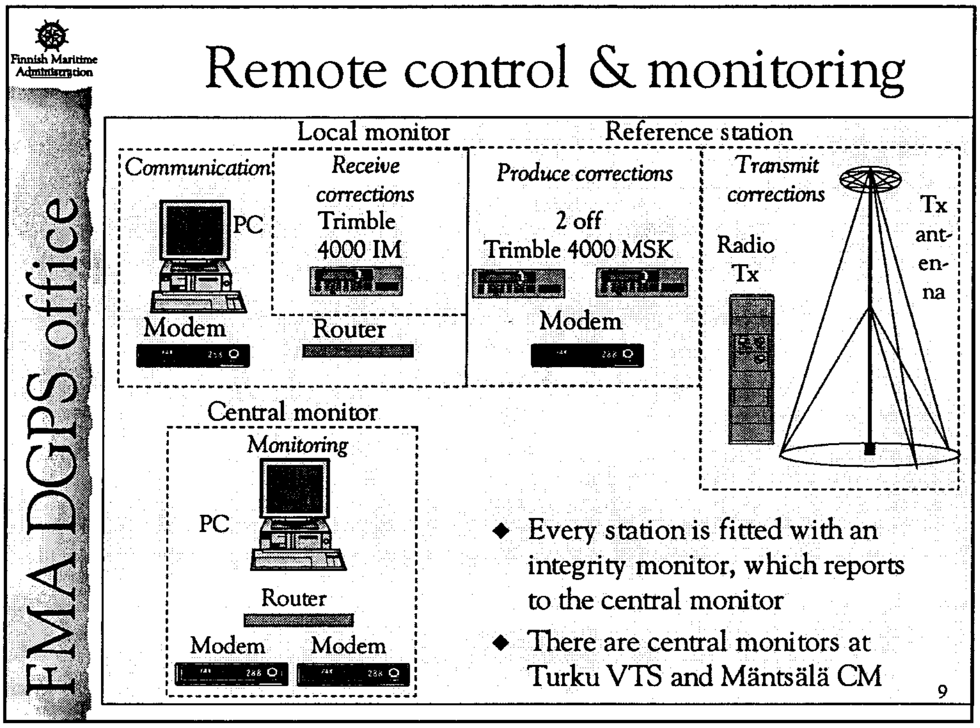
FMA DGPS office

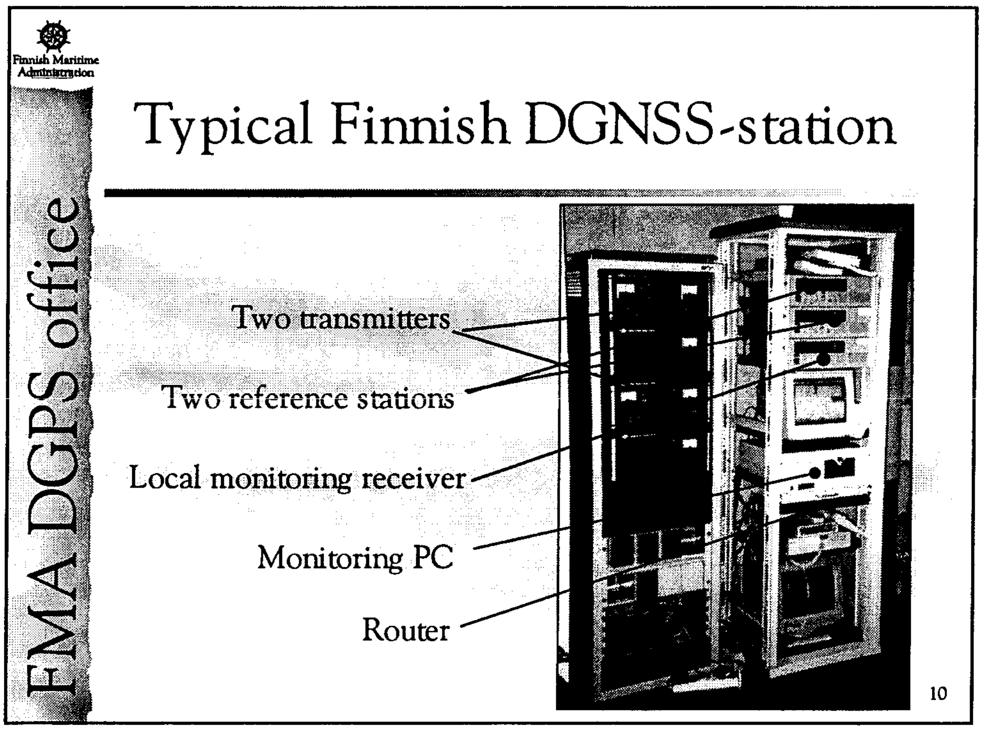
Present coverage

- A high signal availability is achieved by combined coverage
- Bilateral agree-ments required but do not exist, yet



8


Finnish Maritime Administration
FMA DGPS office
Remote control & monitoring
Local monitor
Reference station
Communication
PC
Modem
Receive corrections
Trimble 4000 IM
Router
Produce corrections
2 off Trimble 4000 MSK
Modem
Transmit corrections
Radio Tx
Tx ant-en-na
Central monitor
Monitoring
PC
Router
Modem
Modem
◆ Every station is fitted with an integrity monitor, which reports to the central monitor
◆ There are central monitors at Turku VTS and Mäntsälä CM
9


Finnish Maritime Administration
FMA DGPS office
Typical Finnish DGNSS-station
Two transmitters
Two reference stations
Local monitoring receiver
Monitoring PC
Router
10

Finnish Maritime Administration

FMA DGPS office

Our achievement account

- An accurate and reliable DGPS service, to 99,8% better than 1,1 m - has a lot of users
- At least single DGPS coverage all along our sea coasts, except for a few patches
- Inadequate coverage in the lake area
- Remote control and monitoring network operating, including promulgation of errors
- Repair response time better than 2 hours within the whole coverage area

11

Finnish Maritime Administration

FMA DGPS office

Ongoing challenges I

- Major efforts have been made to increase the availability to 99,8 %
  - define what availability really is
  - field strength measurements by aeroplane
  - long term accuracy & availability measurements
  - high quality coverage design and frequency management, multiple coverage

12

Finnish Maritime Administration

FMA DGPS office

Ongoing challenges II

- Frequency reshuffle within EMA to reduce interference and increase availability, orchestrated by IALA
- Reduce the effect of precipitation noise by promoting use of H-field receiver antennas
- Certification of data link receivers for marine use

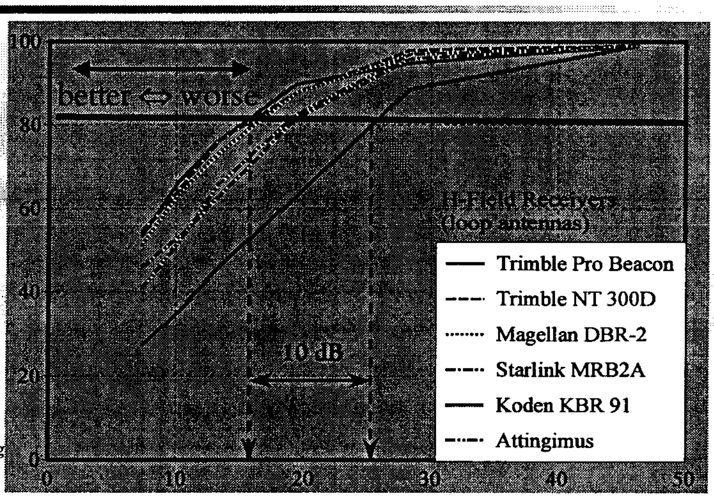
13

Finnish Maritime Administration

FMA DGPS office

DGPS data link receiver

RTCM Words %



Min S/N [dB]

Source:
Hans Speckter
Michael Hoppe
Mario Walterfang
Wilfried Rink

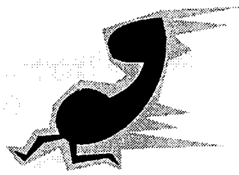
14

Finnish Maritime Administration

FMA DGPS office

For more information

- Visit our web-site www.fma.fi
- Contact the author by E-mail: rolf.backstrom@fma.fi
- Call the author by phone: +358 204 484262
- Fax the author: +358 204 484470



We wait for you to contact...

15

Finnish Maritime Administration

FMA DGPS office

The End

Finnish Maritime Administration
1998

Comments to

Rolf

16

0157

CHARACTERISTICS

OF

THE FINNISH MARITIME ADMINISTRATION

DIFFERENTIAL GPS

BROADCAST SERVICES

Finnish Maritime
Administration

Department of Hydrography and Waterways

PREFACE

This publication is intended for unrestricted public release and distribution. The editors of this issue were Rolf Bäckström and Kaisu Heikonen at the Finnish Maritime Administration. Contact details, refer to section 13.

It is envisaged that this publication will be amended from time to time to reflect changes to the Finnish DGPS broadcast services.

CONTENT

1. INTRODUCTION

1.1. The main purpose of this publication is to provide information on the Finnish Maritime Administration DGPS broadcast services for maritime users, equipment designers and suppliers, which is in it's test phase.

1.2. The Finnish Maritime Administration is operating a chain of DGPS broadcasting stations along the Finnish coastline. In March 1991, one DGPS broadcasting stations were put on trial. During 1993-96 four additional stations were built to get a nearly complete coverage in Finnish waters, when combined with the coverage from Swedish and Estonian DGPS-stations.

1.3. This publication provides information on the signal characteristics, the radio broadcast characteristics and on system characteristics for the DGPS trial services. Information is also given on the characteristics of user equipment needed to access the services. Other general information on GPS, DGPS and related matters is provided.

1.4. Marine navigation authorities in other countries are providing networks of DGPS broadcasting stations. Our neighbouring countries Sweden, Estonia, Russia, Norway, Denmark, Poland, Germany are among those, but also numerous others. The services provided by the Finnish Maritime Administration will follow the agreed international standards for DGPS data transmissions. The desired outcome is that a single set of ship borne equipment will be capable of accessing any DGPS service when the ship is within range of the particular DGPS broadcasting station.

1.5. This publication is to some extent based on the United States Coast Guard (USCG) Broadcast Standard for its DGPS Navigation Service, /1/. Although there are some minor differences between the signal format and other characteristics described in that document and those to be employed by the Finnish Maritime Administration, these differences should not inhibit the use of the same DGPS receiving equipment in conjunction with either the USCG services, the services provided by other European countries or the Finnish Maritime Administration services.

1.6. Whilst the DGPS stations are transmitting on a trial basis, mariners should exercise special caution in using the transmitted data. The Finnish Maritime Administration accepts no liability whatsoever in respect of the transmission of any data which may be considered to be in error. Neither are errors promulgated. The 1st of April 1998 the DGPS stations are planned to be declared fully operational. Mariners should still continue to observe sound navigational practice and regularly check their position using other aids to navigation.

1.7. The Finnish Maritime Administration DGPS services are being provided in the interest of improving the safety and efficiency of marine navigation along the Finnish coastline and in the lake area. Although the broadcast data is available to anyone with the appropriate receiving equipment, *non-maritime* users should be aware that the services are not provided to meet their needs for navigational safety. The real time accuracy provided by the system, is such, that with proper receivers, it can also be used for purposes where submeter accuracies are required. With postprocessing an even better accuracy can be achieved. FMA accommodates special arrangements on temporary basis, if required. The cost of establishing and operating the Finnish Maritime Administration DGPS services are being met by the Finnish government and recovered by fairway dues from the users.

2. OVERVIEW OF GPS

2.1. The NAVSTAR Global Positioning System (GPS) is operated by the US Department of Defence. GPS is a world-wide space-based radio navigation system that will be the primary US radio navigation system well into the next century. The system provides suitably equipped users with highly accurate position, velocity, and time data. When fully operational, this service will be provided globally, continuously and under all weather conditions. In its full configuration the GPS space segment comprises 24 satellites in six orbital planes. The spacing of the satellites in orbit will be arranged so that a minimum of five satellites will be in view to users world-wide.

2.2. A GPS receiver determines its position by making range measurements to satellites which are in view. Each satellite transmits its own unique digital code. Superimposed on this code is the Navigation Message which contains information describing the orbital location of the satellite, and its health. A three dimensional fix requires measurements to a minimum of four satellites. If height is known, then range measurements to a minimum of three satellites are required.

2.3. GPS provides two levels of service: Standard Positioning Service (SPS) and Precise Positioning Service (PPS). SPS is the standard level of positioning, velocity and timing accuracy that is available to all civil users around the world with an accuracy of 60 metres (2 distance root mean squared (2drms), 95% probability). The maximum error is expected to be 200 m. PPS will be limited to authorised US Federal and Allied Government users (civil and military). PPS military user equipment will provide horizontal positioning accuracy of 21 metres (2 drms).

2.4. In providing the SPS version of GPS, the US Department of Defence deliberately degrades the achievable accuracy, by a process known as Selective Availability (SA). SA is implemented by degrading the basic accuracy of the SPS through adjustment and introducing errors in the timing and position information broadcast by the satellites. By US: presidential decree SA is going to be removed in the foreseeable future, probably between years 2000-2006. The removal of SA is not expected to alleviate the need for the differential service.

2.5. The NAVSTAR Global Positioning System reached its Intermittent Operational Capability (IOC), /2/, in 1994. It means that 24 GPS satellites (any model) are operating in their assigned orbits, are available for navigation and provide the

SPS levels of services defined in the US Federal Radionavigation Plan (FRP), /3/. Full Operational Capability (FOC) has also now been achieved as 24 GPS satellites (Block II or newer) are operating in their assigned orbits and when the constellation has successfully completed testing for operational military functionality.

2.6. According to the FRP, the US decided to make available the SPS of the GPS with no direct users fees for a period of at least ten years beginning in 1993. The US intends to provide a minimum six-year advance notice of termination of GPS operations or elimination of the GPS-SPS. Any planned disruption of the GPS in peacetime will be subject to a minimum 48-hour advance notice provided by the DOD to the USCG's Navigation Information Service (NIS) which is a part of the Navigation Centre (NAVCEN), located in Alexandria, Virginia.

3. OVERVIEW OF DGPS

3.1. Although the SPS version of GPS provides sufficient accuracy for many navigational situations, it does not meet the requirements for some of the more demanding applications, such as navigation in channels, ports and confined waterways. Even if SA is taken off, the resulting accuracy is not adequate for most marine applications. Differential GPS services have been developed to provide considerable improvement in position fixing using GPS, /5/.

3.2. The type of Differential GPS (DGPS) service employed by the Finnish Maritime Administration is based on the principle that an "all in view" 12-channel GPS reference receiver is located at a site which has been geodetically surveyed ("reference station" location). The receiver monitors all visible satellites (7 degree elevation mask) and measures the pseudo range to each satellite. Since the satellite signal contains information on the precise satellite orbits and the reference receiver knows its position, the true range to each satellite can be calculated. By comparing the calculated true range and the measured pseudo range, a correction term can be determined for each satellite. These corrections are then broadcast to the users over the marine radio beacon attached to the reference station, and can be received by the user with a DGPS receiver. The user's receiving equipment will apply the corrections to improve the accuracy of position fixing. With the full satellite constellation in place, the user will achieve a position accuracy within 10 metres (2 distance root mean squared (2 drms), approx. 95% probability). Within the particular DGPS coverage area, DGPS cancels out the effects of Selective Availability, as well as correcting for some other factors which contribute to the errors of GPS measurements.

3.3 In addition to improving the accuracy of position determination and other data, DGPS performs an important function in monitoring the integrity of GPS itself. One of the shortcomings of GPS for civil navigation is its problem meeting integrity requirements. The Navigation Message, including the satellite health message, broadcast by each satellite, is periodically updated by the GPS Master Control Station (MCS) in Colorado Springs, Colorado. Certain types of satellite clock failures, signal availability failures and navigation data errors are monitored internally within the satellite. If such internal failures are detected, users are notified within six seconds. Other failures are only detectable by the MCS and it may take up to six hours before users are notified of a problem. That means it is possible for a satellite to transmit an unhealthy signal for up to six hours before users can be appropriately warned or the failure is corrected, /6/. The average amount of time that the failed satellite will be in view for those locations on the Earth's surface which can see it, is approximately three hours. Given a 24 satellite constellation, an average of eight satellites will be in view of any user on or near the Earth. With all satellites weighted equally, the probability of a failed satellite being in the position solution of any user located within the failure visibility region is 50 %, /6/. DGPS can effectively reduce the GPS integrity check interval from several hours to a few seconds. This is due to the DGPS reference station capability of observing that a satellite has exceeded predetermined tolerances. With DGPS messages, a direction can be given not to use a particular satellite, which may or may not be marked as unhealthy.

4. GEODETIC COORDINATE SYSTEMS AND HYDROGRAPHIC CHARTS

4.1. The geodetic coordinate system used by GPS is the World Geodetic System 1984 (WGS-84). This is also the geodetic system used to determine the differential correction information broadcast by the Finnish Maritime Administration services. Most nautical charts are referred to datums other than WGS-84, and Finnish nautical charts are no exception. Consequently discrepancies of several hundred metres can exist between a GPS derived position and a charted position. Care must therefore be taken when using charts based on datums other than WGS-84.

4.2. Charts in the Finnish area have a datum which is noted in the map title. Charts issued by the Finnish Maritime Administration are based on the Finnish Datum KKJ (Karttakoordinaatistojärjestelmä) and may or may not contain a note that will provide latitude and longitude corrections to be applied to GPS derived positions.

4.3. Most GPS receivers have the facility to automatically translate positions in WGS-84 to positions in other geodetic coordinate systems. A certain loss of accuracy is always inherent in such a translation process - in the order of 0,5-2,0 metres.

4.4. When employing GPS, and even more so with DGPS, mariners will be able to position their vessels to a higher accuracy than that applying to the features on many charts. Mariners will need to be aware of the danger of assuming that the absolute position of charted features is shown to a level of accuracy comparable with the accuracy provided by GPS and DGPS receiving equipment.

4.5. Every local reference station in the Finnish Maritime Administration chain of DGPS broadcasting stations, has been geodetically surveyed by FMA surveyors. The coordinates related to the local 12-channel GPS reference station, are all measured and calculated in the WGS 84. The standard deviation of the measurements and calculations are within a few millimetres.

4.7. DGPS is the most accurate non-commercial radio navigation aid available at present, and it is a shared opinion that it will play an important role as a highly accurate position sensor feeding data to other ship borne equipment like ECDIS and GMDSS systems.

5. INTERNATIONAL STANDARDS

5.1. The Finnish Maritime Administration intends to follow the DGPS transmission standards as recommended by the International Association of Lighthouse Authorities (IALA). IALA and the US Coast Guard cooperated for some years in studying the feasibility of using marine radio beacons for DGPS broadcasts, and in developing standards and operational characteristics. IALA gave detailed consideration to the use of various data link options for the transmission of DGPS information. The IALA decision to recommend the use of maritime radio beacons for public services was based on an assessment of technical, economic and administrative factors.

5.2. The IALA recommendations are in turn based on the RTCM (Radio Technical Commission for Maritime Services, USA) Special Committee No. 104 "Recommended Standards for Differential NAVSTAR GPS Service", version 2.2, usually abbreviated to "RTCM SC104", /7/.

5.3. IALA prepared a proposed recommendation for submission to ITU-R (International Radio Consultative Committee of ITU) on the "Technical Characteristics of Differential Transmissions for Global Navigation Satellite Systems". This Recommendation (Number 823) was adopted by CCIR in 1992. The Draft Revision of Recommendation ITU-R (International Telecommunication Union - Radiocommunication) M.823, /8/, has later been updated and considered by ITU-R Study Group 8 at its meeting 21-25 March 1994. Since the Differential GNSS services are currently under development, it can be expected that further revisions will occur to ensure that the Recommendation will continue to reflect the current state of development.

5.4. ITU-R Recommendation Number M.823 prescribes a generic data and message format but which is based on the RTCM SC104 Recommended Standards.

5.5. ITU-R Recommendation Number M.823 includes the following system characteristics after the revision considered by ITU-R Study Group 8 at its meeting 21-25 March 1994:

- radio transmissions to be in band allocated for maritime radio navigation (radio beacons)
- carrier frequency to be integer multiple of 500 Hz
- carrier frequency tolerance 2 Hz
- transmission of differential corrections to be continuous, synchronous and most significant bit first

- message data rate to be selectable from 50, 100 and 200 bits per second
- minimum shift keying (MSK) modulation to be used (class of emission G1D), with 90 degree phase retard representing binary "0" and 90 degree phase advance representing binary "1"
- MSK modulation to be bandpass filtered to produce a maximum occupied bandwidth of 230 Hz at the maximum transmission rate
- the transmitting station identification codes are in binary numbers

5.6. ITU-R Recommendation Number M.823 includes the following recommended user receiver characteristics after the revision considered by ITU-R Study Group 8 at its meeting 21-25 March 1994:

- frequency range at least 283.5 to 325 kHz, selectable in 500 Hz steps
- dynamic range 10 V/m to 150 mV/m
- operation at a maximum bit error ratio of 10^{-3} in the presence of Gaussian noise at a signal-to-noise ratio of 7 dB in the occupied bandwidth
- where serial data ports are provided, these are to International Electro-technical Commission (IEC) standards IEC Publication 1162...1993 (Digital Interfaces; Navigational and Radiocommunications equipment on board ships)
- warning indication to be given of failure of data link
- where automatic frequency selection is provided, the receiver will be capable of receiving, storing and utilizing reference station almanac messages.

5.7. At its September 1993 meeting, the International Maritime Organisation Sub Committee on Safety of Navigation decided to recommend to the Maritime Safety Committee that it "urge Member Governments intending to provide differential transmission (for GPS) using maritime radio beacons to ensure that the transmissions conform with ITU-R Recommendation 823 and are not encoded".

6. THE FINNISH MARITIME ADMINISTRATION DGPS MESSAGE CHARACTERISTICS

6.1. The data broadcast by the Finnish Maritime Administration stations consists of a selected subset of the Message Types contained in the RTCM SC104 version 2.2 Recommended Standard, /7/.

6.2. All Message Types used are applied in the manner recommended in the RTCM SC104 Recommended Standard. Each Message Type consists of a variable number of 30 bit words, with each word including 6 parity bits for error detection.

6.3. In the trial period the users of the service can expect the following Message Types with repetition interval and transmission duration is shown:

Nr	Message Type	Frequency	Duration
3	Reference Station Parameters	Every 30 minutes	Continuous
6	Null frame	Only if required	

7	Beacon Almanac	Every fifteen minutes	Continuous
9	Satellite pseudo range corrections	As often as possible	Continuous
16	Special Message	Twice	

6.4. Type 3 Message: The users may observe two different reference station coordinates and identification numbers for any specific DGPS-station. This is due to the fact that every DGPS station is fitted with two sets of equipments, including two receiving antennas. As these two antennas slightly differ in position, there is also a slight difference in coordinates. Corrections from one of the two reference stations will always be broadcast. One of the reference stations will act as a backup when the other is transmitted. If one value, of many different internally monitored threshold values, is exceeding its preset limits, in seconds the backup will take over and sustain the broadcast.
With some user equipments it is possible to acquire the distance between the ship and the reference station. It is important to be aware that this distance is to the reference station which, may or may not be co-located with the *broadcasting* station.

6.5. Type 6 Message: Failure of certain DGPS broadcast station equipment items may result in the broadcast of alternating "ones" and "zeros", a single tone, or no output at all. It is therefore important that the user equipment suite be capable of detecting the absence of RTCM messages containing pseudo range corrections in the data stream, and alerting the users to that effect. The user also might draw some conclusions whether his equipment *or* the system providers transmission equipment is at fault.

6.6. Type 7 Message: The radio beacon almanac provides the ID, location, frequency, service range and health information on a few neighbouring broadcasting DGPS-stations.

6.7. Type 9 Message: Within the Type 9 Message (High Rate Differential GPS Corrections), pseudo range corrections will be broadcast for all satellites at an elevation of 7 degrees or higher. The corrections will be broadcasted in groups of three satellites and a remainder message of either one or two satellites. If more than nine satellites are above an elevation mask of 7 degrees then corrections are broadcast for the nine satellites with the highest elevation angles. An equal number of corrections will be broadcast for each satellite. Message Type 9 is described in more detail in the USCG Broadcast Standard for its DGPS Navigation Service, /1/, and in RTCM SC104, /7/. Satellites, at elevation angles of less than about 7 degrees, are adversely affected by errors in atmospheric modelling, spatial decorrelation, multipath, and minimal processing time between acquisition and actual use. The pseudo range correction of each satellite in the Message Type 9 will diverge from the proper value as it "grows old". Because of this characteristic, it will be updated and transmitted as often as possible. It is possible to use any part of the message which has been received *before* a fatal transient, corrupting a part of the message.

6.8. Type 16 Message: This message will only be transmitted when required. It will possibly provide additional information, in text form, on the status of the DGPS service to the part it is not already included in message 9. It will only provide information which is important to the safety of navigation. Each Type 16 Message can be up to 90 characters long. The Type 16 Message will be broadcast in English. The Type 16 Messages will be sent twice, when required. The usefulness of this message is limited, as numerous receivers do not display these messages.

6.9. Each message will include a reference station health status within the header of the message (UERE), as follows:
111: Reference station Not Working
110: Reference station Not Monitored
000: Reference station working within specifications
Codes 111 and 110 indicate a problem and the user should immediately stop using this reference station. Normally the user receiver should take care of this situation automatically.

6.10. PRC (pseudo range correction) and RRC (range rate correction) in message 9 may be set to binary 1000 0000 0000 0000 and 1000 0000, respectively, to indicate a problem on a specific satellite. The user equipment should immediately stop using this satellite.

7. RADIO BROADCAST CHARACTERISTICS

7.1. DGPS data will be transmitted in the band from 283.5 kHz to 315 kHz, which is the band allocated for maritime radio navigation in Region 1 including northern Europe. Consequent to the decision of World Radio Conference 97, transmission of DGPS signals only are now also allowed on this band.

7.2. No direction finding signal will be transmitted 500 Hz below or above the DGPS data transmission.

7.3. The antennas of the broadcasting stations are of the capacitively loaded monopole type, approximately 35 metres high. Even though the antennas are optimally tuned, they have an inherently low efficiency (approximately 1-5 %).

7.4. The transmission rate of the DGPS data, is 200 bits per second.

7.5. The carrier frequency tolerance, MSK modulation, and maximum occupied bandwidth will be in accordance with ITU-R Recommendation Number M.823. (Refer to Section 5.5.).

8. SYSTEM PERFORMANCE CHARACTERISTICS

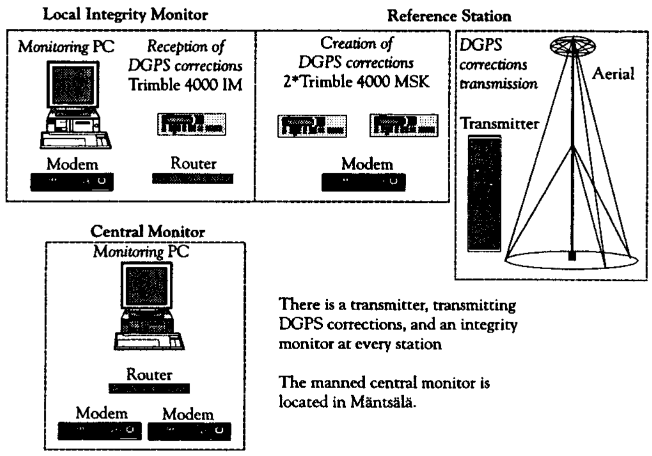
8.1. With the full GPS constellation in place, the position accuracy of the Finnish Maritime Administration DGPS services, anywhere within range of a broadcasting station, is expected to be **better than 10 metres** (2 distance root mean squared (2drms), approx. 95% probability), assuming the use of appropriate receiving equipment. High quality receiving equipment gives even better accuracy.

8.2. There is only a small increase in position error as the distance between a DGPS reference station and the user increases. A reasonable approximation is that the position error will increase by approximately 1 metre for each 150 kilometre separation between a DGPS reference station and the user, /1/.

8.3. If DGPS correction information is used at a distance of greater than 500 kilometre from a DGPS reference station, then additional error components become significant, due to spatial decorrelation and increased correction latency (which is due to a less robust broadcast channel), /1/.

8.4. Each DGPS broadcasting station includes an on-site integrity monitor. The integrity monitor includes a complete 12-channel DGPS-receiving system. The main purpose of the integrity monitor is to ensure that the broadcast corrections are valid and to provide timely warnings to the users if this is not the case. If an "out of tolerance" condition is detected, the integrity monitor causes the broadcasting station to switch to the backup DGPS reference station or change advice on the station health condition, as included in the header of all messages.
If an out-of-tolerance situation is detected and prevails for more than 20 seconds, an automatic alarm is transmitted to the user within 10 seconds. Modern receivers react to this, by switching automatically to another broadcasting station, if available.

8.5. The FMA DGPS navigation service is designed for a Broadcast Availability exceeding 99,8%, assuming a complete and healthy satellite constellation. The availability figure as the percentage of time in one month during which a DGPS-station transmits healthy PRC's according to it's specifications. The figure will be given as a mean value for the combined coverage of all FMA stations covering a sea area common to these stations.



8.6. The most important availability parameter is the User Availability. It is almost impossible to quantify precisely due to the nature of atmospheric noise. Estimates indicate that an User Availability of slightly more than 98% is to be expected.

8.7. The reliability of the system is such the probability of a failure for any 560 s interval is less than 0,01%.

8.8. The Finnish Maritime Administration is presently updating the monitor and remote control system with Trimble software products. The system is totally PC-based and uses modern router and LAN technology. The local GPS reference receiver implemented in the system is the 12-channel Trimble 4000 MSK. The Broadcasting Stations consist of the Amplidan "Radio beacon/DGPS Transmitter System Type 015770".

9. BROADCASTING STATION DETAILS

9.1. As mentioned in Section 1.2, a total of five DGPS broadcasting stations are operative on intermittent operational capability basis. In All five stations are fully equipped with integrity monitors (Refer Section 8.4.).

9.2. FMA DGPS-stations are operated from mains buffered batteries which, in the case of a mains failure, may operate for 0,5-1 hour.

9.2. The DGPS broadcasting stations of the Finnish Maritime Administration and Estonia show the following details:

Public DGPS-stations in Finland and Estonia

Broadcast Station Name	ID number 4) Reference station(s)	ID number 4) Broadcast station	Position Latitude Longitude	Range (50 µV/m) [km]	Range (20 µV/m) [km]	Station operative	Transmitted message types	Frequency [kHz]	Bit Rate [bits/s]	Remarks
Ristna 3)	840 841	530	58N56 22E04	200	250	Yes	3 6 7 9 16	307,0	200	
Mäntyluoto	601 606	401	61N36 21E28	250	300	Yes	3 6 7 9 16	298,0	200	1)
Outokumpu	603 608	403	62N41 26E01	70	120	Yes	3 6 7 9 16	293,5	200	1)
Porkkala	600 605	400	59N58 24E23	250	300	Yes	3 6 7 9 16	285,0	200	1)
Puumala	602 607	402	61N24 28E14	70	120	Yes	3 6 7 9 16	301,5	200	1)
Turku	604 609	404	60N26 22E13	200	250	Yes	3 6 7 9 16	304,0	200	1)

1) Ranges are based upon average values from actual field strength measurements at open sea paths in good atmospheric conditions. Land paths between the user and the reference station severly limit the range.
2) Ristna is the property of the Estonian government but is listed in the list above because the station is by mutual agreement monitored and controlled by the Central Monitor of the Finnish Maritime Administration.
3) Note, that the reference station ID number is sent within the body of message #3, whereas the broadcast station ID is sent within the header of every message and the beacon list in message #7.

10. COVERAGE OF BROADCASTING STATIONS

10.1. The main factors, which limit the achievable range of a DGPS broadcasting station, are the signal strength and the signal to noise ratio of the DGPS transmissions, as received by the user. The performance of the user's receiver at low signal strengths, at low signal to noise ratios and at high atmospheric noise levels is also important. The Finnish Maritime Administration has not yet determined the criteria to be applied to determine the advertised nominal ranges of the Broadcasting Stations. The Finnish Maritime Administration and indeed the whole DGPS operator community, needs to carry out further studies before declaring a final nominal range for each system.

10.2. In locations well distant from the broadcasting station, the level of electrical noise (atmospheric or man-made), compared to the desired signal will be the limiting factor. A low signal to noise ratio will cause loss of the broadcast data. A good "radio ground" connection for the user equipment is essential. This requirement is partly eliminated by the use of H-field, ie. loop antennas, for DGPS broadcast reception. With the loss of many successive messages, the DGPS corrections will become more and more stale, position determination accuracy will progressively worsen, and eventually the receiving equipment should automatically switch to the "GPS only mode" and disregard the excessively stale DGPS corrections.

10.3. In Finnish waters the single most important form of interference is precipitation noise. Several times a year, but particularly in the autumn, rain drops or sleet in a rainfall become electrically charged. These drops hit the receiver antenna or other neighbour objects and are discharged, causing severe radio interference of a high amplitude. Sometimes the precipitation noise is strong enough to block all DGPS reception completely for minutes up to hours. This type of interference is greatly attenuated by using H-field receiver antennas, ie. magnetic antennas, instead of E-field whip antennas.

10.4. The Finnish Maritime Administration currently defines the coverage areas of its broadcasting stations using the transmission rates of 200 bits per second, as the distance over water at which the predicted signal strength falls to 50 µV/m (micro Volt per metre). This equals an availability of 99,9%, all other factors disregarded. Sometimes a minimum field strength as low as 10 µV/m may provide an adequate signal. This depends on the level and nature of the atmospheric noise which is present. 20 µV/m is indicated in the range table as a usable range in good conditions.

11. USER EQUIPMENT CHARACTERISTICS

11.1. This publication does not purport to present a complete specification for any user equipment item. It does attempt however to indicate what features should be provided in user equipment which utilises the DGPS data broadcast by the Finnish Maritime Administration services.

11.2. The following are features which should be provided by a DGPS radio beacon receiver:

- the output should provide proper interface to the particular GPS receiver to which it is connected
- should be capable of correctly processing all broadcast RTCM Message Types (see Section 6 above)
- should comply with relevant provisions of ITU-R Recommendation Number M.823.

11.3. The user equipment should include a display to show those RTCM Messages (in particular Type 16 Messages) transmitted as text messages.

11.4. The user equipment should provide a positive indication in the event that RTCM Messages are not being received, as mentioned in Section 6.7. Pseudo range corrections should not be applied by the user equipment suite if their age exceeds 30 seconds.

11.5. A DGPS radio beacon receiver should not lock on to an aeronautical radio beacon. There are some aeronautical radio beacons in Finland which transmits on frequencies within the band from 283.5 to 315 kHz.

11.6. The Finnish Maritime Administration advises that *sequencing* type GPS receivers are *not* to be used for navigational purposes within their DGPS service.

12. INFORMATION ON USER EQUIPMENT

12.1. The Finnish Maritime Administration does not maintain any list of DGPS data link receivers believed to operate flawlessly within the service. It has already been shown that all data links adhering to the standard work properly. It might be advisable to test any product before buying, if the vendor cannot verify that it works by other means.

13. SUBMISSION OF COMMENTS

13.1. Comments will be welcomed by the Finnish Maritime Administration on the content of this publication. Comments received will be taken into account in producing future revised issues of the publication.

13.2. Comments will also be welcomed regarding the usefulness of the DGPS broadcast services for navigation, and on any other aspect of the service. Comments from users will assist the Finnish Maritime Administration to direct development of the system in the direction the user wants.

13.3. Comments should be submitted to:

The Finnish Maritime Administration
P.O.B. 171
FIN-00181 HELSINKI
Finland

13.4 Enquiries about the DGPS services are welcomed.

Contact information:
Sr Development Engineer Rolf Bäckström Telephone: +358 204 48 1
E-mail: rolf.backstrom@fma.fi

Systems Engineer Kaisu Heikonen Telefax: +358 204 48 4470
E-mail: kaisu.heikonen@fma.fi
WWW: http://www.fma.fi

13.5. If users experience fault indications or anomalous behaviour of the DGPS services it should be reported as soon as possible and will be acted upon promptly. The DGPS services are not yet fully operational, but users should contact numbers above.

REFERENCES

/1/ United States Coast Guard, "Broadcast Standard for the USCG DGPS Navigation Service" COMDTINST M16577.1 (April 1993)

/2/ United States Coast Guard, "Announcement of Global Position System (GPS) Initial Operational Capability (IOC) and its Impact on Vessel Carriage Requirement Regulations" [CGD 94-006] (March 23, 1994)

/3/ US Department of Transportation and US Department of Defence "1992 Federal Radionavigation Plan" DOT-VNTSC-RSPA-95-1/DOD-4650.5 (March 1995)

/4/ DGPS-Info by the FMA

/5/ IALA AIDS TO NAVIGATION GUIDE (NAVGUIDE). Second edition. December 1993. ISBN 2-910312-03-8

/6/ US Department of Defence "Global Positioning System (GPS) Standard Positioning Service (SPS) Signal Specification (November 5, 1993)

/7/ RTCM Special Committee 104, "RTCM Recommended Standards for Differential NAVSTAR GPS Service", Future Revision of Version 2.0. (January 3, 1994)

/8/ International Telecommunication Union, Working Party 8C Draft Revision of Recommendation ITU-R M.823 "Technical Characteristics of Differential Transmissions For Global Navigation Satellite Systems (GNSS) From Maritime Radio Beacons In The Frequency Band 285 - 325 kHz (283.5 - 315 kHz In Region 1) Document 8/136-E (Last issue)

Present status and future plans of radio beacon DGPS in Sweden

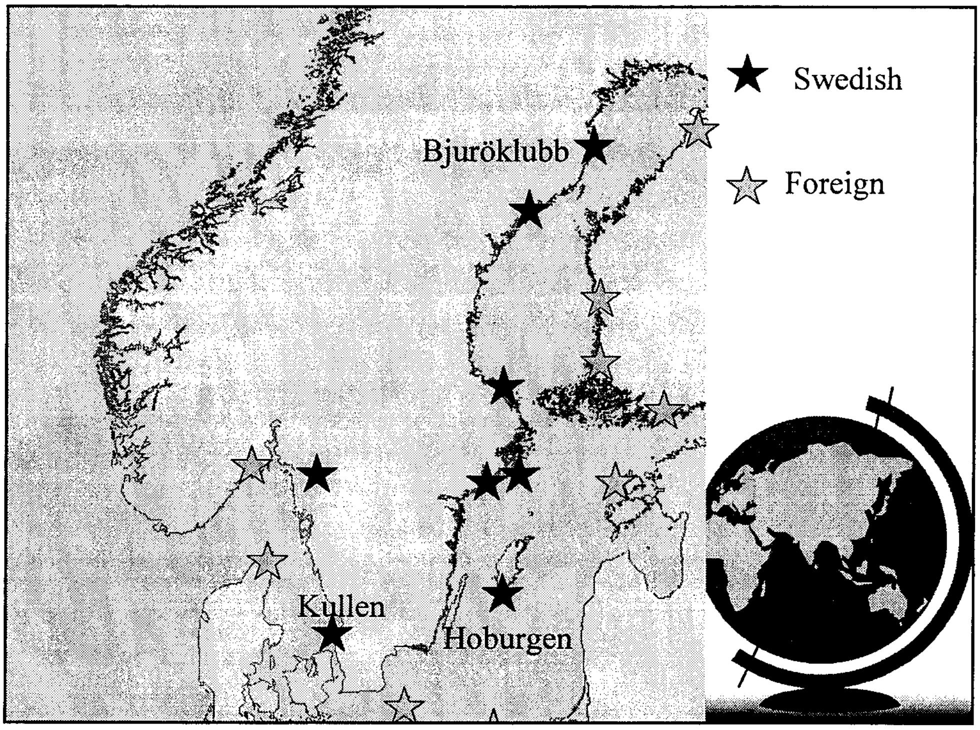
Christian Axelsson

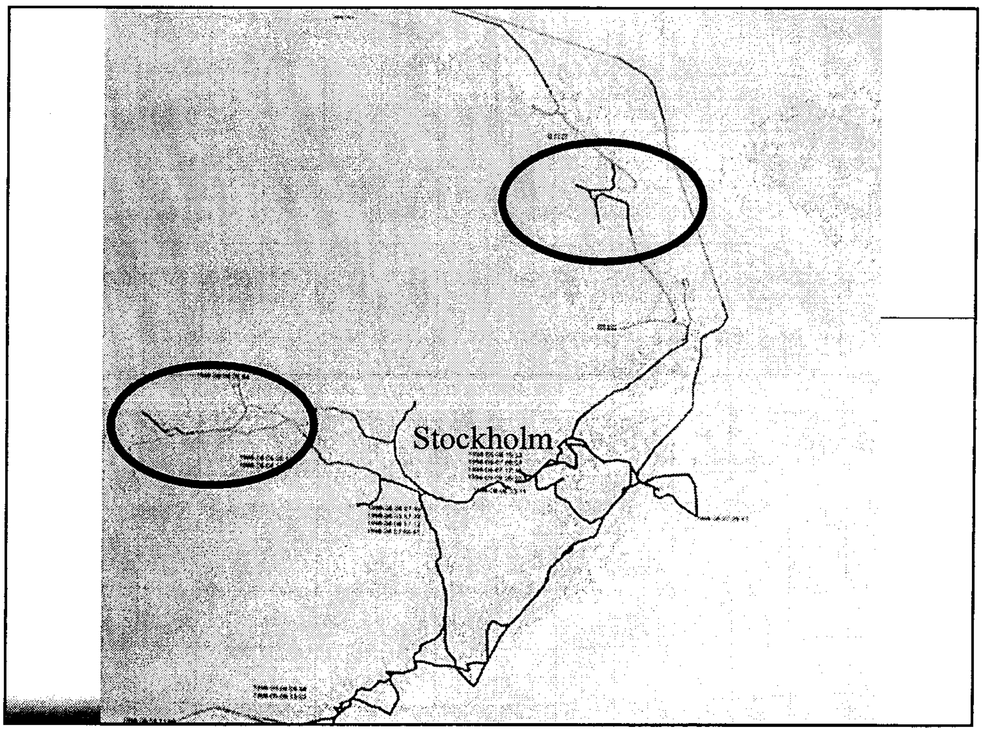
Swedish Maritime Administration, SMA

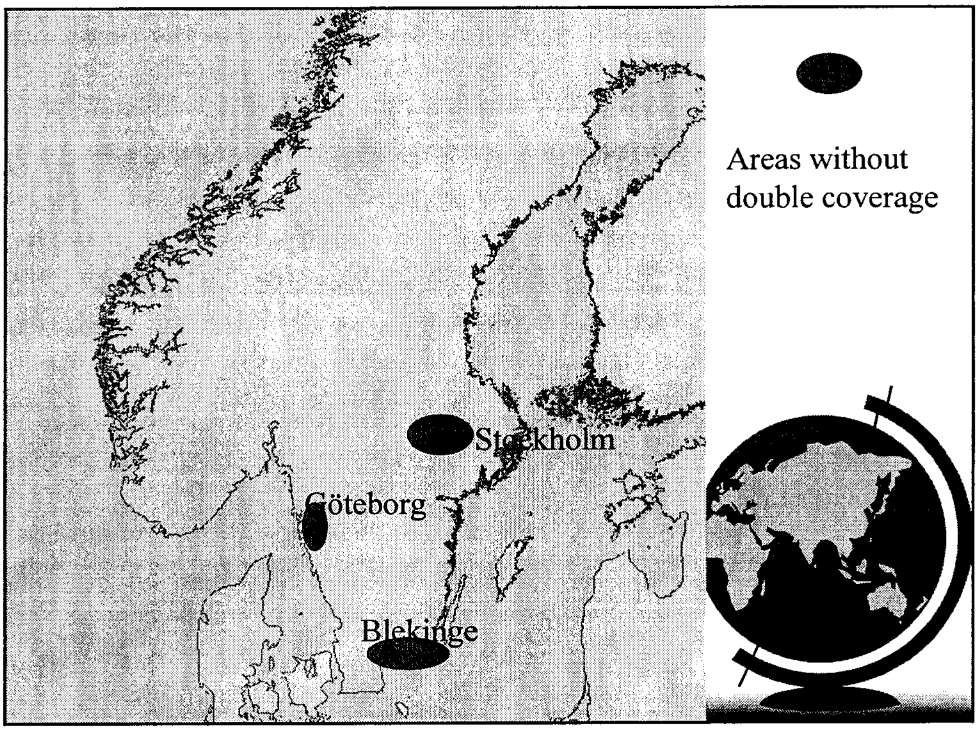
Sweden

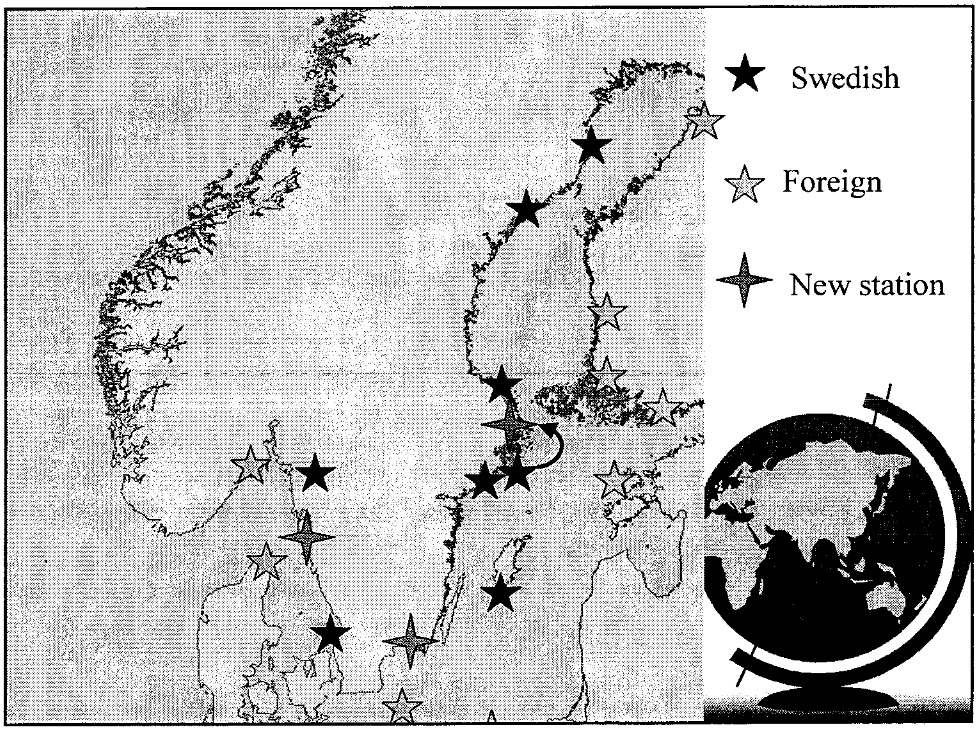
Present status

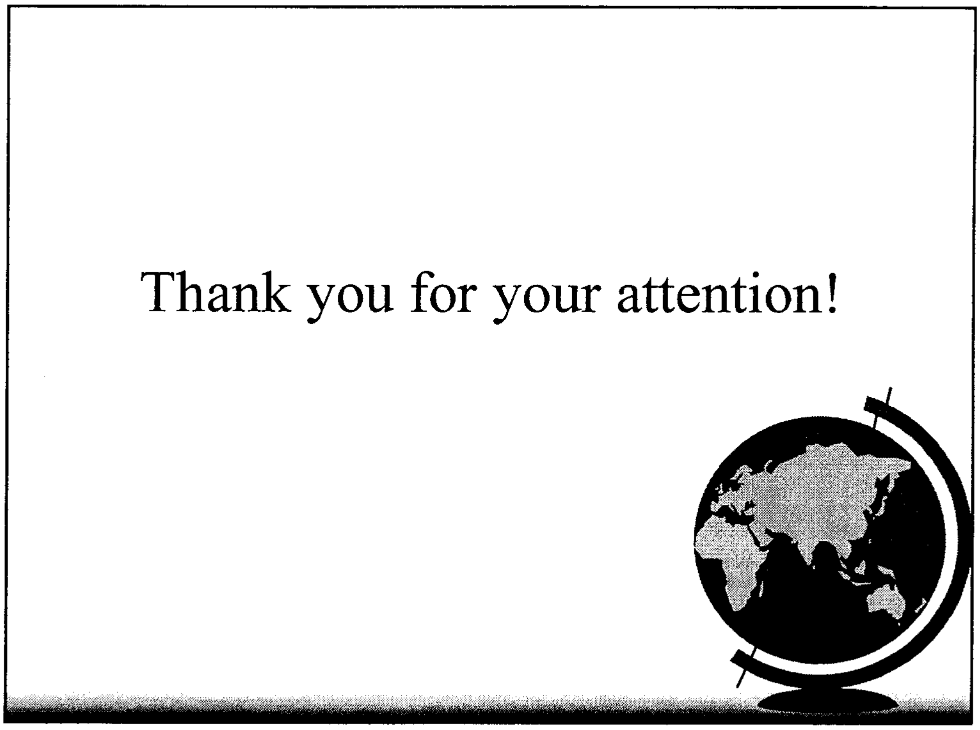
- DGPS system operational since 1 May 1996
- 8 Beacon stations


Swedish
Foreign
Bjuröklubb
Kullen
Hoburgen


Stockholm


Areas without
double coverage
Stockholm
Göteborg
Blekinge


Swedish
Foreign
New station


Thank you for your attention!

LUFTFARTSVERKET
Swedish Civil Aviation Administration

CARD

IISC
Gävle 3-4 December 1998

Technology leaps to solve air congestion and accommodate air traffic growth in the 21st century -
GPS, data links for *Communication*, *Navigation* and *Surveillance*.

Gunnar Frisk
CNS/ATM Engineer
Swedish Civil Aviation Administration (LFV)
CNS/ATM Research and Development Team (CARD)

LUFTFARTSVERKET
Swedish Civil Aviation Administration

CARD

Agenda

- The problem. **Air congestion & traffic growth.**
- A technical solution.
- Gate-to-gate flight.
- Road ahead...

LUFTFARTSVERKET
Swedish Civil Aviation Administration

LUFTFARTSVERKET
Swedish Civil Aviation Administration

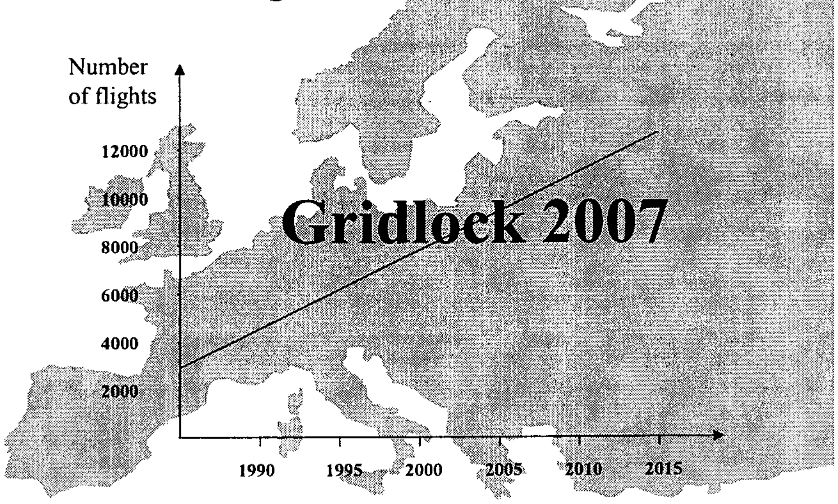
ATC induced delays

- 43 million Euro in 1997
- increased by 36% first half of 1998

LUFTFARTSVERKET
Swedish Civil Aviation Administration

CARD-97

Traffic growth in the ECAC area

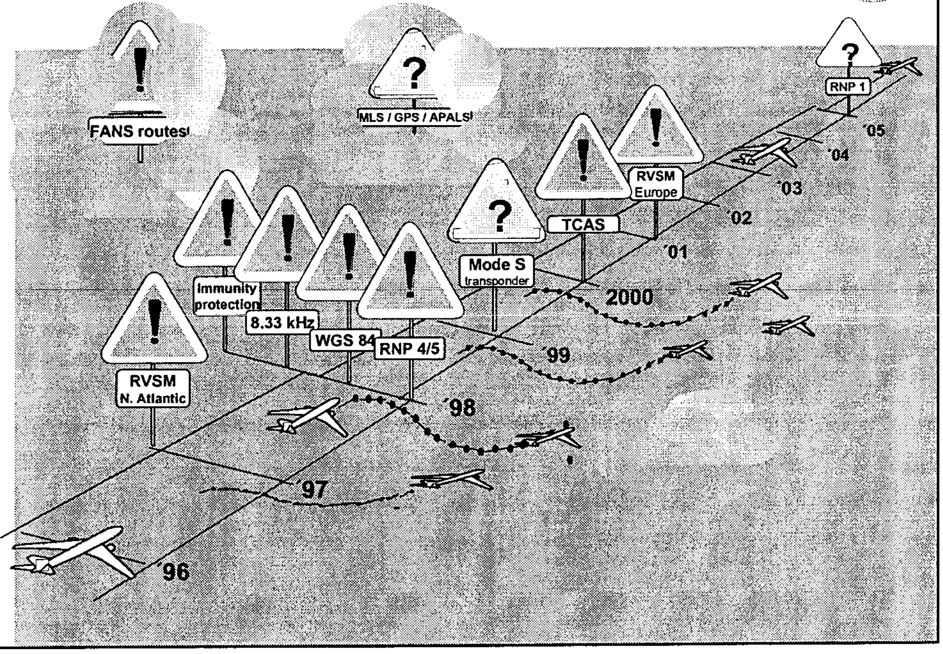


source: Eurocontrol ATM strategy for 2000+

LUFTFARTSVERKET
Swedish Civil Aviation Administration

Road map ?

CARD-97



Agenda

- The problem.
- "The solution".
- Gate-to-gate flight.
- Road ahead...

LUFTFARTSVERKET
Swedish Civil Aviation Administration

Agenda

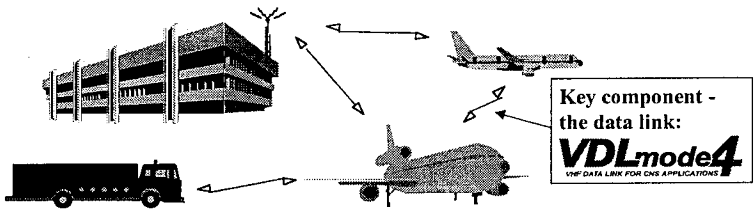
- "The solution".

is…
abbreviations!
VDL Mode 4, GPS
ADS-B, ASAS, A-SMGCS
and more!

LUFTFARTSVERKET
Swedish Civil Aviation Administration

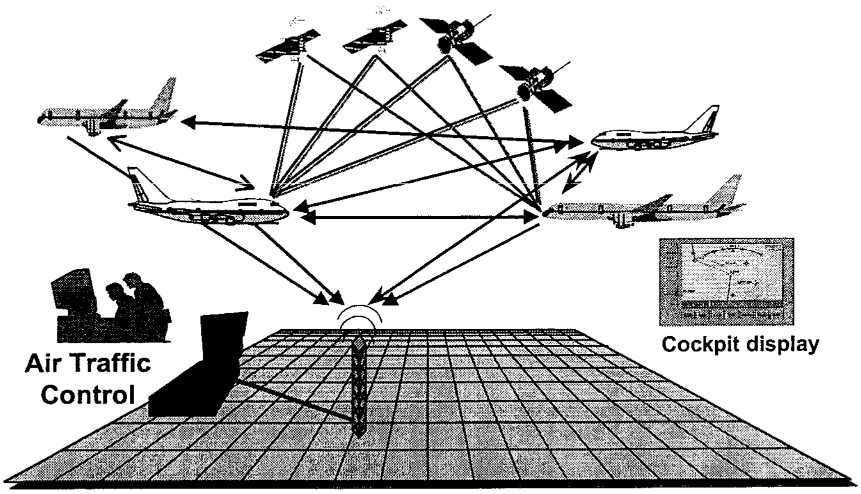
Automatic Dependent Surveillance - Broadcast

ADS-B = All vehicles transmit details of their identity, position (and intent)
These position reports allow all users to build a picture of the location of all other users



LUFTFARTSVERKET
Swedish Civil Aviation Administration

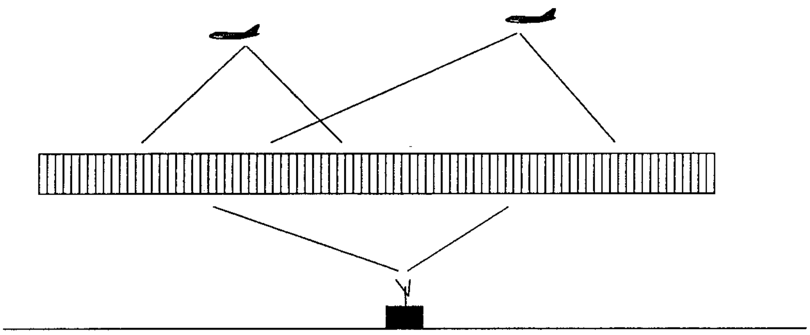
VDL Mode 4 ADS-B



LUFTFARTSVERKET
Swedish Civil Aviation Administration

CARD 97

VDL Mode 4 basics

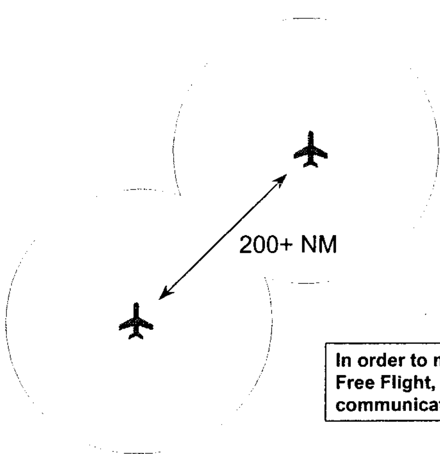


- Principle characteristics: short timeslot system, GPS for timing, 'reservation' protocols.
- 4500 slots/min/channel.
- 2 Global Signalling Channels: 1500 a/c at 10s.
- Also known as STDMA - *Self-organising Time Division Multiple Access*

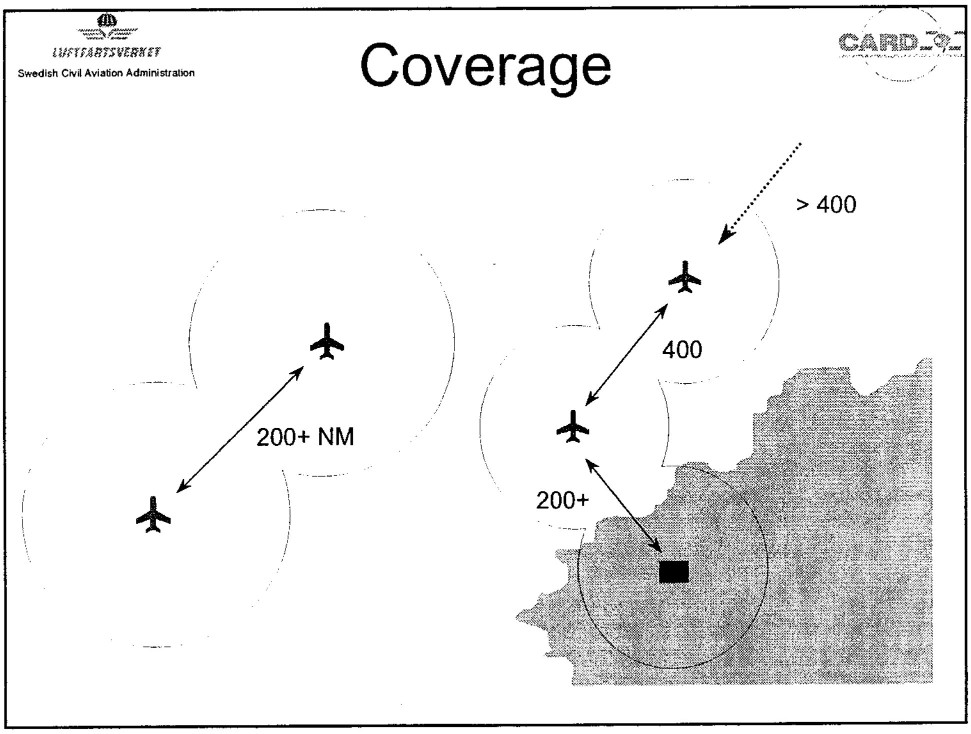
LUFTFARTSVERKET
Swedish Civil Aviation Administration

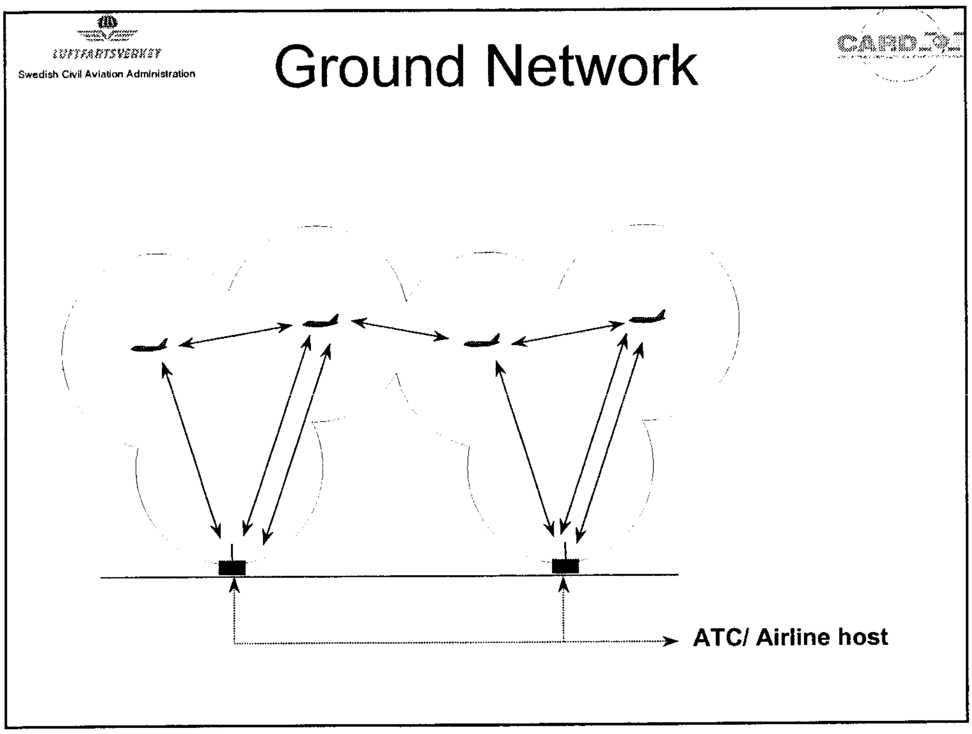
CARD 97

Cellular Concept



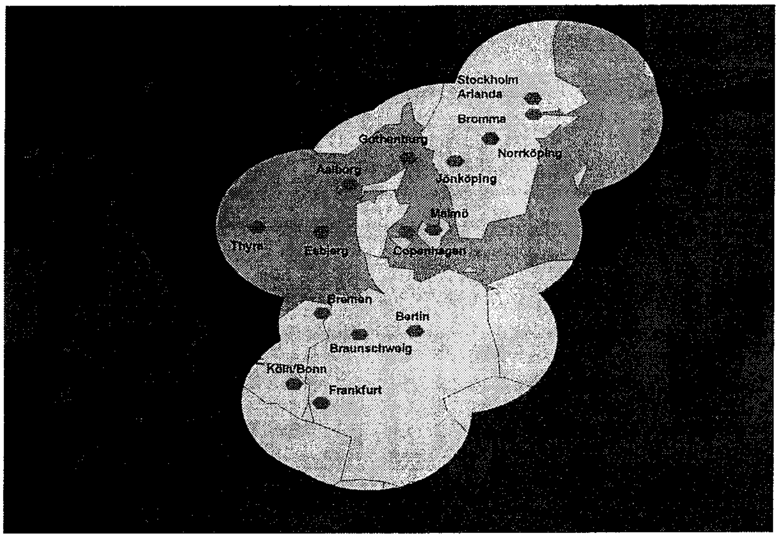
In order to meet future operational scenarios e.g. Free Flight, EATMS, etc. Air-to-Air communications are required.


LUFTFARTSVERKET
Swedish Civil Aviation Administration
Coverage
> 400
400
200+ NM
200+


LUFTFARTSVERKET
Swedish Civil Aviation Administration
Ground Network
ATC/ Airline host

Swedish Civil Aviation Administration

North European ADS-B Network (NEAN), coverage at FL330



Swedish Civil Aviation Administration

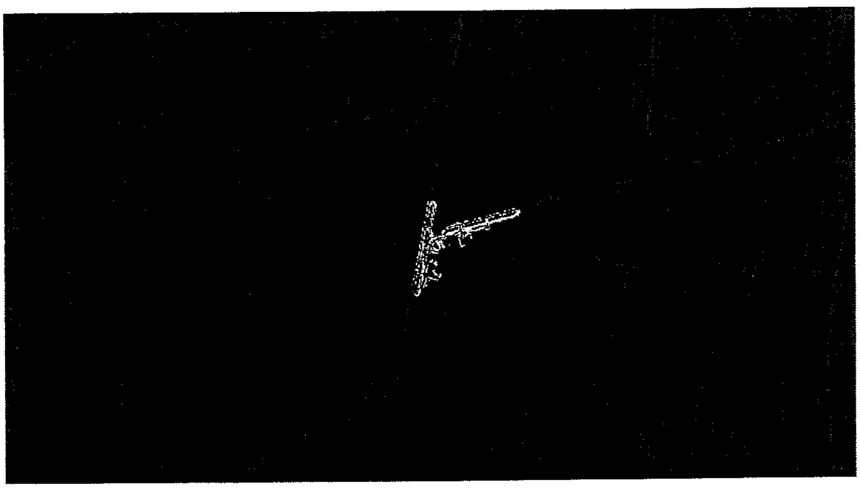
NEAN+NAAN+EEPAN

LUFTFARTSVERKET
Swedish Civil Aviation Administration

Data from NEAN (SAS F28)

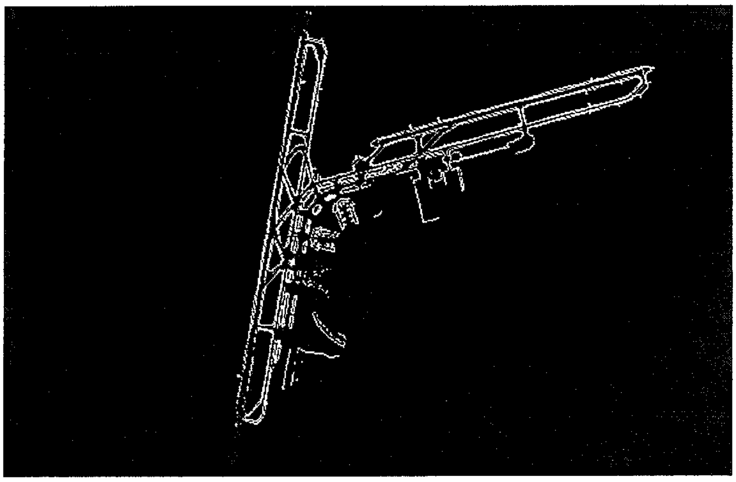
LUFTFARTSVERKET
Swedish Civil Aviation Administration

Data from NEAN



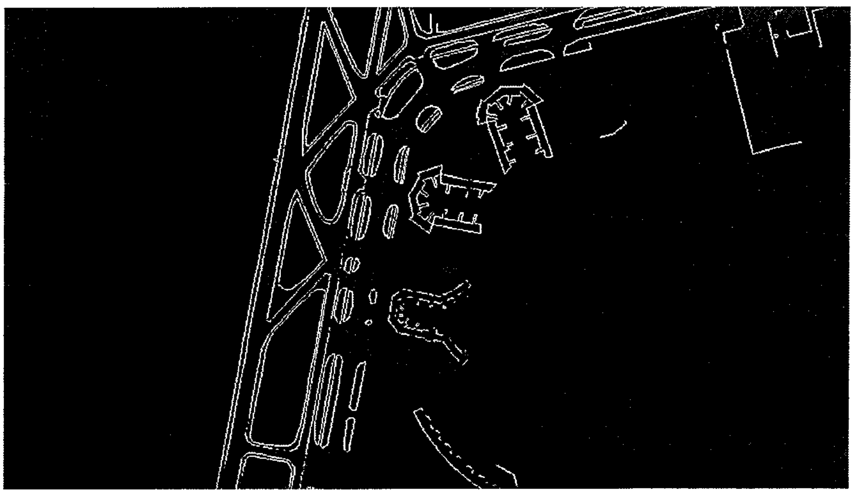
LUFTFARTSVERKET
Swedish Civil Aviation Administration

Data from NEAN



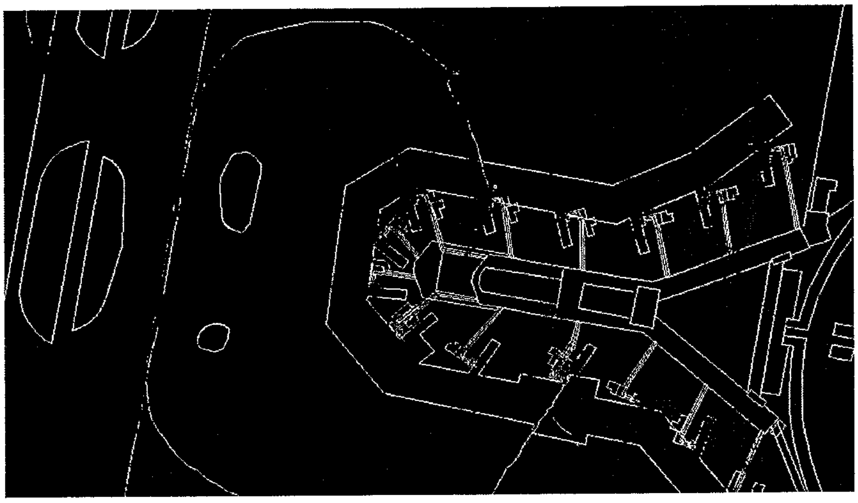
LUFTFARTSVERKET
Swedish Civil Aviation Administration

Data from NEAN



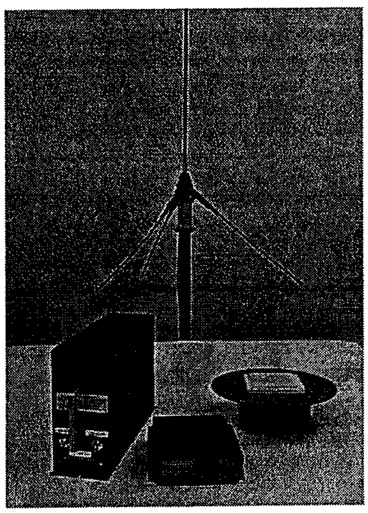
LUFTFARTSVERKET
Swedish Civil Aviation Administration

Data from NEAN



LUFTFARTSVERKET
Swedish Civil Aviation Administration

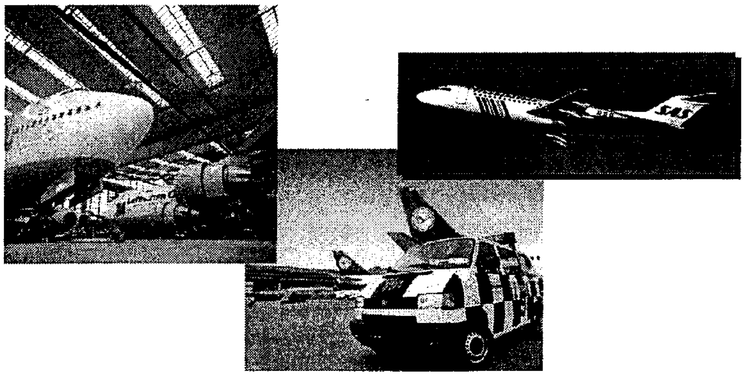
Prototype equipment - "GNSS Transponder"



LUFTFARTSVERKET
Swedish Civil Aviation Administration

Equipped vehicles

CARD

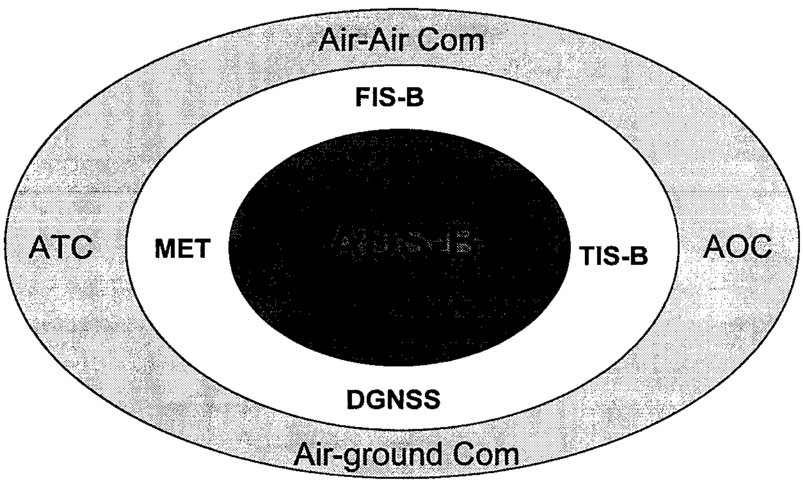


- > 30 aircraft (747… Piper Tomahawk)
- > 30 ground vehicles
- >15000 flying hours

LUFTFARTSVERKET
Swedish Civil Aviation Administration

VDL Mode 4 Applications

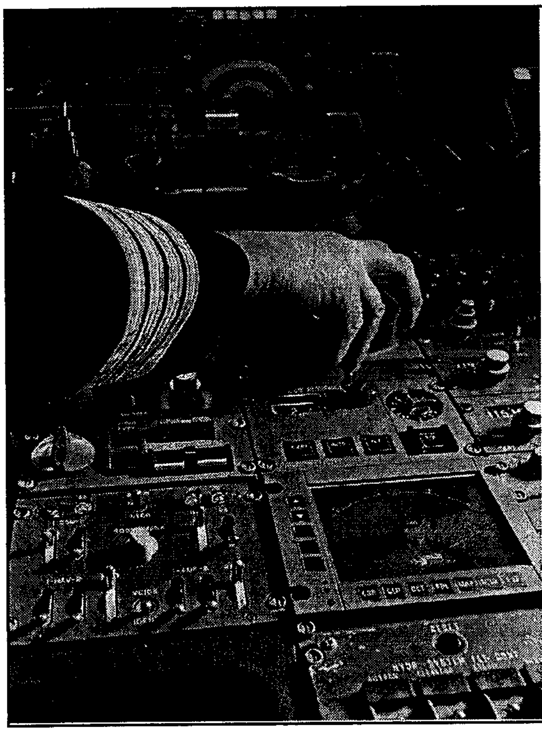
CARD



LUFTFARTSVERKET
Swedish Civil Aviation Administration

Agenda

- The problem.
- "The solution".
- Gate-to-gate flight.
- Road ahead...



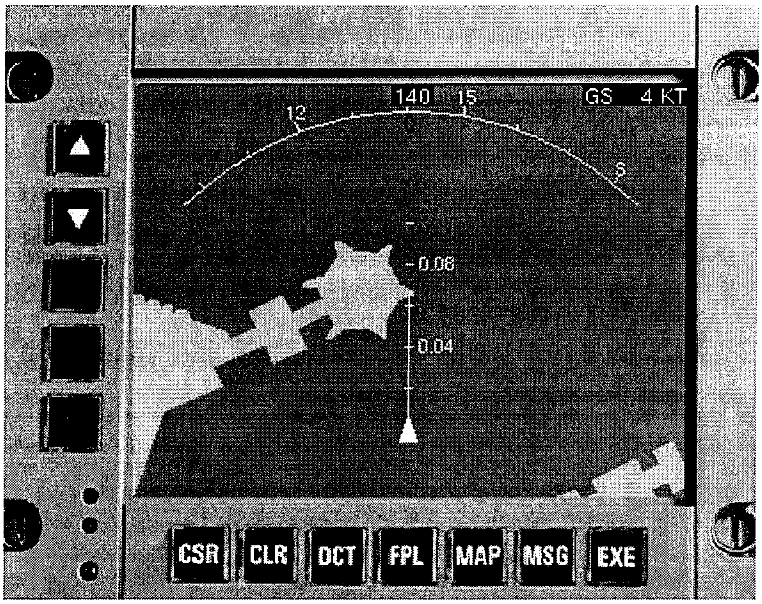
Gate-to-gate Flight

Using exiting technologies and equipment:
- VDL Mode 4 data link
- MMI5000 cockpit display
- NEAN ground network
- Differential GPS

LUFTFARTSVERKET
Swedish Civil Aviation Administration

GATE

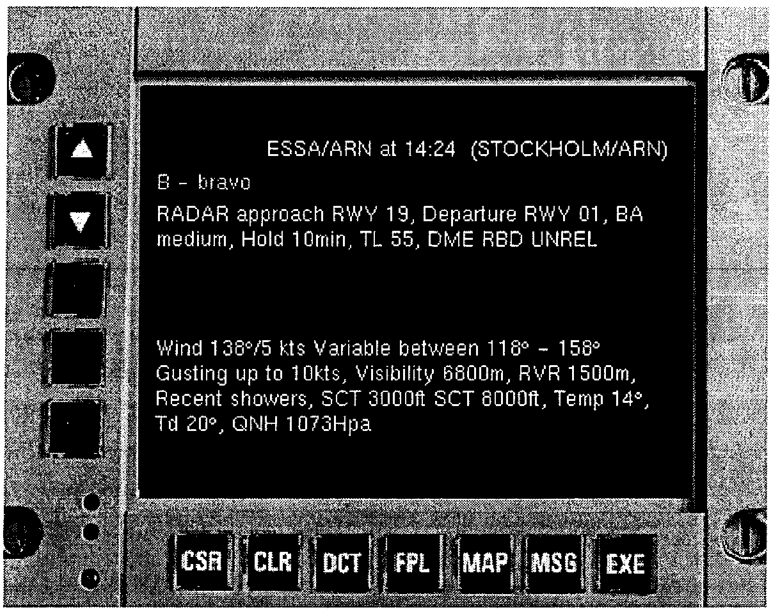
CARD 97



LUFTFARTSVERKET
Swedish Civil Aviation Administration

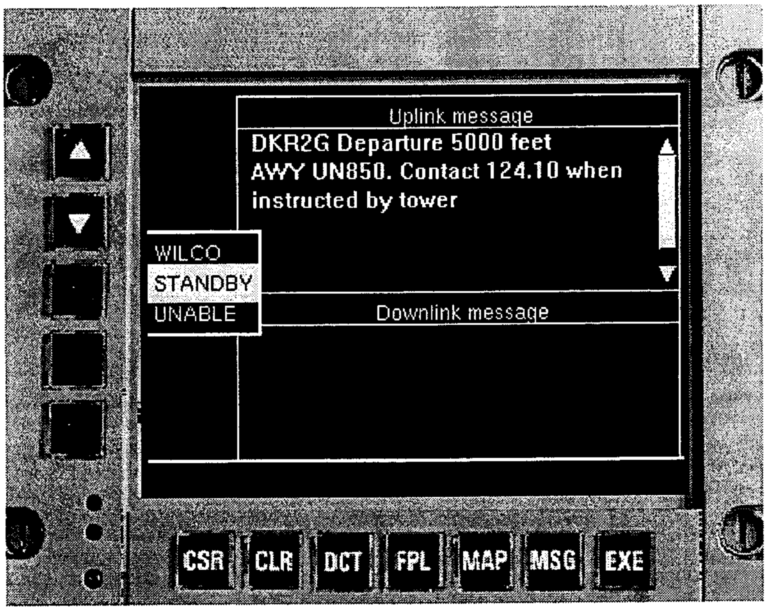
ATIS

CARD 97



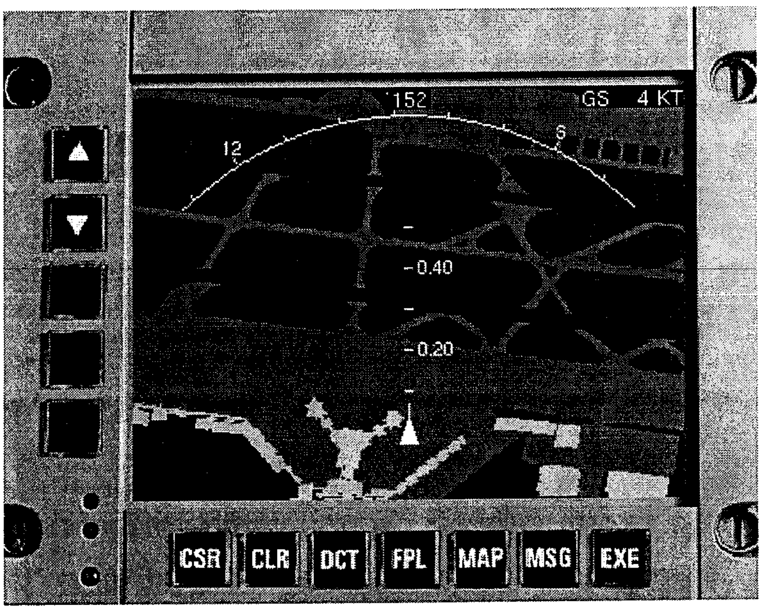
LUFTFARTSVERKET
Swedish Civil Aviation Administration

Clearance



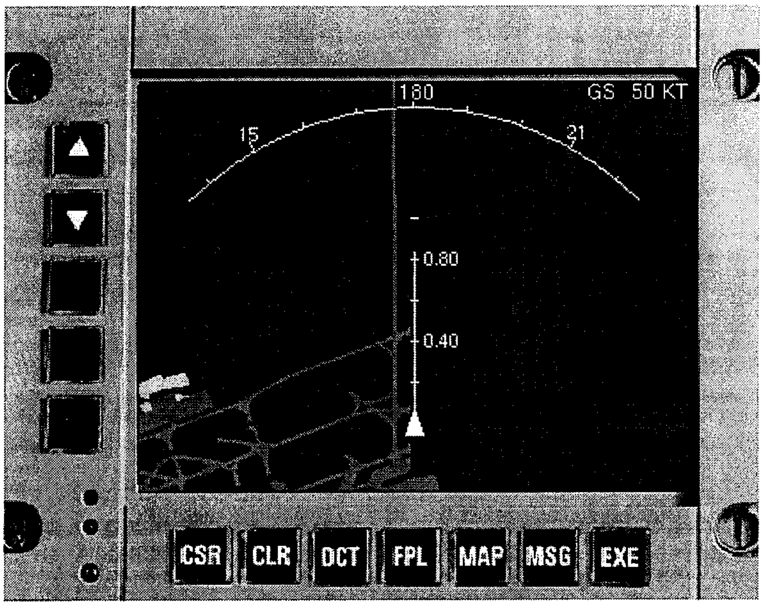
LUFTFARTSVERKET
Swedish Civil Aviation Administration

Surface movement



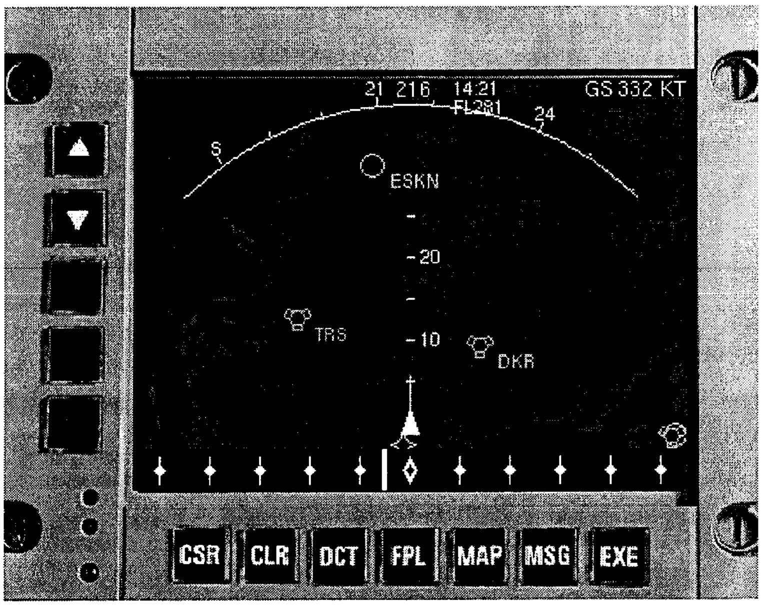
LUFTFARTSVERKET
Swedish Civil Aviation Administration

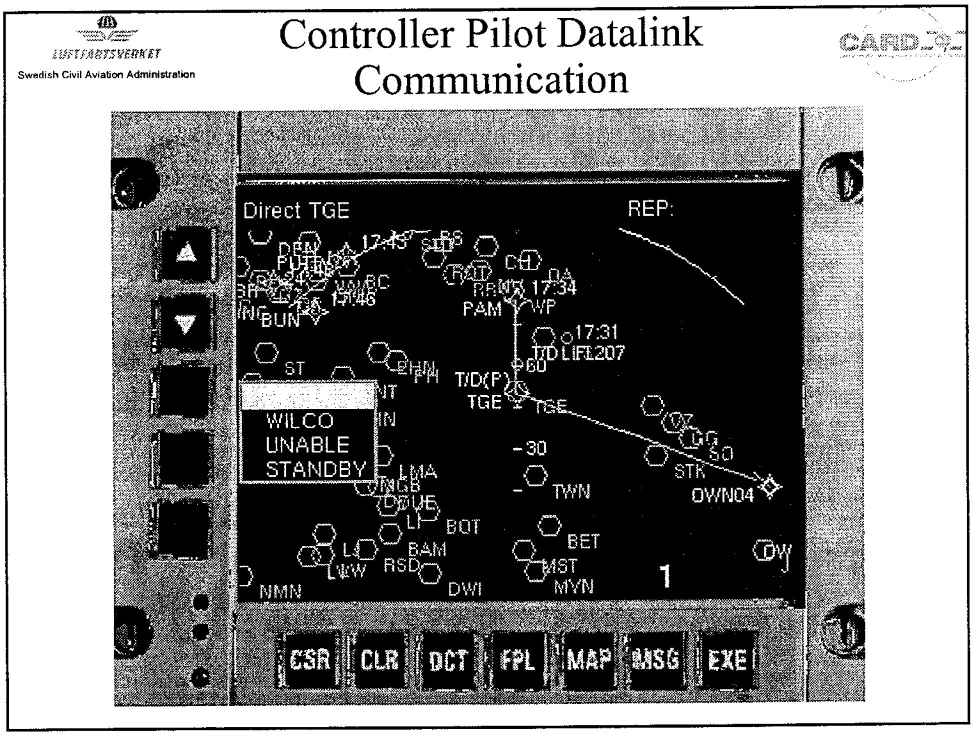
Runway incursion

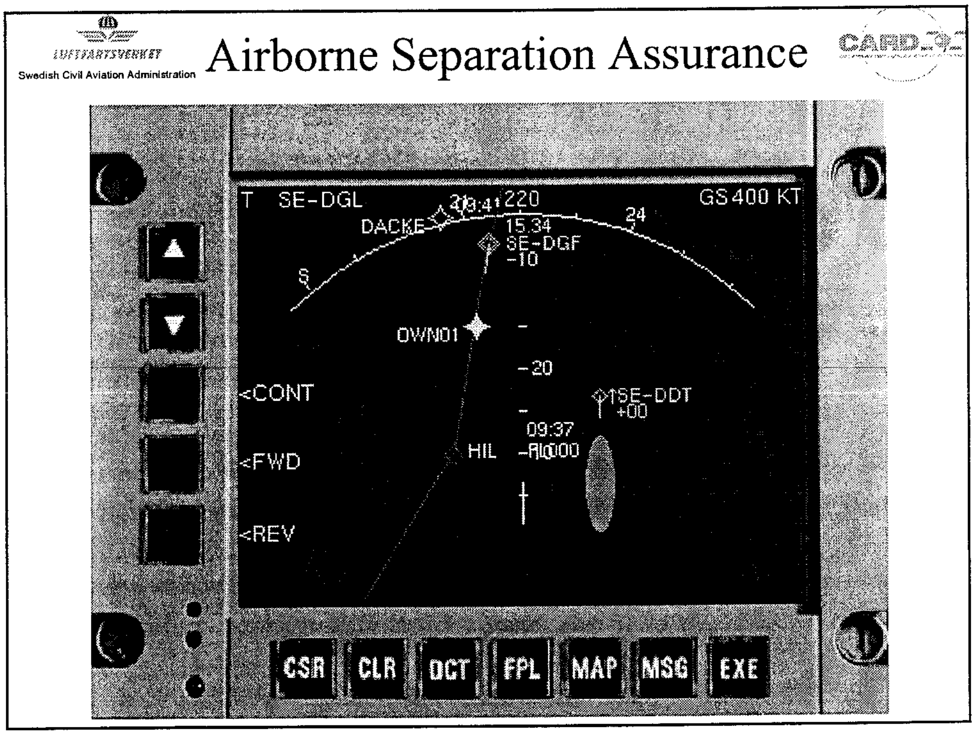


LUFTFARTSVERKET
Swedish Civil Aviation Administration

Enroute navigation




LUFTFARTSVERKET
Swedish Civil Aviation Administration
Controller Pilot Datalink Communication
CARD
Direct TGE
REP:
WILCO
UNABLE
STANDBY
CSR
CLR
DCT
FPL
MAP
MSG
EXE


LUFTFARTSVERKET
Swedish Civil Aviation Administration
Airborne Separation Assurance
CARD
T SE-DGL
GS 400 KT
DACKE
SE-DGF
OWN01
<CONT
<FWD
<REV
SE-DDT
HIL
CSR
CLR
DCT
FPL
MAP
MSG
EXE

LUFTFARTSVERKET
Swedish Civil Aviation Administration

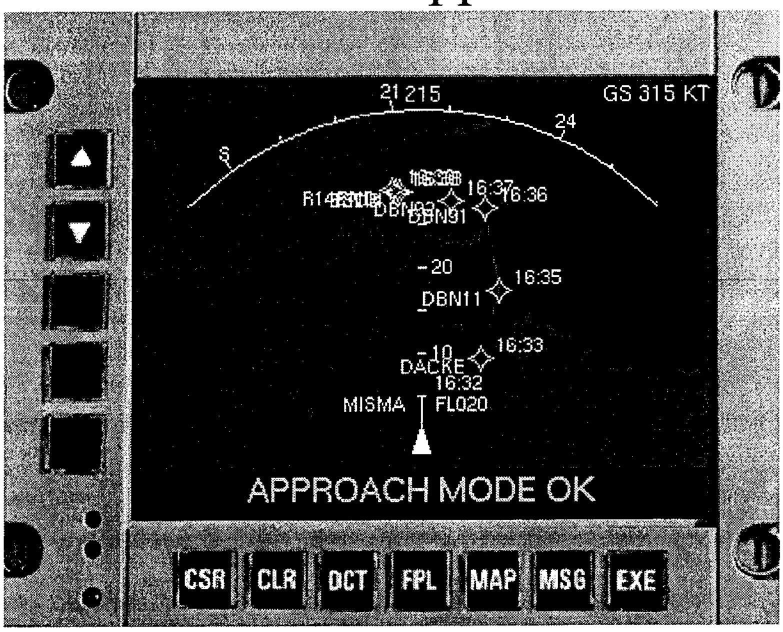
Airborne Separation Assurance

CARD

LUFTFARTSVERKET
Swedish Civil Aviation Administration

DGNSS in approach

CARD

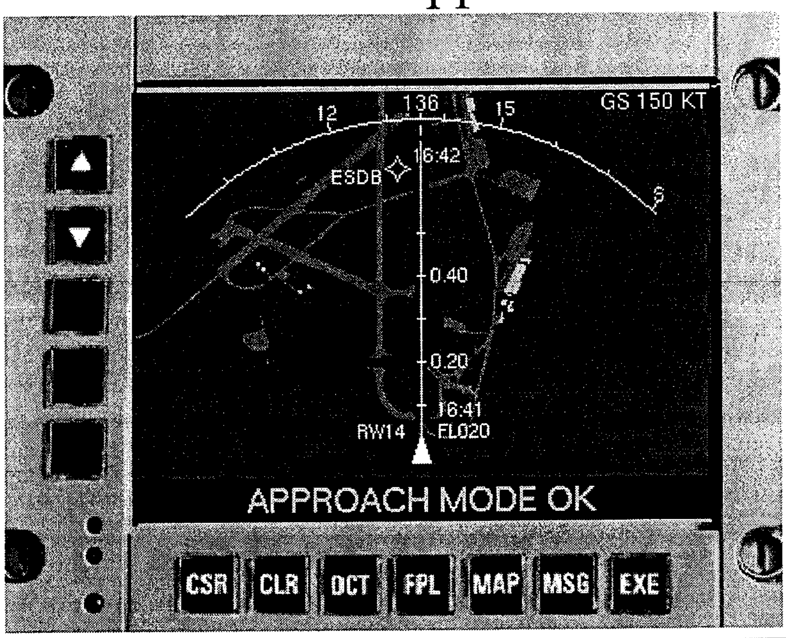


LUFTFARTSVERKET
Swedish Civil Aviation Administration

DGNSS in approach

LUFTFARTSVERKET
Swedish Civil Aviation Administration

DGNSS in approach



LUFTFARTSVERKET
Swedish Civil Aviation Administration

Agenda

CARD 97

- The problem.
- "The solution".
- Gate-to-gate flight.
- Road ahead...

LUFTFARTSVERKET
Swedish Civil Aviation Administration

VDL Mode 4 Vision

CARD 97

One system solution for...

...all elements in the ICAO CNS/ATM concept...

An efficient data link will be the basic component in support of Communications, Navigation and Surveillance applications.

...all phases of flight...

A single system for all phases of flight, "gate to gate", has to meet the user requirements to avoid a large number of different installations on-board aircraft.

...all user groups...

The required equipment has to be affordable and possible to install for all user groups.

...all over the globe implementation...

The technology has to be expandable and support the needs of all regions with maintained functionality independent of a ground infrastructure.

LUFTFARTSVERKET
Swedish Civil Aviation Administration

Major future activities

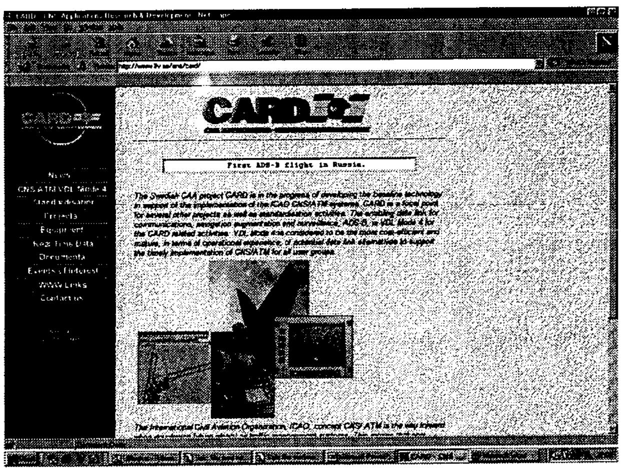
CARD

- Main project:
  22 MECU/USD (phase one 8 MECU)
  EC Funded
  SAS, DLH, LFV, SLV, DFS, Eurocontrol...
  1998-2002
- Standardisation:
  ICAO SARPs published in Annex 10 2001
  EUROCAE MOPS and ETSI
  IMO-standard exists.
- Operational Use:
  Initial use 1998/1999
  ADS-B fully operational 2005?

LUFTFARTSVERKET
Swedish Civil Aviation Administration

Further information

CARD



- Contact us!
  Gunnar Frisk:
  Swedish CAA
  gunnar.frisk@ans.lfv.se
- CARD WWW:
  http://www.lfv.se/ans/card

Delivering CNS/ATM Applications with VDL Mode 4

Introduction

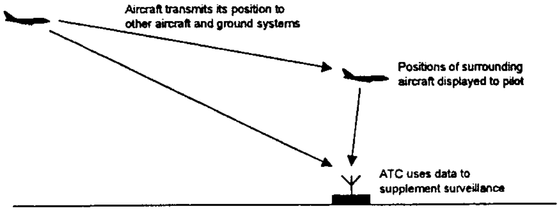
This paper describes how CNS/ATM applications can be provided using VDL Mode 4. The paper describes:

- the CNS/ATM concept, as it can be supported by VDL Mode 4;
- how VDL Mode 4 provides different CNS/ATM applications;
- the benefits of VDL Mode 4;
- the standardisation process of VDL Mode 4;
- projects that are demonstrating and evaluating the VDL Mode 4 concept;
- the implementation of VDL Mode 4 in aircraft and on the ground.

The role of VDL Mode 4 in the CNS/ATM concept

The ICAO CNS/ATM concept refers to the use of new technology such as advanced satellite and communications systems, to assist in the management of air traffic. VDL Mode 4 is a digital communications system that provides mobile communications from aircraft-to-aircraft and between aircraft and ground. VDL Mode 4 is integrated with navigation systems, for example satellite navigation GNSS systems, and may also be integrated to cockpit displays.

The main application of VDL Mode 4 is Automatic Dependent Surveillance – Broadcast (ADS-B). ADS-B is an ATM function that allows all pilots to 'see' other aircraft on a cockpit display. VDL Mode 4 also provides other ATM applications, described later in this paper.



ADS-B provided with VDL Mode 4

VDL Mode 4 aims to deliver several advanced applications in an integrated manner. In this way, it can meet the needs of different user groups with low complexity and the minimum of equipment. The design of VDL Mode 4 aims to meet the following requirements:

- To operate from gate-to-gate, on the ground and in all types of airspace, with global implementation.
- To operate without the need for complex ground infrastructure, although additional benefits may be gained if this is available.
- To offer a solution for all user groups with appropriate cost and performance for different user requirements.
- To support as many CNS/ATM applications as possible, including time-critical ones.

Providing multiple CNS applications

VDL Mode 4 is intended to provide several different CNS applications, including:

Automatic Dependent Surveillance-broadcast (ADS-B): In ADS-B an aircraft reports its position and other related data, such as speed and heading, to all other mobile and ground based users in the vicinity. This function is an integral part of VDL Mode 4, so ADS-B can be supported very simply and at low cost, providing information on aircraft velocity (true track, airspeed, etc.) and long term intent (eg cleared flight level, next waypoint) as well as basic position information. The information provided and the reporting rate can be tailored to suit all phases of flight. ADS-B enables many new user applications, particularly when used with a cockpit display of traffic information (CDTI), since this may allow airborne separation assurance in some areas and some new manoeuvres for aircraft. ADS-B can also be used to improve the quality of the surveillance data available to ATC.

Advanced Surface movement guidance and control (A-SMGCS): A-SMGCSs require the exchange of surveillance and other types of data between all users in the vicinity of the airport. The ADS-B function described above also provides highly accurate surveillance data to users on the ground. The CDTI can be used to assist mobile user surveillance, guidance and collision avoidance.

Uplink broadcast information: VDL Mode 4 can be used to transmit broadcast data from the ground to many aircraft simultaneously. This can be used to provide broadcast uplinked information on, for example, Meteorological data, flight information services (FIS) and traffic information services (TIS).

Controller Pilot Data Link Communications (CPDLC): CPDLC is used to provide data communications directly between controller and pilot, using the two-way data link capabilities of VDL Mode 4. The data link may also support other two-way applications such as pre-departure clearances (PDCs).

Differential GNSS uplink: When using GNSS data for navigation or surveillance, a GNSS augmentation system can be used to improve the quality of the position data. VDL Mode 4 can be used to provide GNSS augmentation signals, which provide information on the quality of the GNSS signals and correction data to overcome errors in the signals from the satellites. This service has been named 'GRAS' (GNSS Regional Augmentation System) and it is complementary to other satellite augmentation systems.

Benefits of VDL Mode 4

VDL Mode 4 will deliver benefits to aircrew that are equipped with VDL Mode 4 equipment and a cockpit display. Pilots can use the cockpit display to monitor the VDL Mode 4 traffic around themselves and to keep abreast of the traffic situation. This gives them better situation awareness than they have ever had before.

Using VDL Mode 4, traffic can be monitored at long range, for example at range of beyond 200nm. Pilots can easily monitor essential traffic and for the first time will have the same surveillance picture as the controller. The cockpit displays will support new manoeuvres such as station keeping in which a pilot is asked to follow another aircraft maintaining a particular separation. This does not relieve the ground controller of his responsibilities for separation assurance, but it does allow the controller to share some of his workload with the pilot. Station keeping can be used, for example, to efficiently sequence aircraft during departure operations.

One of the benefits of the cockpit display is that it can replace the 'party-line', which refers to the way in which pilots listen to VHF R/T to hear the exchanges between other pilots and the ground controller. By listening to the radio, the pilot builds up a mental picture of traffic close to himself. The cockpit display gives a much more complete and accurate picture of essential traffic to the pilot than can be gained by listening to the VHF R/T.

For the ground ATC system, VDL Mode 4 can be used to provide an alternative surveillance system to conventional SSR radar. Where SSR is not available, VDL Mode 4 ground stations are likely to be cheaper than radar ground stations because of their greater simplicity.

The standardisation of VDL Mode 4

Standardisation of VDL Mode 4 is underway in several groups: ICAO AMCP, EUROCAE and ETSI.

ICAO Aeronautical Mobile Communications Panel (AMCP). AMCP is developing VDL Mode 4 Standards and Recommended Practices (SARPs). The validation of VDL Mode 4 SARPs for surveillance applications has begun in AMCP. The SARPs describe the 'signal-in-space' operation of VDL Mode 4 equipment. The SARPs are a set of generic communication protocols that define the basic operation of the system, but they do not specify the applications that use the system (this is a similar approach as that used for ATN standardisation). Draft SARPs have been published and work is underway in several states to validate these. A Validation Sub Group (VSG) has been established by AMCP Working Group D to oversee the validation process. The VSG aims to have validated SARPs available at the end of 1998.

EUROCAE. EUROCAE is the European organisation of equipment manufacturers and civil aviation authorities responsible for standardising aircraft equipment. EUROCAE Working Group 51, Sub-Group 2 is developing Minimum Operation Performance Standards (MOPS) for VDL Mode 4 for ADS-B. The MOPS describe the performance of airborne equipment and are critical for the certification of equipment. The MOPS also define certain application-specific parameters that are not fixed in the VDL Mode 4 SARPs. In the future, MOPS for VDL Mode 4 applications other than ADS-B may be developed and these will also make use of SARPs. The EUROCAE MOPS group aims to have finalised draft MOPS available at the end of 1998.

European Telecommunications Standards Institute (ETSI). ETSI has undertaken a study to determine whether VDL Mode 4 can be standardised by ETSI. The study concluded that it should be standardised in two stages: surveillance applications first and then remaining applications second. ETSI plans to start this work in 1998.

Projects

There are many project underway to investigate the benefits of VDL Mode 4 and to help mature the technology. Practical demonstration/evaluation projects are underway in: Sweden, Germany, Italy, Denmark, the Netherlands. Projects have recently been completed in Spain and the USA. New projects are being discussed and planned in Russia and Australia. The projects involve commercial airlines, civil aviation authorities, general aviation users and ground vehicles.

The projects varies aim to investigate the benefits of the different applications of VDL Mode 4 to pilots and ATC service providers. The projects cover surveillance, communication and navigation applications. Most projects covers civil aviation use but military users has also tested the system, e.g. in the US Navy F/A-18 and Swedish Airforce SK60.

The projects use prototype equipment that integrates a VHF transceiver, GPS receiver and the necessary processing equipment into a single box. This 'transponder' is interfaced to a cockpit display that has also been developed for the purposes of the trials. Some of the projects have matured into operational VDL Mode 4 applications.

The following list summarises some of the prototype VDL Mode 4 projects:

- **NEAN** ***(Sponsored by the European Commission)*** The largest European activity is known as the North European ADS-B Network (NEAN). Under NEAN, an ADS-B capability is being created through a network of ground stations and mobile VDL Mode 4 equipment that is being installed in commercial aircraft and airport vehicles. The network spans Germany, Denmark and Sweden, and once position reports are received by a ground station they are then distributed throughout the network to air traffic control and other users. There are 15 ground stations in the NEAN project and 16 aircraft equipped including six 747s, two DC9s, two F28s and a helicopter. Around 30 ground-vehicles are also equipped. NEAN is a collaborative venture between the German, Danish and Swedish Civil Aviation Administrations and the following aircraft operators: Lufthansa, SAS, OLT, Maersk Helicopters and Golden Air. In June 1997, Flight International Magazine gave an Aerospace Industry Award to Luftfartsverket (the Swedish CAA) and SAS for 'pioneering work within the NEAN project to demonstrate the potential of ADS-B'.
- **NEAP** ***(Sponsored by the European Commission)*** The North European CNS/ATM Applications Project (NEAP) is a sister project to the NEAN, with the same participants. Using the infrastructure implemented in the NEAN, the NEAP is demonstrating end-to-end (airborne and ground based) applications using the prototype VDL Mode 4 data link. The applications being tested are: GNSS precision navigation capability for en-route and approach; on ground situation awareness and taxi guidance awareness; in flight situation awareness; enhanced surveillance; automatic terminal information service; extended helicopter surveillance and runway incursion.
- **FARAWAY** ***(Sponsored by the European Commission)*** The objective of FARAWAY is to investigate the enhanced operational performance of ground surveillance and aircraft navigation made possible through the fusion of radar and ADS-B data. The Faraway project is co-ordinated by Alenia, Italy and involves ATM service providers and airlines in Germany, Italy and Sweden. Three Alitalia MD-82s have been equipped with prototype VDL Mode 4 and cockpit display equipment and one ground station has been installed at Ciampino airport, Rome.
- **SUPRA (Sponsored by the European Commission)** This project investigated the benefits of ADS-B to general aviation. SUPRA involved a demonstration of ADS-B at a small airfield outside of Madrid. The project was co-ordinated by Indra, Spain and it was successfully completed in 1997. The project was the winner of a Flight International Aerospace Industry award 1998.
- **PETAL II** ***(Sponsored by Eurocontrol)*** PETAL-II is a Eurocontrol project to investigate use of air-ground data link to perform real-time Controller Pilot Data Link Communications (CPDLC). One of the data links that Petal II is using to provide

this application is the prototype VDL Mode 4 data link. Prototype VDL Mode 4 ground stations have been installed at the Maastricht ATC Centre and at the Eurocontrol Experimental Centre and flight trials have begun.

In addition to the various projects, there are also practical activities that are underway. One of the most important is the simulation of the VDL Mode 4 system to check its operation under different scenarios. The simulation uses a computer model and scenarios based on high traffic density areas (the LA Basin and the core area of Europe) have been modelled.

Airborne implementation

A VDL Mode 4 installation on an aircraft will require connection to a navigation system to provide the position data to be transmitted for the ADS-B application. Additional benefits can be delivered if the VDL Mode 4 equipment is integrated to a cockpit display that allows surveillance data and other information to be presented to the pilot.

VDL Mode 4 is intended to be low cost and easy to implement on aircraft and different types of aircraft will have different implementations of VDL Mode 4. For example, Air Transport (AT-class) aircraft may implement additional VDR (VHF Digital Radio) systems to provide VDL Mode 4 functionality. The VDL Mode 4 will need to be integrated to some of the other avionics systems. AT-class aircraft may also use several redundant systems to provide the required continuity of service.

For smaller aircraft, such as general aviation (GA) aircraft, it is likely that more integrated on-board equipment could be used. This would mean that GPS receivers, VHF communications equipment and cockpit displays could be integrated into a single unit. GA aircraft will usually require less redundancy than AT-class aircraft.

Ground implementation

There is no requirement to install VDL Mode 4 ground infrastructure if only air-to-air communications are required. However, if air-to-ground communications are also required, then VHF ground stations must be installed. For ATC service providers, the main costs of implementation is installing new VHF ground stations. Many states have a VHF infrastructure already for voice communications, so this greatly reduces implementation costs. For states without a VHF communications infrastructure, then ground stations must be installed.

The cost of purchasing and maintaining operational VDL Mode 4 ground stations is expected to be considerably less than the cost of conventional radar ground stations because they do not have rotating antenna parts and have simpler electronic circuitry.

Summary

This paper has presented an overview of VDL Mode 4, describing the role of VDL Mode 4 in the CNS/ATM concept and how VDL Mode 4 can deliver different CNS/ATM applications.

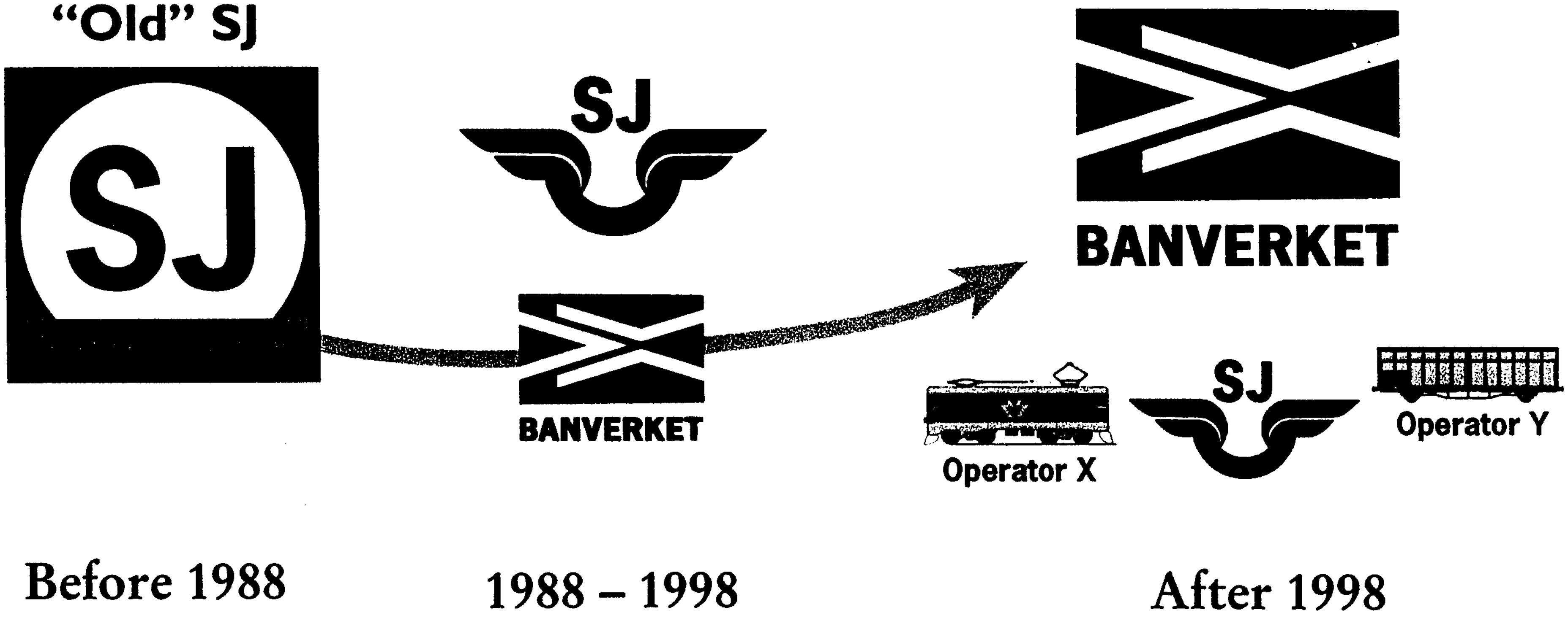
VDL Mode 4 is a flexible system that can deliver many benefits to different ATM users and shows great promise for the future. Different organisations (e.g. airlines and CAAs) will need to undertake cost-benefit analysis to gain confidence that they should invest in VDL Mode 4. Some organisations have already gained this confidence and it is likely that more will decide to use VDL Mode 4 as they see the benefits of its applications.

GPS in the Swedish National Rail Administration

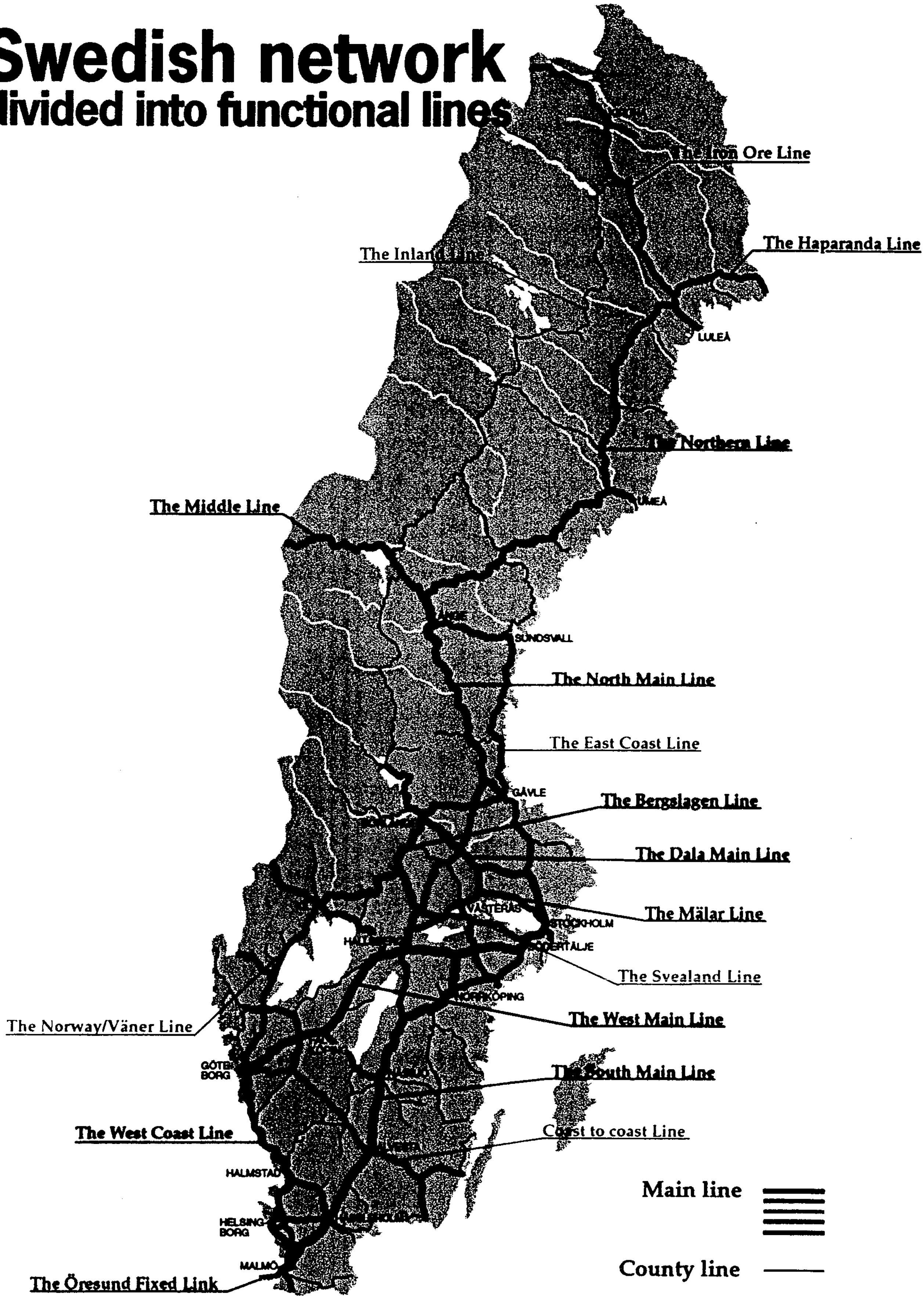
Marie Malmberg
Sten Lundén

marie.malmberg@hk.banverket.se
sten.lunden@hk.banverket.se

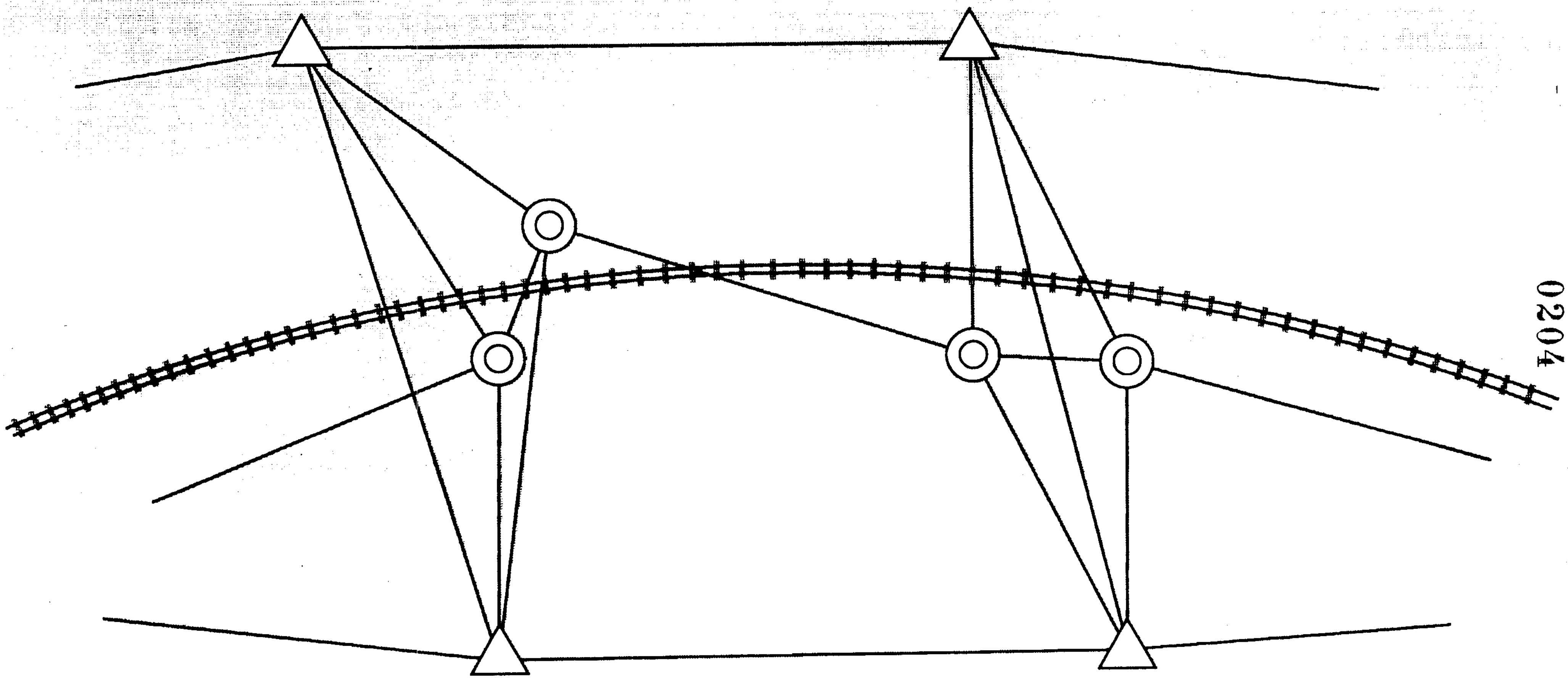
From
SJ Technical department
to
established
National Rail Administration



Swedish network
divided into functional lines

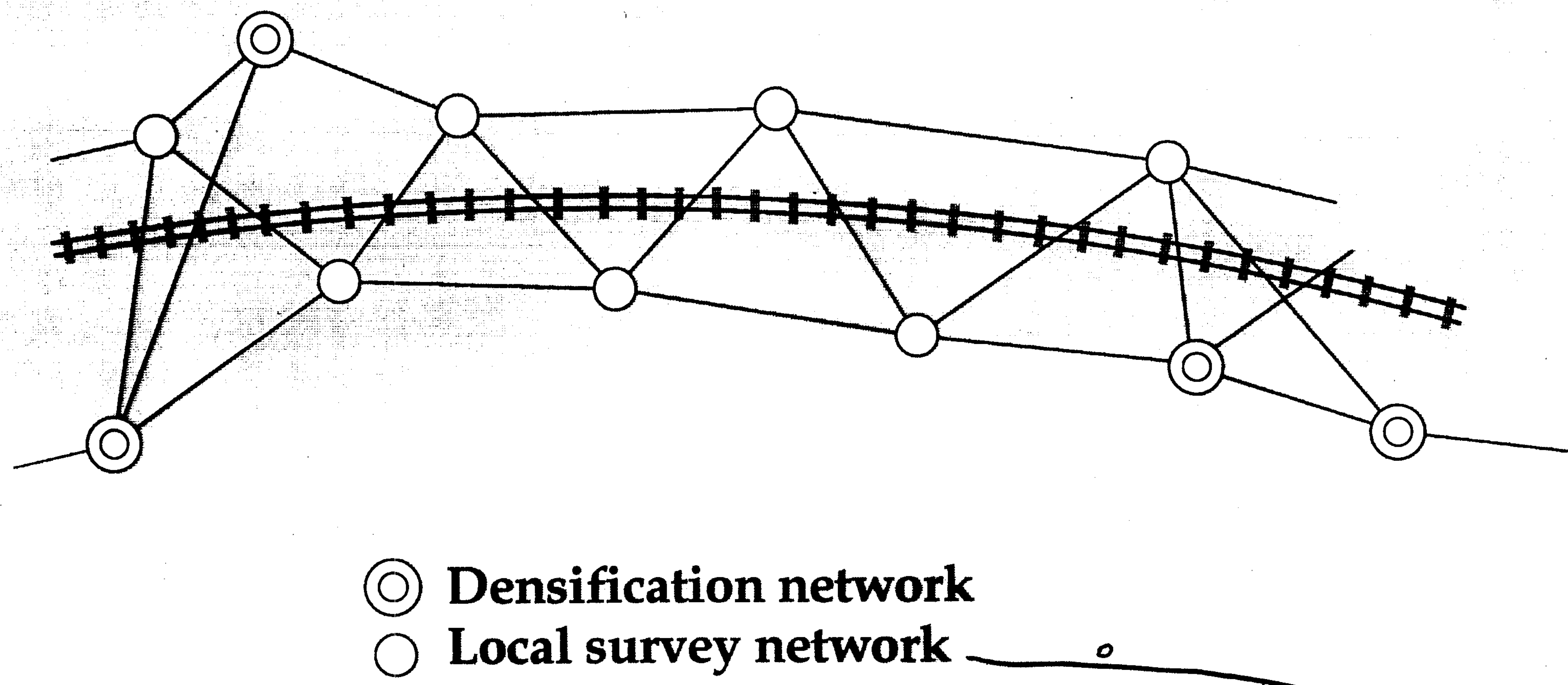


Schematic densification network

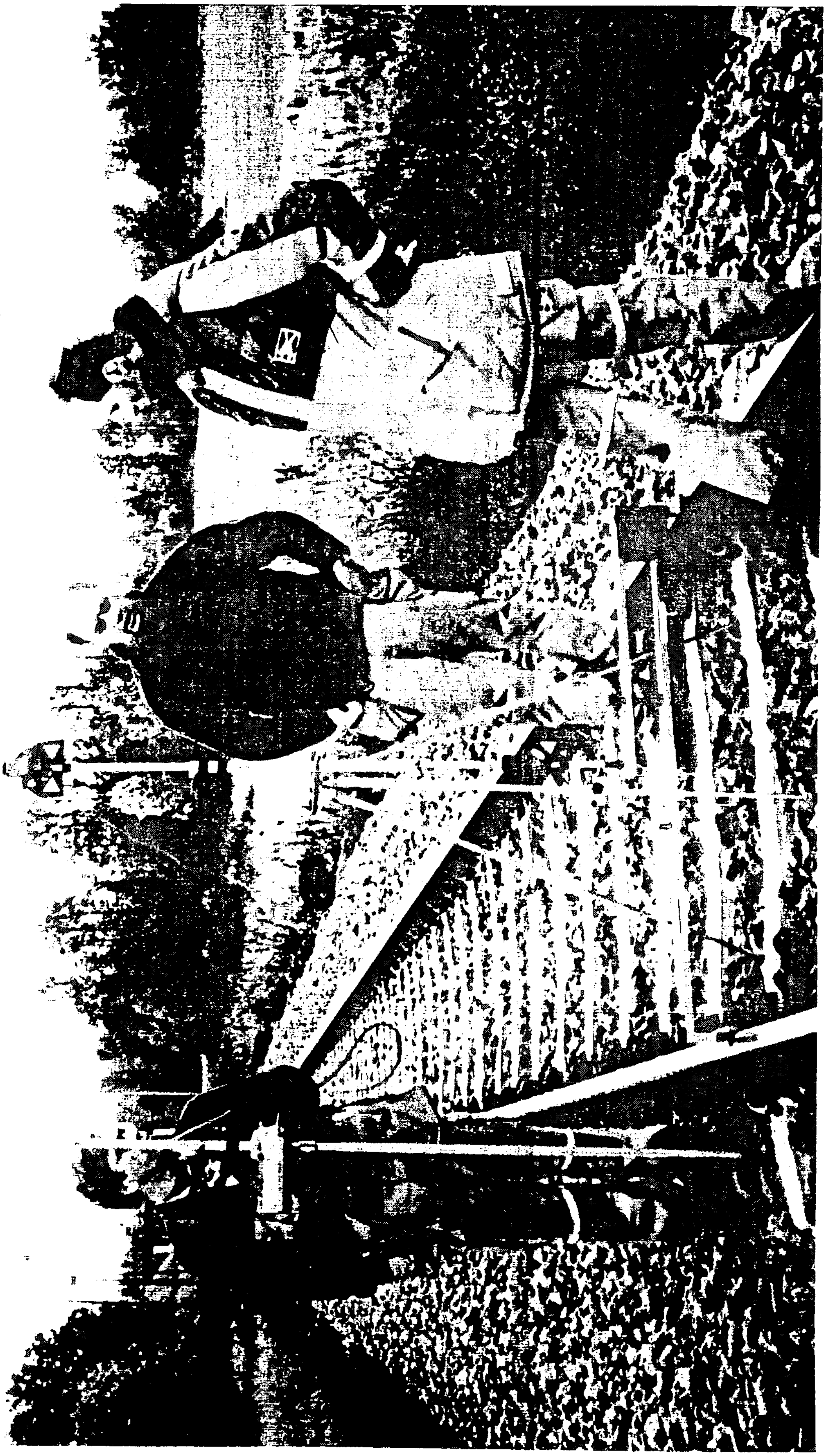


△ National geodetic network
◎ Densification network

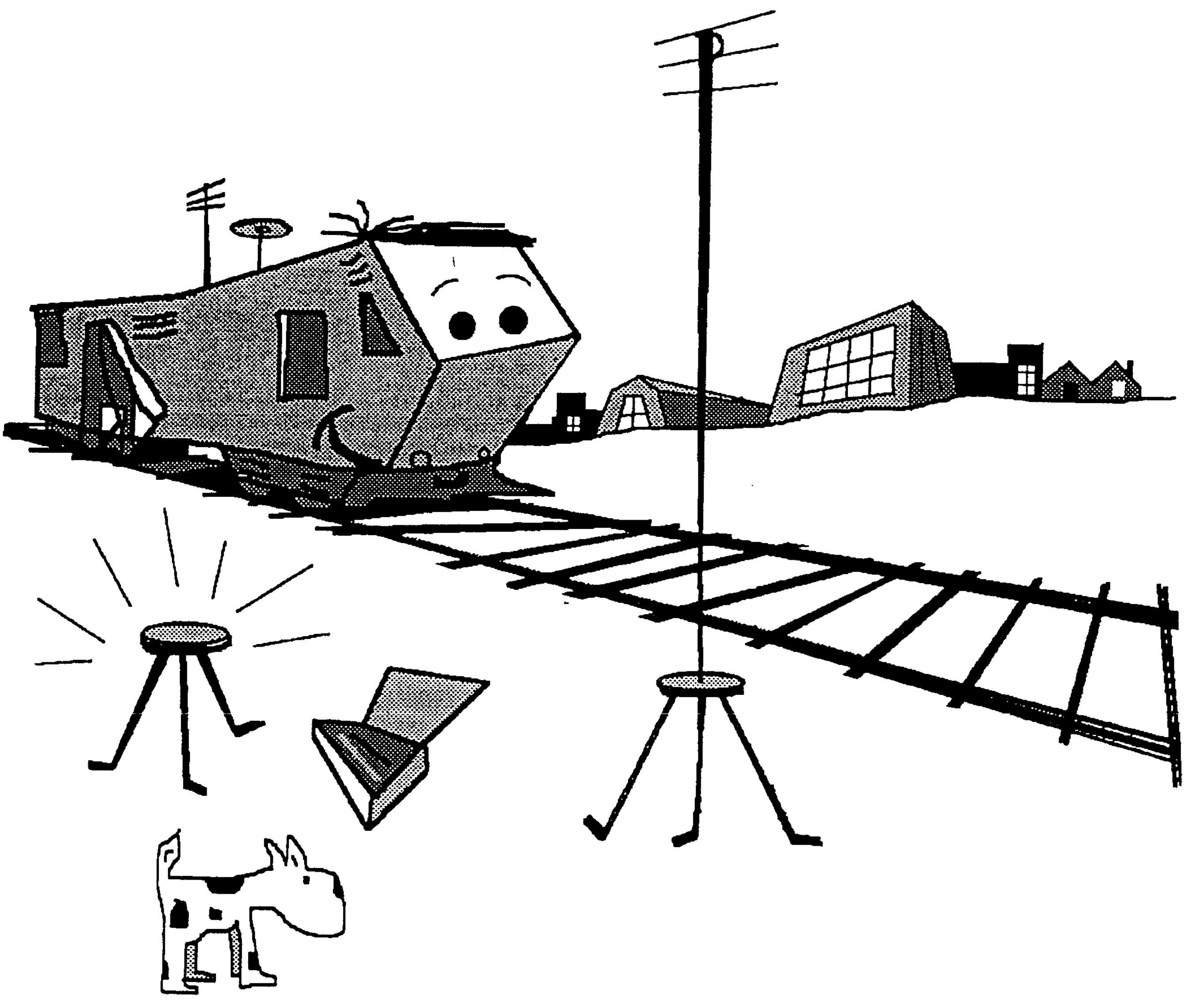
Schematic local survey network



0205



RTK on a vehicle

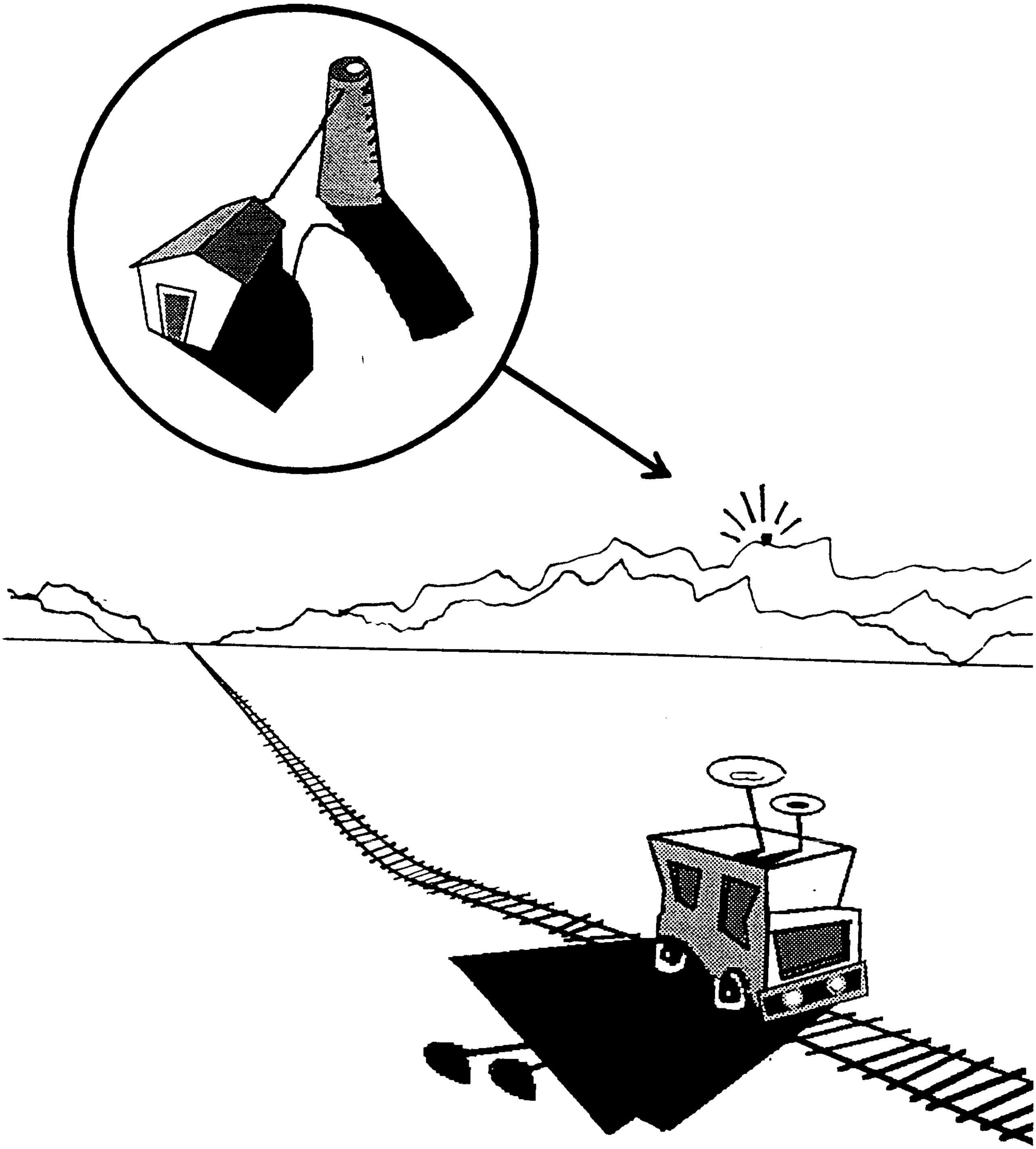


BANVERKET
SWEDISH NATIONAL RAIL ADMINISTRATION

Conclusions: RTK in BV

- Problems with satellite coverage
- To low accuracy.
- BV demands are:
  - 15 mm horisontal
  - 10 mm in height

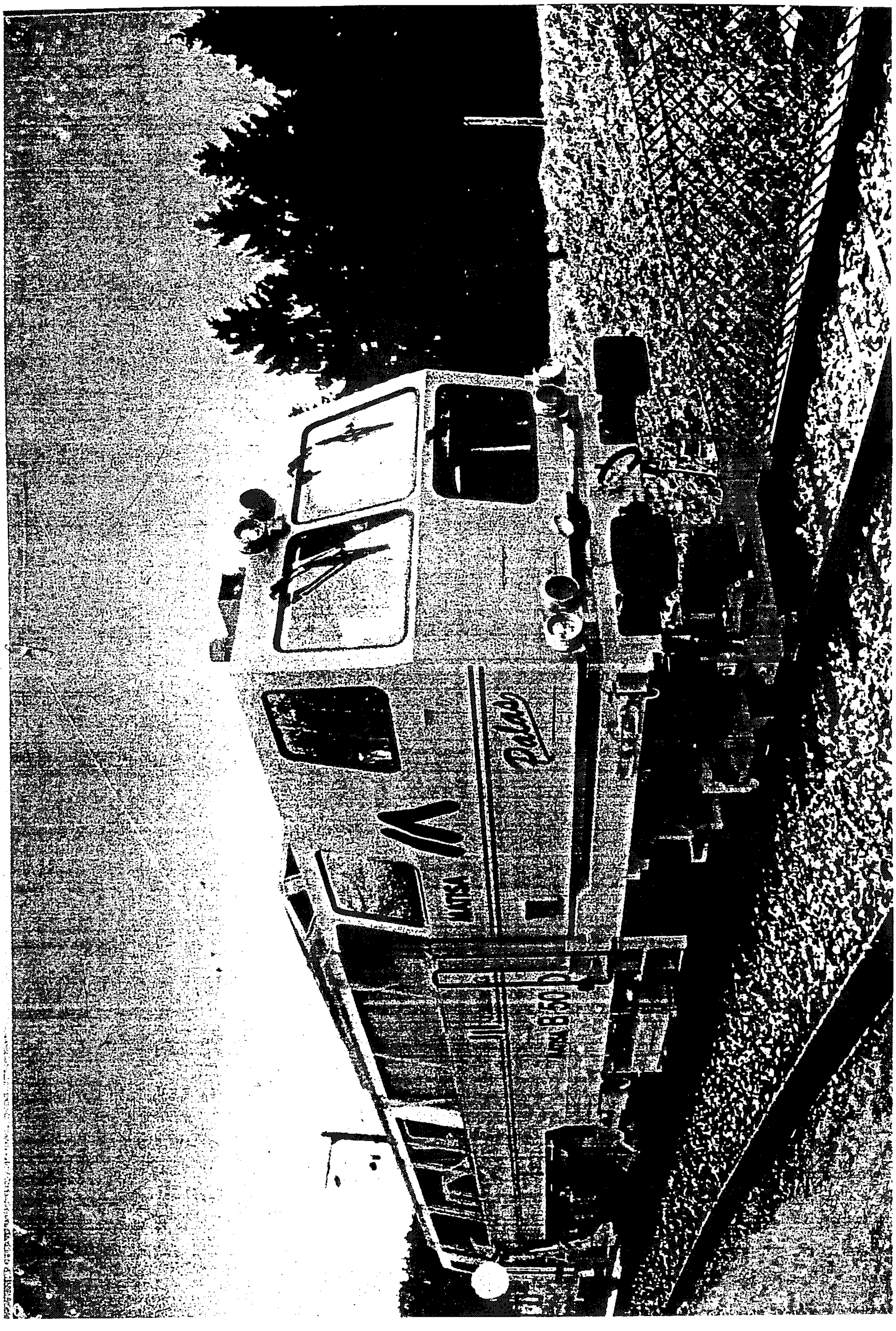
DGPS to SWEPOS

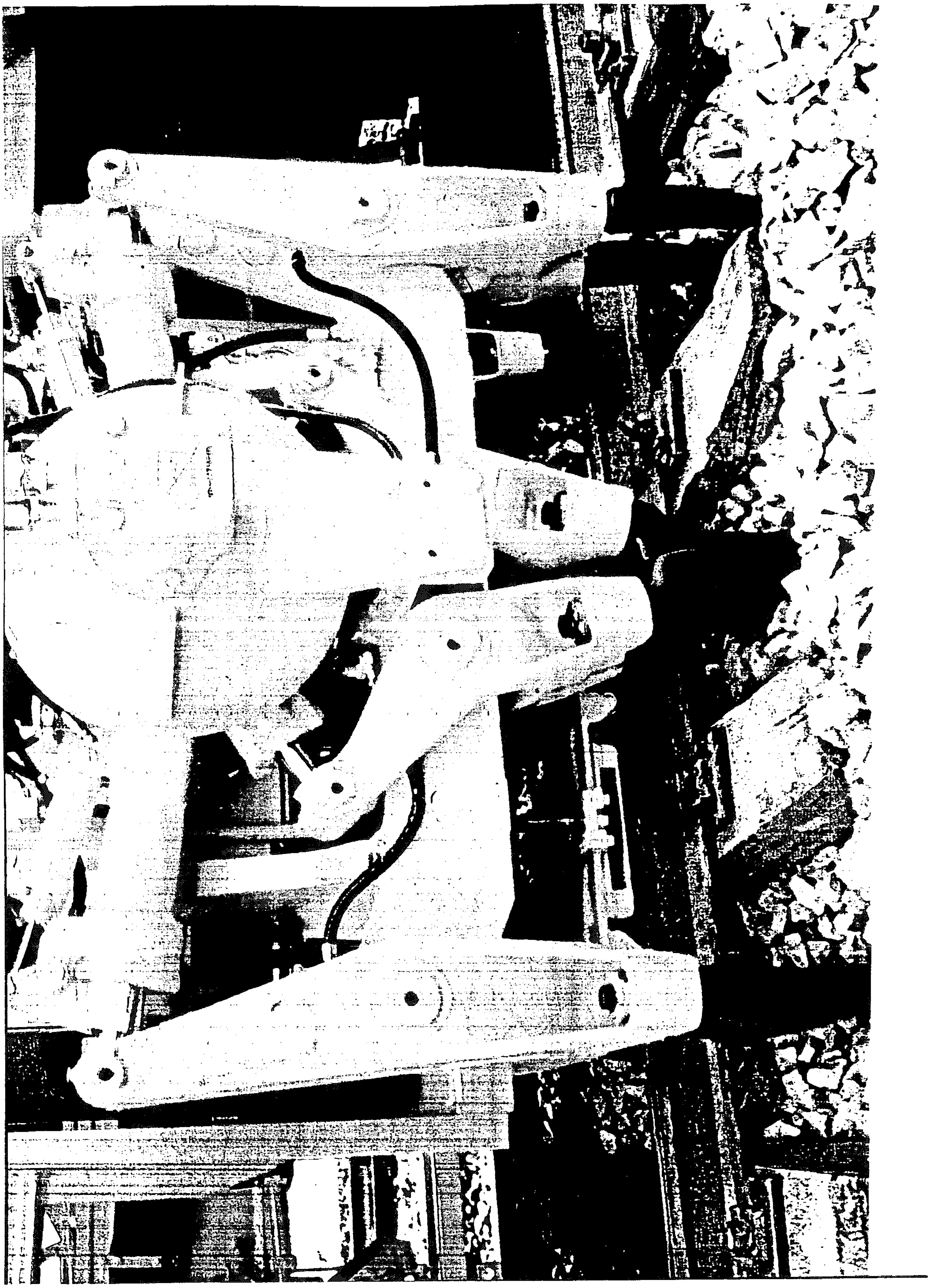


BANVERKET
SWEDISH NATIONAL RAIL ADMINISTRATION

New use of GPS in BV

- Geodetic measurement, RTK
- Positioning of trains
- Machine control



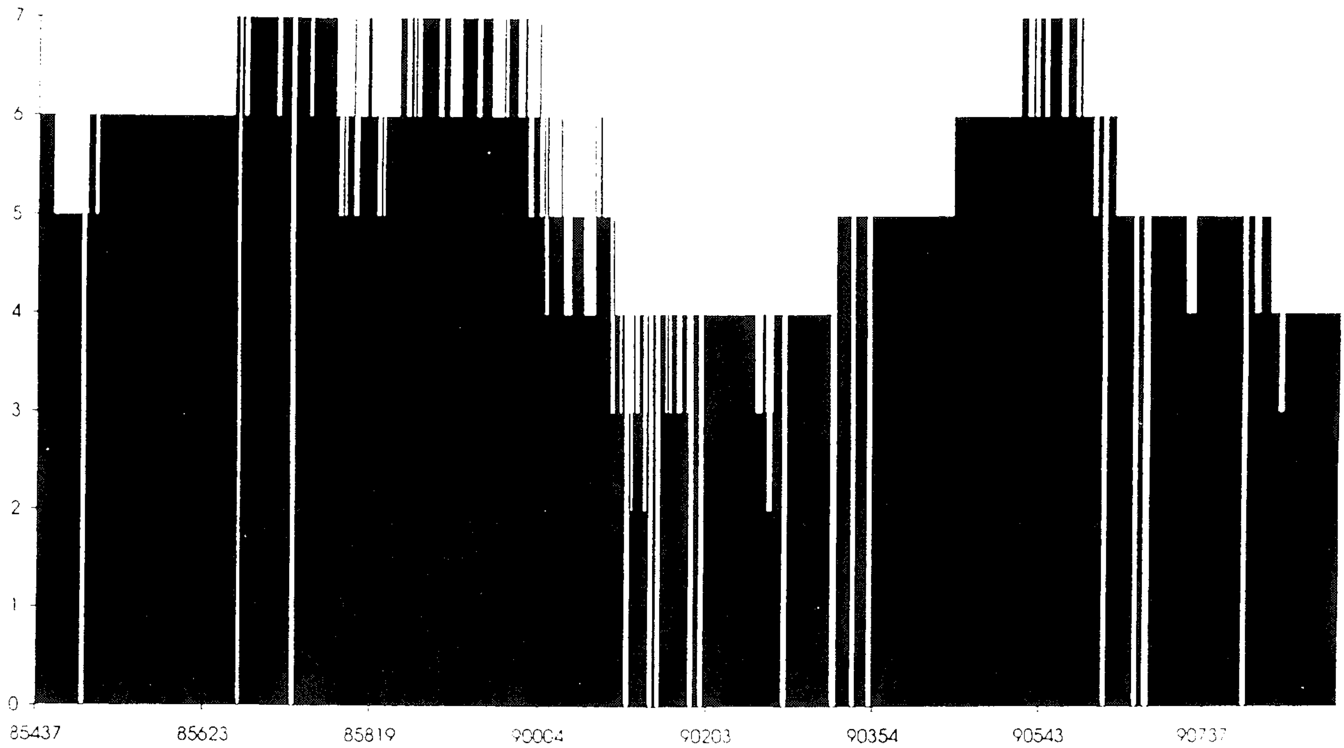


TOLERANCE OF TRACK
(after tamping)

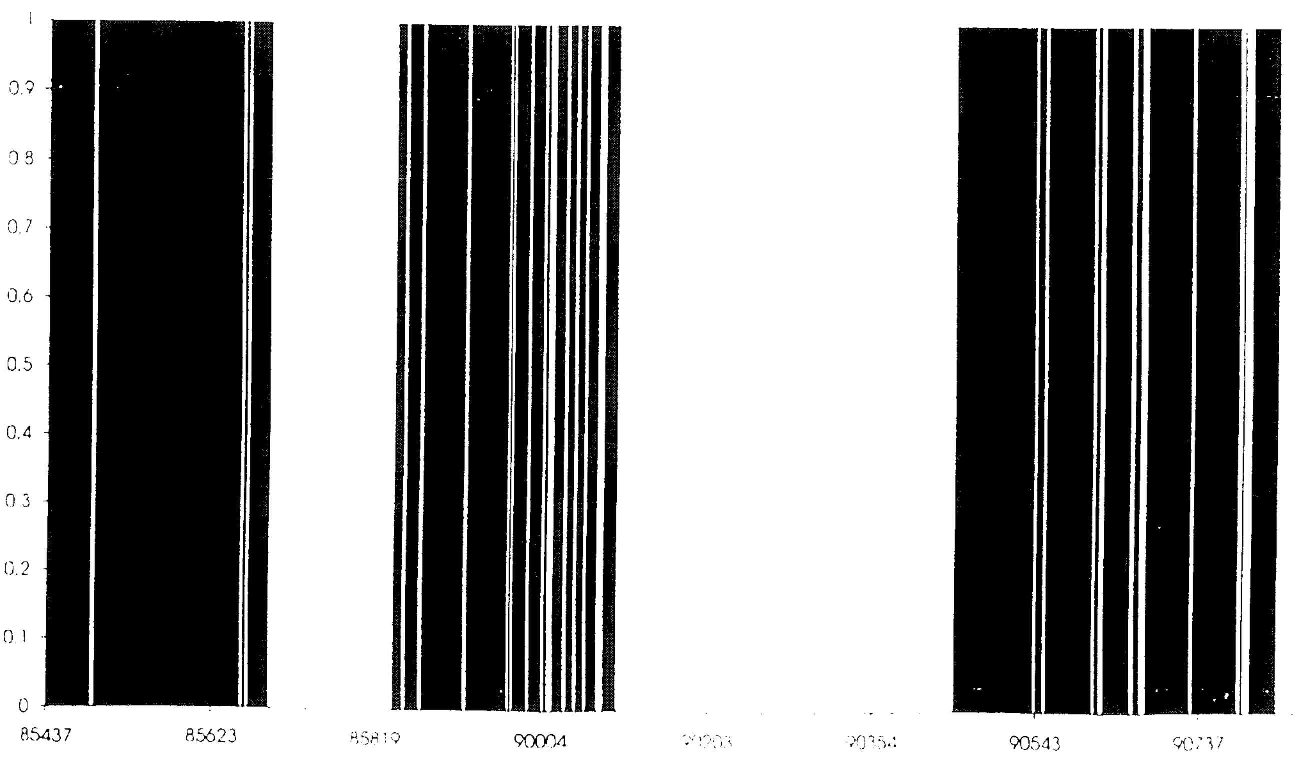
	LATERAL	VERTICAL
RELATIVE	2 MM	2 MM
LONGWAVE	5 MM	7 MM
ABSOLUTE	+- 15 MM	+10, -20

RTK-mätning 96-11-08

Antal satelliter

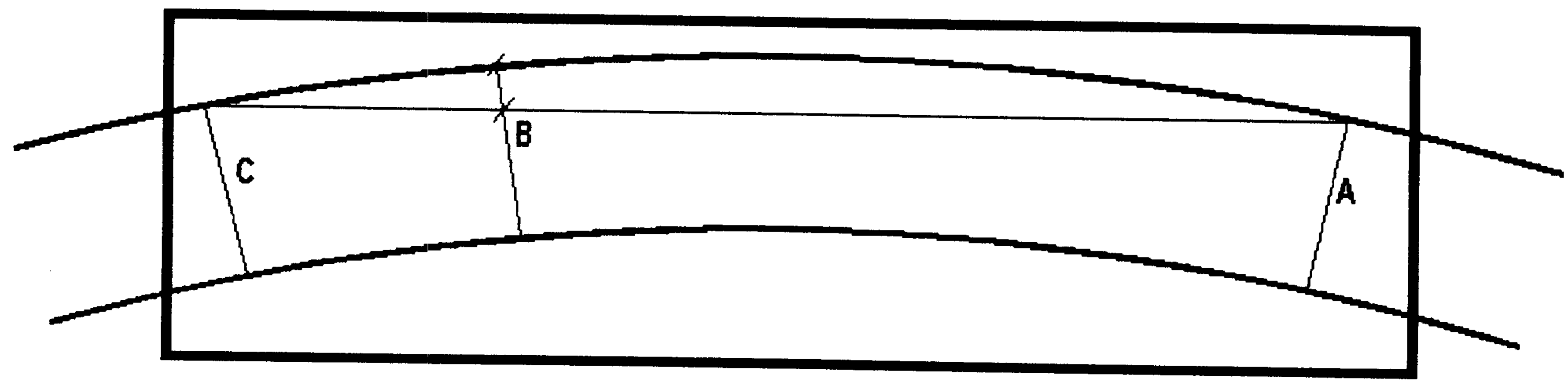


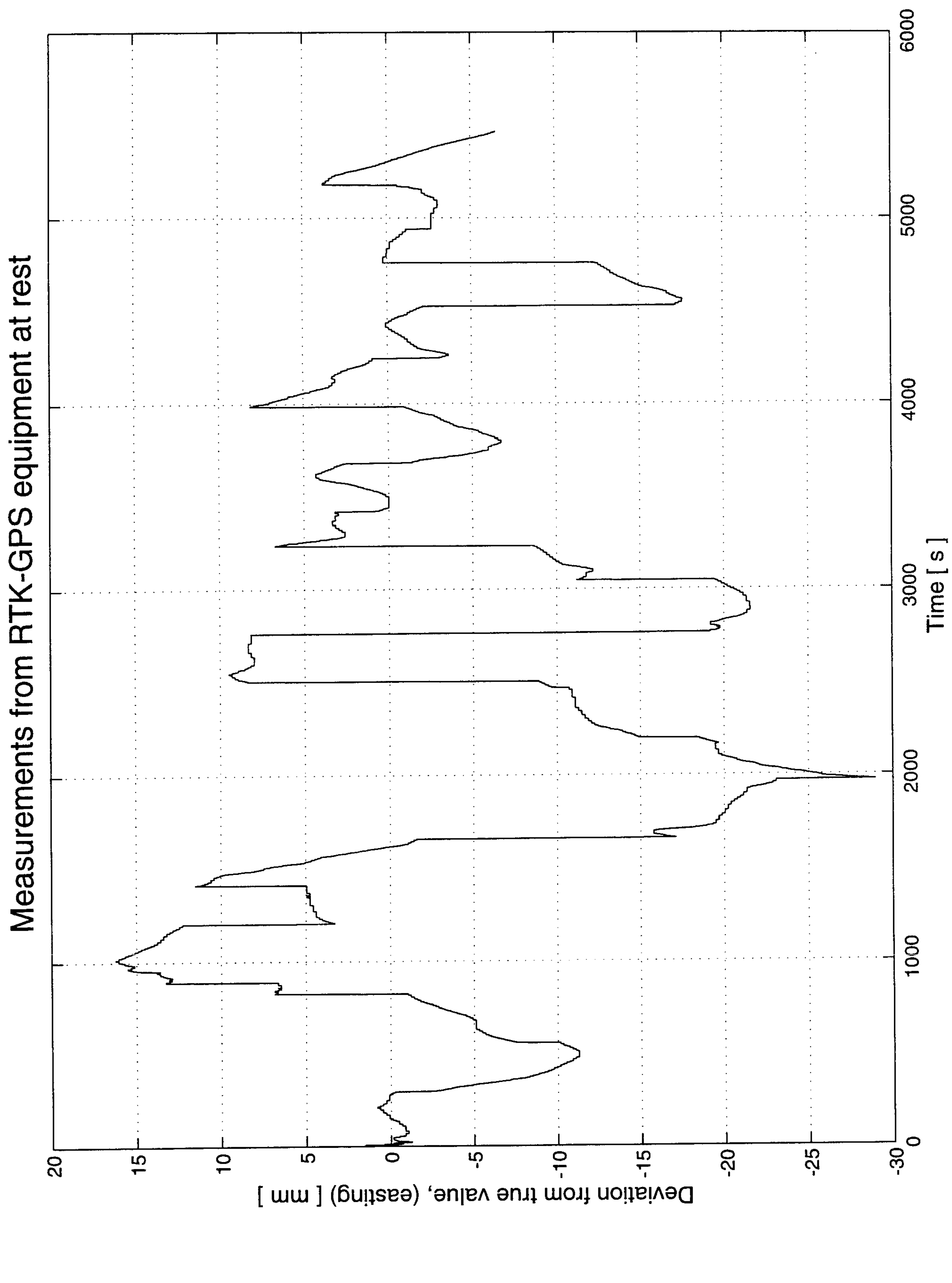
Fixlösning



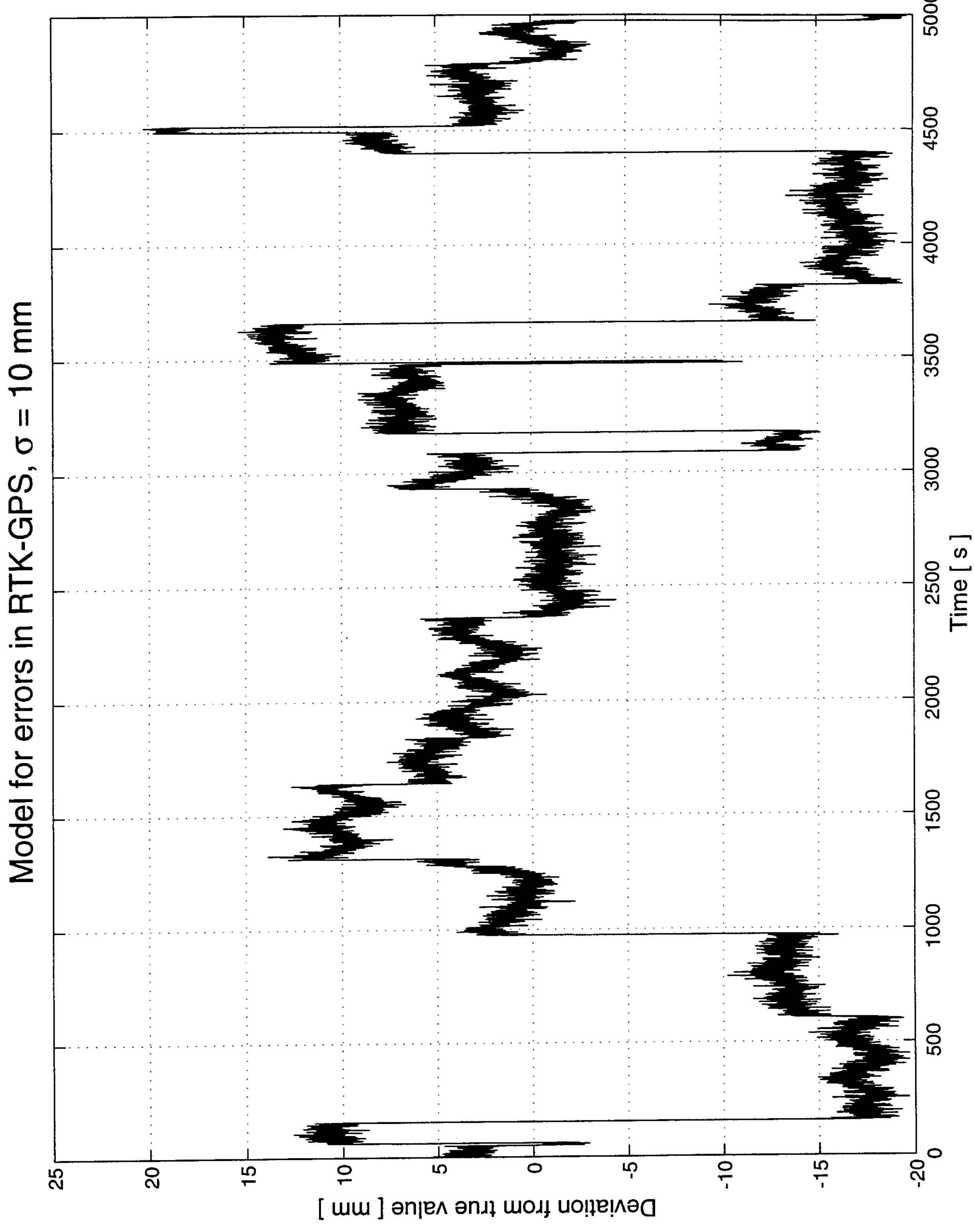
TAMPING MACHINE

Internal measuring system

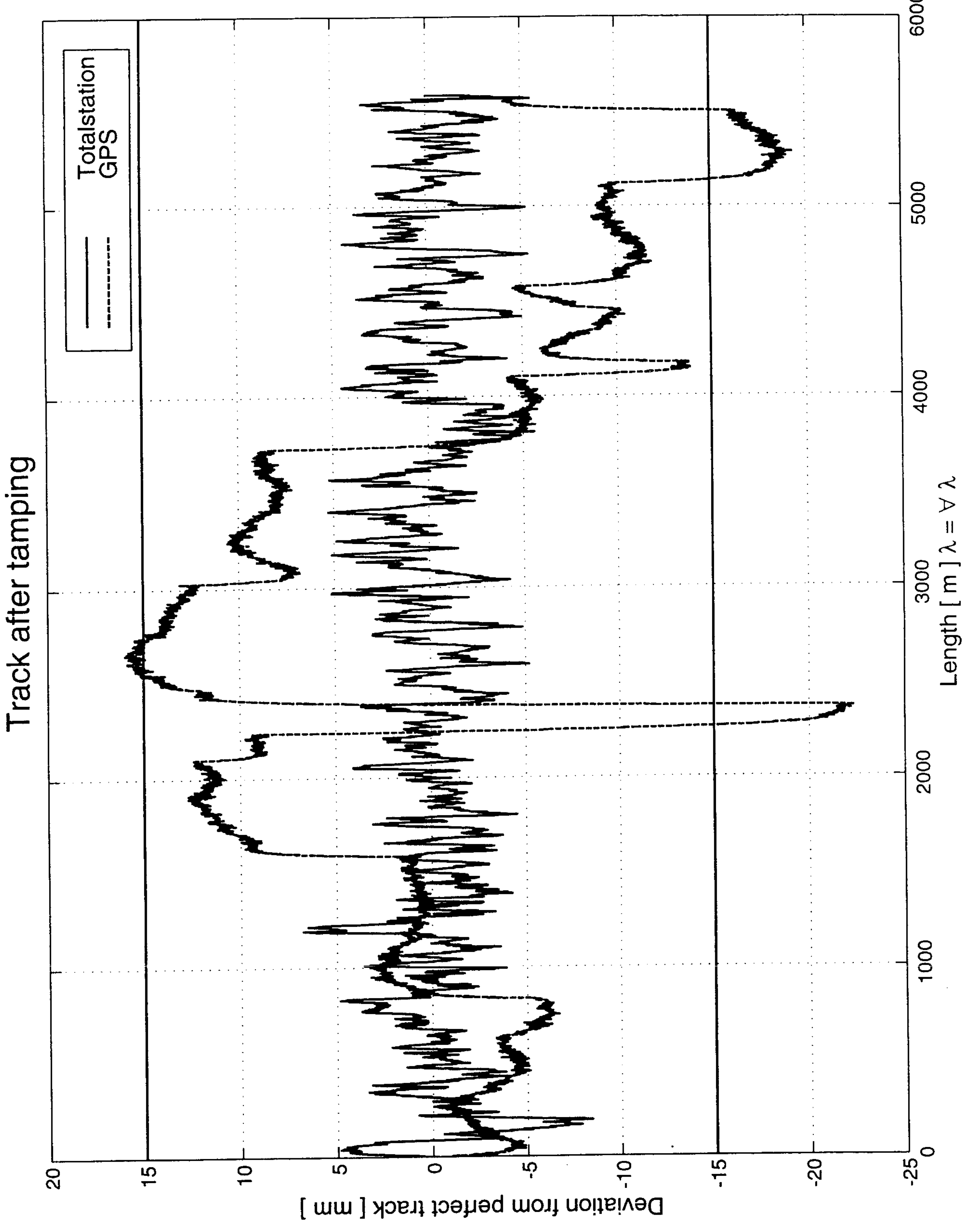




\\blgp5n\matlab\workarea\GeoBax\loadGPSdata



\\blgp5n\matlab\workarea\GeoBax\GBDoldMarkov(20000,0.997,0.04,0.5,30,10).m



\\BLGP5N\matlab\workarea\GeoBax\gbEngBil.m

CONCLUSION

* Supply of satellites
* Configuration of satellites
* Software development
* Machine guidance
* Train control

Pilot mounted GPS concept

by Patric Jansson, Enator Telub AB, Solna, Sweden

Technical verification of air traffic control systems and their performance is crucial to the main task of air traffic control. The entire chain of information from the sensor (radar) to the eyes of the controller must be checked and verified. Tests of the performance should be carried out whenever a parameter of the system has been changed or whenever there is a doubt that the system is not working properly according to its specified performance.

The company Enator Telub AB has developed various generations and versions of radar testing equipment. In order to verify the accuracy of a radar station, an independent sensor able to measure the positions of the target with an inherent higher accuracy than the radar is needed. The accuracy of a radar station is approximately some hundreds of metres. Therefore, the concept using relative GPS (Global Positioning System) was chosen for the latest version of our radar performance validation system, called the GPSREF system (cf. Figure 1).

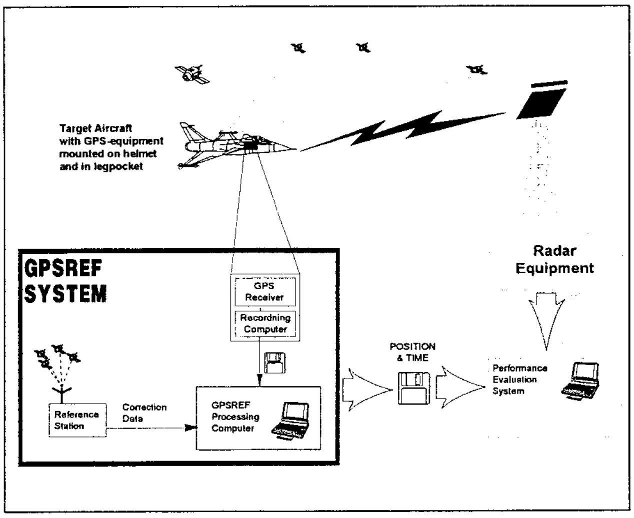


Figure 1. The GPS reference system for radar testing (GPSREF).

The project resulting in this concept was originally initiated by Försvarets Materielverk (Swedish Defence Material Administration) and was aimed for military purposes. However, it can, of course, also be used in other applications too.

During performance validation, the target aircraft, "the enemy", is equipped with a GPS receiver logging data during the flight. During the flight of the target aircraft, radar stations try to detect, locate and follow the aircraft. The computed positions of the two systems are compared afterwards in order to verify the accuracy in distance and bearing of the radar.

In order to verify the performance of radar stations, one would like to test the performance on different aeroplane types (it is not likely that a possible enemy would use only one type of aeroplane). Consequently, if one chooses to attach the GPS equipment to each different type of aeroplane, this would become very expensive and lead to a radar testing system being not very flexible. If one would like to attach for instance a GPS antenna to an aeroplane, there are several tests to be carried out by aviation authorities before it will certified for airworthiness, leading to high costs. Therefore, we developed the newest version of our GPS reference system for radar testing.

The GPSREF system for radar testing consists of three parts: a GPS logging system mounted on the pilot in the target aircraft, a ground-based GPS reference receiver, and software for the computation of target aircraft positions and for detailed statistical analyses of the data.

The mobile unit, or the pilot mounted GPS concept, consists of (cf. Figure 2):

> -GPS antenna mounted on the helmet of the pilot (fixed with Velcro bands).
> -leg pack, consisting of GPS receiver and a computer in a leather case on the upper part of the leg of the pilot
> -battery attached to the lower part of the leg of the pilot

Figure 2. Pilot mounted GPS concept.

During flight, the GPS data is stored on a PCMCIA RAM memory card by the logging software. Navigation and GPS control information is shown on the screen of the logging computer. The pilot has the possibility to choose among different navigation menus in the software during flight (*e.g.* distance, time and course to a specific waypoint, course, speed, signal-to-noise ratio for each satellite)(cf. Figure 3).

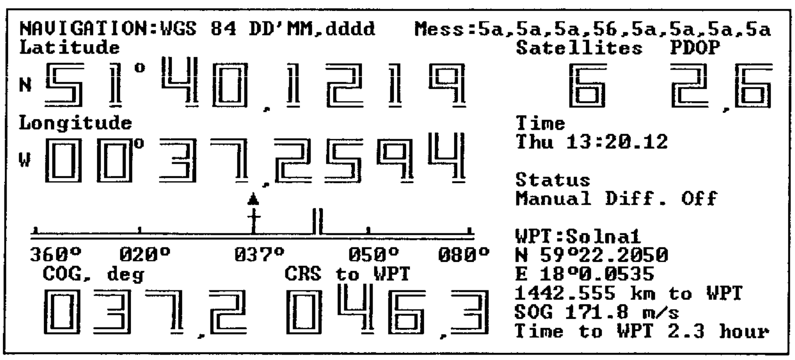


Figure 3. One of the navigation menus.

After the flight, processing of observed data is performed in the GPS post-processing software. The computed positions and information about different parameters are displayed on the screen and stored in a file for later comparison with the radar data (cf. Figure 4). In the post-processing software there are many facilities, *e.g.* co-ordinate transformation between many different geodetic datum is possible.

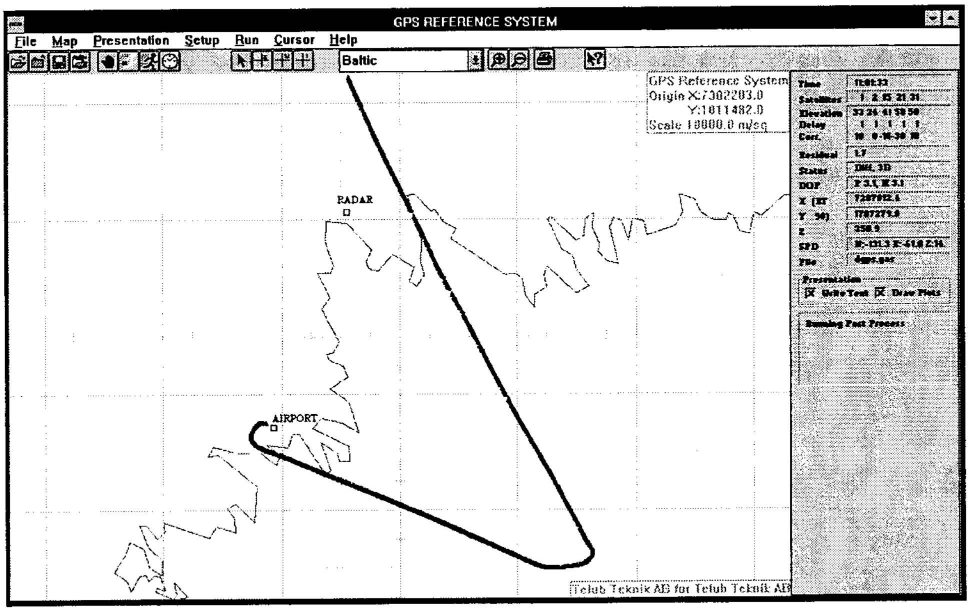


Figure 4. Post-processing software window.

Statistical analysis is performed in the post-processing software. Plots from the output of the tested radar data are normally recorded by our RADAC system. The radar plots are analysed, using the GPS reference files, in the RADAC software. Our software provide various statistics about the GPS and radar data, e.g. speed, altitude and bearing error statistics, relative accumulated diagram (cf. Figure 5).

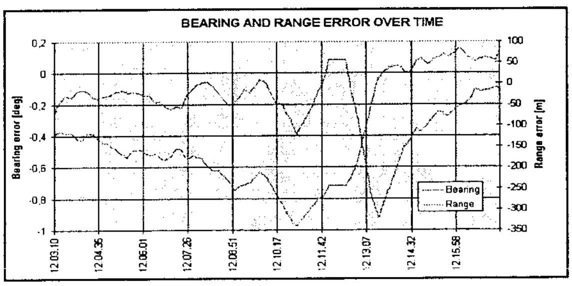


Figure 5. One example of the output from the statistical analysis software showing bearing and range errors over time.

An important basis for the successful use of reference data, no matter what kind, is the accurate time tagging of the radar data as well as of the reference data. Therefore, we use a separate GPS clock for the time tagging of the radar data. Before this use, it was not possible to determine the time delay within the radar system, leading to time synchronisation errors in the validation system, which is hereby overcome.

The pilot mounted GPS concept is certified for airworthiness for the Swedish Air Force, which has given us the opportunity to sell our concept to customers in other countries, e.g. Royal Air Force in United Kingdom (UK) and the Civil Aviation Authority in UK.

One Year Experience with DGPS Correction Dissemination by use of Long Wave Transmitter

František Vejražka, Jan Fišer, Libor Seidl, Jiří Plášil
CTU Prague

Technická 2, 166 27 Praha 6, Czech Republic
tel.: +420 2 2435 2246
e-mail: VEJRAZKA@FELD.CVUT.CZ

In Warsaw we presented a paper [1] about the Czech Technical University Project of a DGPS reference station. We mentioned our first results there. Now, we will are going to summarise our experience with its one-year operation.

The Czech Technical University (CTU) Reference Station (Fig. 1) is based on three GPS receivers:

1. Leica MX9400R receiver
2. Trimble GPS Pathfinder Community Base Station
3. Novatel GPSCard 951R in 486 PC computer

The Leica receiver is the core of the reference station and produces corrections which are disseminated wireless. The Trimble receiver generates corrections for postprocessing; it backups Leica also. The Novatel Card is our first – and rather obsolete now – receiver that backups both receivers mentioned above.

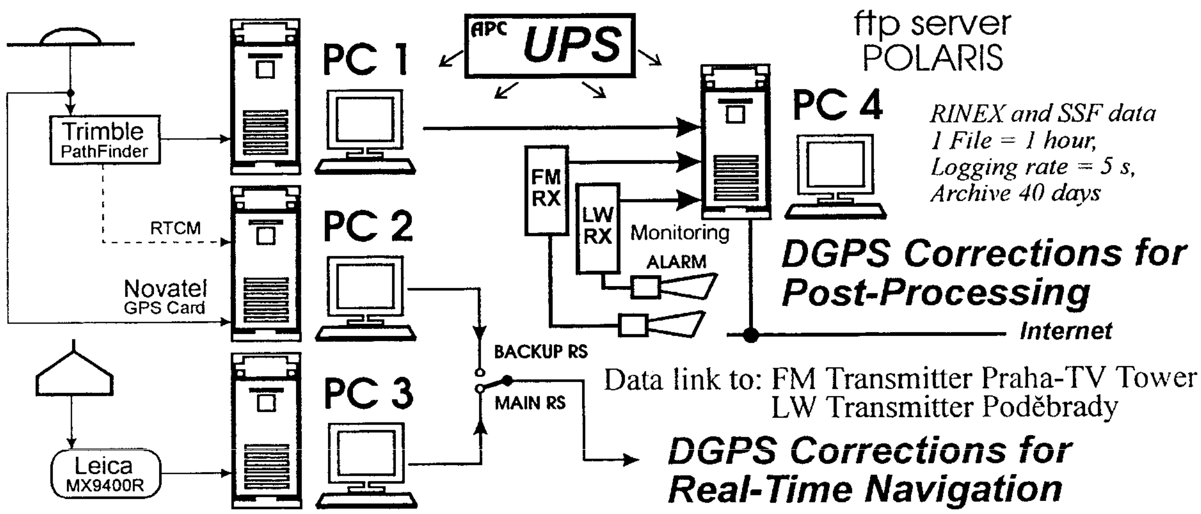


Fig. 1: CTU Reference Station Structure

DGPS corrections are recorded in our Reference Station for postprocessing, too – every hour a record of corrections is saved. Records of last 40 days are stored on a disk. Users can obtain them on diskettes or by the Internet.

Corrections are broadcast with one-second step in real time by

1) VHF R(B)DS channel and
2) LF channel

Correction Dissemination by VHF RDS Channel

The data of pseudorange measurements made by Leica receiver are transformed into a format similar to the NRSC format and transmitted by a microwave link to the TV tower. Correction data are then encoded into an RDS data stream of the FM radio station Regina 92,6 MHz. ERP of the transmitter is 5 kW. Corrections cover Prague and it's near surroundings.

LF Channel

The same corrections modulate a LF transmitter in Poděbrady (Fig. 2) - a small town 50 km east of Prague. The transmitter works on frequency 111.8 kHz with a bit rate of 500 bps. The transmitter output power is 80 kW. It is backupped with a 5 kW standby transmitter. The corrections are placed into 60 bit frames. FEC is provided by CRC code (60, 41).

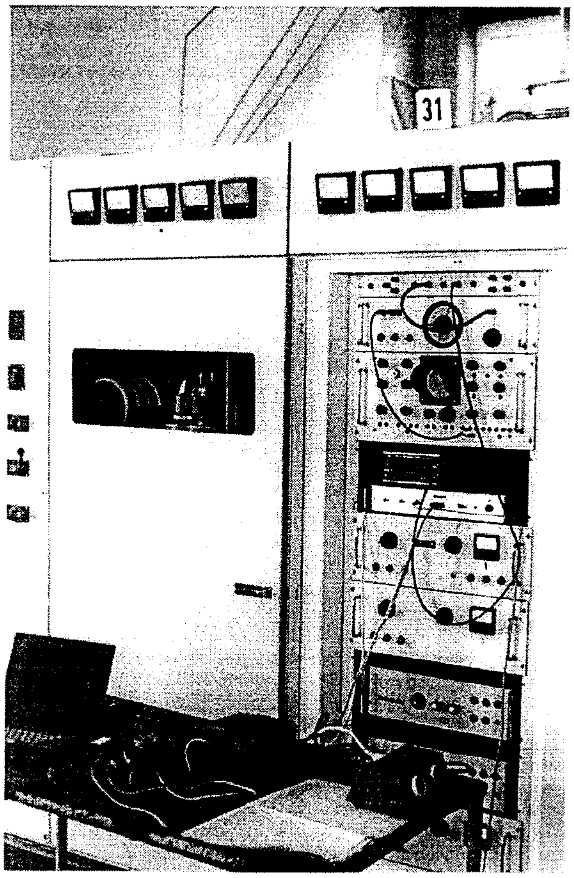


Fig. 2: Poděbrady Transmitter DGPS Modulator

We have designed and produced receivers for both LF and VHF channels (Fig. 3). They receive signals, prove message parity and ignore frames with detected errors. At the output of the receiver there are corrections in RTCM 104 format.

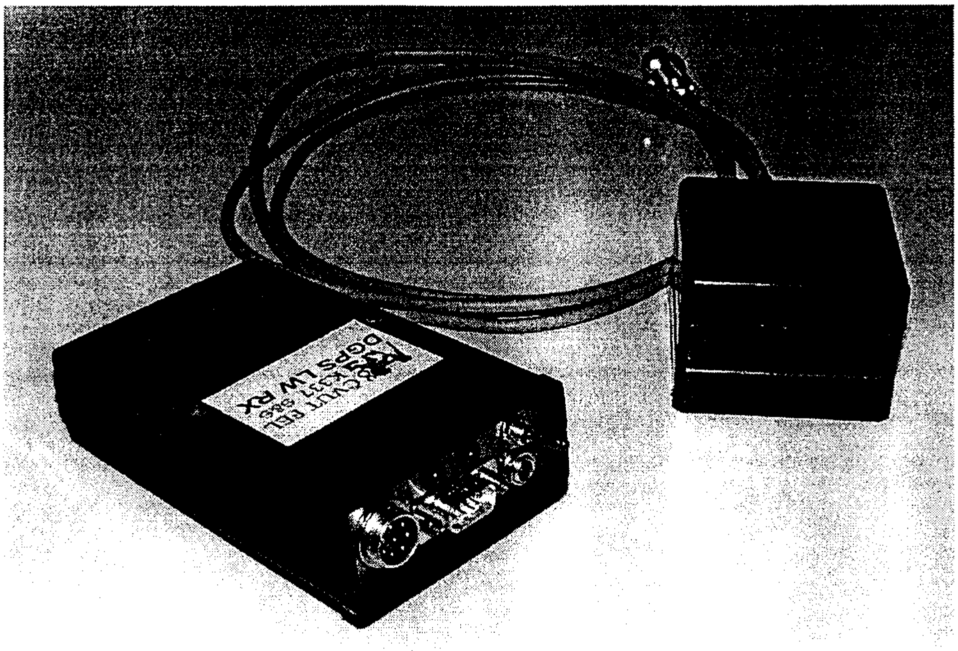


Fig. 3: User LF Receiver of DGPS corrections

You can see how our reference station covers the Central Europe in map Fig. 4. Flags mark places where we tested our corrections- unfortunately with various GPS receivers.

Fig. 4: Map of Coverage of Central Europe

We observed that the precision of position determination depends first and foremost on quality of the GPS receiver. We obtained 2D precision (95%) approximately 0.76 m in Prague and its vicinity. We also tested our corrections in larger distances. Deutsche Telecomm did experiments on the Baltic coast and reported us that precision was about 6 meters. The Czech Army SFOR troops tested LW DGPS receiver in Bosnia with 3 – 6 m precision. We did successful experiments in Netherlands Noordwijk but we could not assess precision there. Our colleagues from Poland did some experiments, too.

In the present time The Czech Army is testing receivers connected with high quality GPS receivers. The obtained precision is 20 centimetres – but with 50% probability.
Because of lack of financial means we transmitted DGPS LW corrections only two days a week. Altogether the reference station operated for more than 1 500 hours (Fig. 5). Total availability of corrections 99.7% is of very good level when we take into account that the transmitter was not backuped.

- LW System Operated Regularly since SEPT 97
- Since JAN 98 Operated Mon-Fri 8 hours a day
- JAN 98 - SEPT 98 More than 1500 Operating Hours
- Total Availability of DGPS Corrections: 99.7%

	Time of all D-outs	Average Time of D-out	Proportion
Ref. Station	52 minutes	4 minutes	16.4%
Data Link	59 minutes	12 minutes	18.6%
LW TX	207 minutes	17 minutes	65.0%
Total	**318 minutes**	**11 minutes**	

1500 hours Analyzed, Incl. Back-up Data Link

Fig. 5: Statistics of LF System Operation

What is the future of our reference station? Ministry of transport of the Czech Republic is interested in use of LW corrections for position determination of trains on regional railways. Ministry of Defence promised a support, too. Therefore we hope to be in air in the next year. We think that the LW technology of correction dissemination is the promising one for countries of former Soviet block because there are several unused LW transmitters on their territories and this technology does not request big investments.

Next year we want to transmit the GLONASS corrections to provide Ashtech GG 24 users with them.

CGSIC IISC meeting, Gavle, Sweden, December 4, 1998

Reference:

[1] Vejražka, F.: Long Wave System of DGPS Correction Dissemination in the Czech Republic. Proceedings of the sixth CGSIC International Information Subcommittee European Meeting. Polish Academy of Sciences, Committee on Space Research. Warsaw, 11. – 13. 12. 1997

Nordic Institute of Navigation

1. The Institute has about 300 members in the Nordic and the Baltic countries. In Sweden we have about only 50 members.
Our goal is to increase the number of members.

The board consists of representatives from the authorities in the Nordic countries
Among them we have the general director for the Board of Civil Aviation on Island Thorgeir Pålsson.
I myself have been the president since May this year, I have my background in the navy but also experience as a pilot.
From Sweden we also have Rolf Zetterberg from the Technical Department in The Swedish Maritime Administration. He is our vice president.
We have a General secretary he is a Norwegian by name Moritz Askildt. He is from the Norwegian navy and has for o long time been working with GPS in NATO.

2. Our main task is to cover the development in navigation on land as well as on the sea and in the air and inform our members about the ongoing development. NNF therefore issue a member newspaper, with 4 numbers every year.

3. NNF is a member of EUGIN, The European Union Group of Institutes of Navigation. In EUGIN there are 8 institutes. The biggest institute is RIN, with 3500 members.
Great in this connection are also IFN, NIN, DGON and IIN.

Several of these Institutes are connected to some University and take part in different ways in the European navigational development.

Through our participation in EUGIN we have the possibility to get information's and we also try to influence the development with remarks on different papers, that is sent to us from the EU council.
Of great interest just now is, if the the EU commission are going to take the decision about the European navigation satellite system, GNSS 2 and if it is going to be fulfilled.

NNF is also a member of IAIN, The International Association of Navigation.

4. One of NNF:s tasks is to arrange conferences. Earlier NNF have arranged conferences, on GPS, education and security for HSS-fairies.
NNF will during 1999 arrange two conferences. The first in May on maritime education, called MARED 99 in Göteborg the 21 to 22 of April. This Conference is arranged together with Sjöfartsforum and the Maritime School at CTH in Göteborg.
The NORNA conference is arranged every three year in co-operation with our Swedish RNN. The last time we had the NORNA was in Island 1996.

This time we will arrange NORNA on the Vikingline´s Mariella on her way between Stockholm and Helsinki the 23 - 25 of November.
We hope we will get as good success as in 1993 when we had the NORNA conference in Mariella.

5. There are possibilities to get information and to influence the development in the nautical area.
It is then of great importance to have a powerful institute with many members behind.
We have in Sweden at present few members but we relay in all of you, who are interested in this field to support the institute and join us as a member in NNF.

The price per year is only 400 NKR, which can be paid according to information in our recruiting brochure.

That member fee you can easily earn if you are going to any of the many international conferences in the world, where you get reduction on the conference fee.

YOU are all very well come.

GPS IN THE SWEDISH NATIONAL FOREST INVENTORY

Härje Bååth
Department of Forest Resource Management and Geomatics, Swedish University of Agricultural Sciences, 901 83 Umeå, Sweden. Phone +46(0)90-7866352. Fax +46(0)90-141915. E-mail: Harje.Baath@resgeom.slu.se

Abstract

DGPS is used in the Swedish National Forest Inventory since 1996. The Swedish NFI is a System for Monitoring Forests and Environment in Sweden. About 10 000 plots are located every year by GPS in order to combine field data and digitized data, foremost satellite data. The technique used is DGPS with post-processing

The Swedish NFI

The Swedish National Forest Inventory is a System for Monitoring Forests and Environment in Sweden.

The Objectives of the NFI are

"To continuously supply analysed data for strategic planning of forestry utilisation on a regional level as well as for the whole country. It shall also supply data for forestry research. . The analysed data shall give information about present state and changes."

The NFI

- An annual systematic cluster sample inventory
- Comprises all land and ownership categories
- Covers the whole country every year
- Records
    - the state of forests
    - forestry measures
    - changes in the environment

* Has been carried out since 1923 by:
The Department of Forest Resource Management and Geomatics.
The Faculty of Forestry
University of Agricultural Sciences
Umeå

Users of results

Government and governmental authorities
Forest companies
The Forest Farmers Association
The Forest Service Organisations
Forest researches

Presentation of results

Public statistcs
Articles
Other publications

Special assignments

Participation in strategic state reports
Special analysises on request from users

Why GPS in the Swedish NFI

Since some years ago a project is ongoing at the department aiming at developing an inventory and estimating method where you combine satellite data and field data from plots in the Swedish NFI. First of all the idea is to use satellite data, but it will also be possible to use other digitized data, such as maps.

An integration of remote sensing data in the NFI would:
* Increase the estimation accuracy for many variables
* Provide estimates with a total geographic cover
* Increase the possibility of estimating changes,
* Allow the presentation of results of high current interest

A key factor in this integration is that the satellite data are adapted to grid coordinates and the location of the field plots is correct.
Therefore the plots in the Swedish NFI are located using GPS techniques since 1996. That means that 18 field teams are using GPS-equipment. Before then we tested the technique with different GPS receivers during some years.

Post-processed Differential Correction

The number of plots to be located are about 10 000 every year. The demand for the accuracy of the GPS position was less than 10 m. To get that accuracy it is necessary to use differential corrections. We decided to apply post-processing. And as we are doing the inventory over the whole country we have to use basedata from all the twenty-one base stations in Sweden, from SWEPOS.
There are many reasons why we decided to use post-processing.

1. As we are working over the whole country there are many places where you can't get real-time base station data, especially in the far north of Sweden where it can be long distance to the nearest radio transmitter.

2. Another problem is hilly terrain.

3. Inconvenient equipment

Equipment

The demands for the equipment used was that it should withstand the rigours of fieldwork. It should also be possible to apply differential GPS corrections both in real-time and as post-processing using basedata from EPOS or SWEPOS.
The equipment that in that time best carried out our demands was Trimble GeoExplorer.

Collecting Data

When we are collecting GPS data the GPS receiver is laying on the ground in the centre of the plot. We collect 40 position fixes. And if you haven't got any position after about three minutes you may move the GPS receiver. Often it is enough to move the GPS receiver within a metre. If you have to move it more than a metre you have to record the distance and the direction from the centre of the plot to the GPS receiver. That gives us the possibility to correct the position of the GPS receiver.

Post-processing

Every field crew once a week sends floppydisks with the collected positional data to the department in Umeå.
At the department we every night get SWEPOS data from the National Land Survey in Gävle. When the inventory is finished in October we differentially correct the GPS data and average to increase the accuracy.
Rover data are differentially corrected with base station data within a distance of 200 kilometres from each plot. That means that most plots are differently corrected with data from two or more base stations. The station with the lowest standard deviation is then chosen. In connection with the corrections the coordinates of the plots are transferred to the Swedish datum RT 90.
The programs used are developed by Thorbjörn Cruse The Department of Forest Resource Management and Geomatics.

Storing of data

The corrected data with coordinates in the Swedish datum RT 90 are stored in the same database as the other data collected in the NFI. Besides the coordinates the PDOP, number of registrations and standard deviation are stored as a form of quality declaration of the data.

Experiences

The experiences from collecting data in field are good although we have had some problems with the equipment.
The treatment of the flopy disks with the field data and the base data from SWEPOS has functioned very well despite of a large number of data.

On about 12 % of the plots we didn't get any positions. The reasons were not enough satellites visible in 53 % of the cases, too high PDOP in 40%.

Consider then that most of the plots were in the forest and that we didn't adapt the collection of GPS data to the best time.

GPS in Swedish Agriculture

Per-Anders Algerbo

Swedish Institute of Agricultural Engineering

P.O.Box 7033
S-750 07 UPPSALA
SWEDEN

Phone: +46 18 30 33 55
Fax: +46 18 30 09 56
E-mail: per-anders.algerbo@jti.slu.se

0233

Agriculture

GPS environment

- Almost optimal satellite visibility
  - large, open, and flat fields
- Only a few obstructions
  - tree avenues
  - forest borders
  - high voltage lines

Agriculture

- Most DGPS-receivers are used with 2 m accuracy
- Increasing precision to cm-accuracy according to new cultivating methods
- Differential signal
  - EPOS system
  - Coast Guard Beacon System
  - Private reference stations
  - WAAS (i.e. Racal)

0234

GPS in Swedish Agriculture

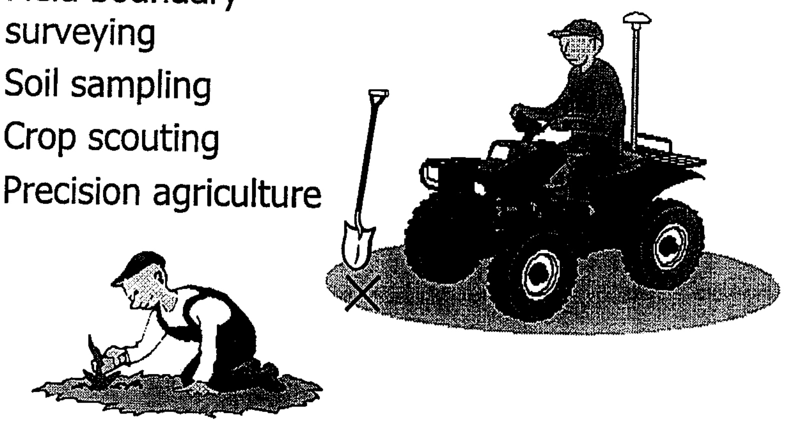
Users

- Farmers
- Advisors
- County-administrators
- Researchers and engineers

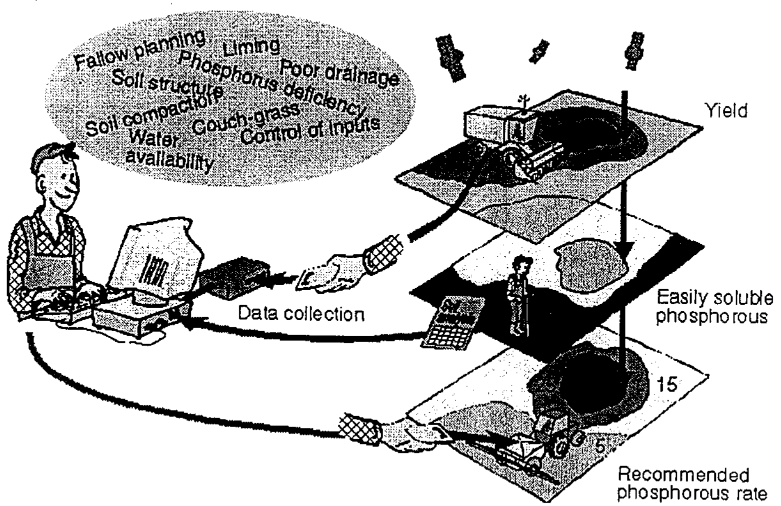
GPS in Swedish Agriculture

Field surveying

- Field boundary surveying
- Soil sampling
- Crop scouting
- Precision agriculture

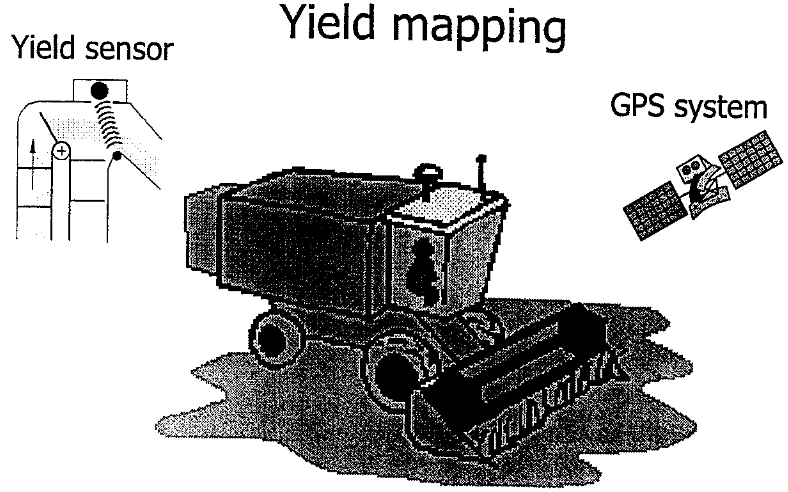


GPS in Swedish Agriculture



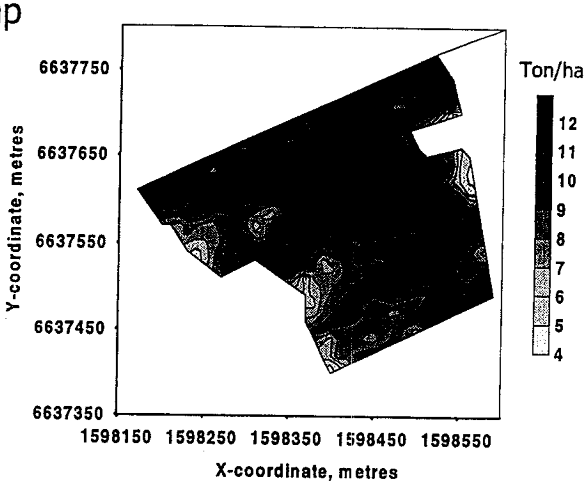
GPS in Swedish Agriculture

Yield mapping



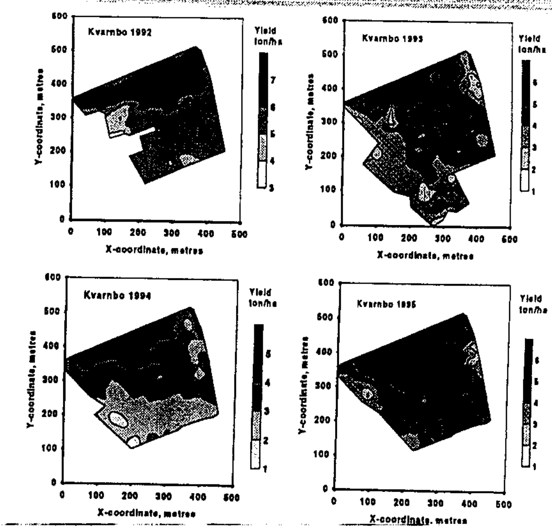
GPS in Swedish Agriculture

- Yield map



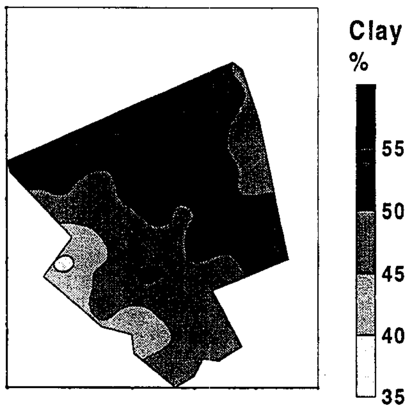
GPS in Swedish Agriculture

- Yield maps 1992-95



GPS in Swedish Agriculture

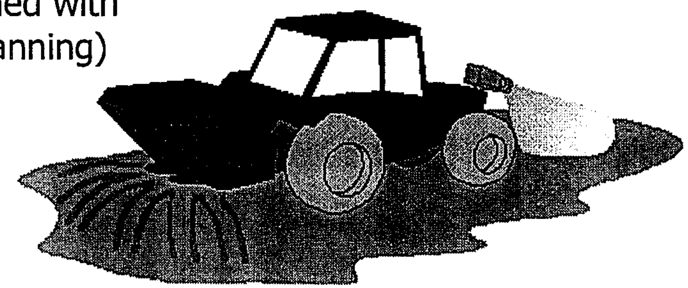
- Soil texture
  - clay content



GPS in Swedish Agriculture

Variable fertiliser application

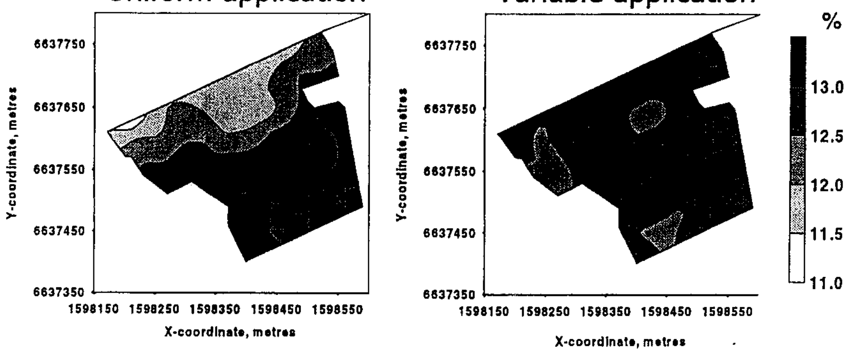
- Variable fertilising (combined with crop scanning)



0236

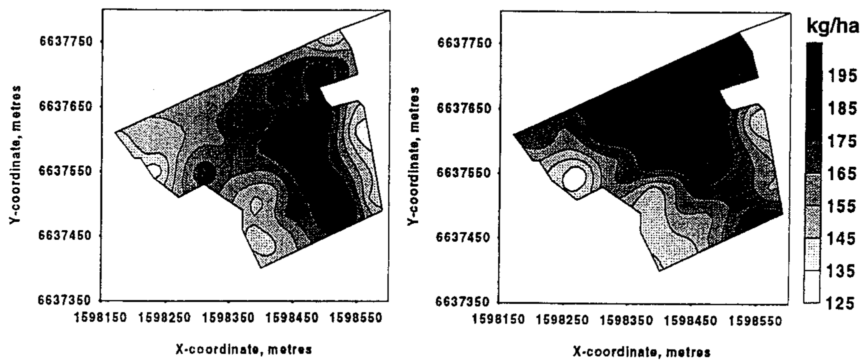
GPS in Swedish Agriculture

- Crop quality
  - protein content



GPS in Swedish Agriculture

- Nitrogen uptake



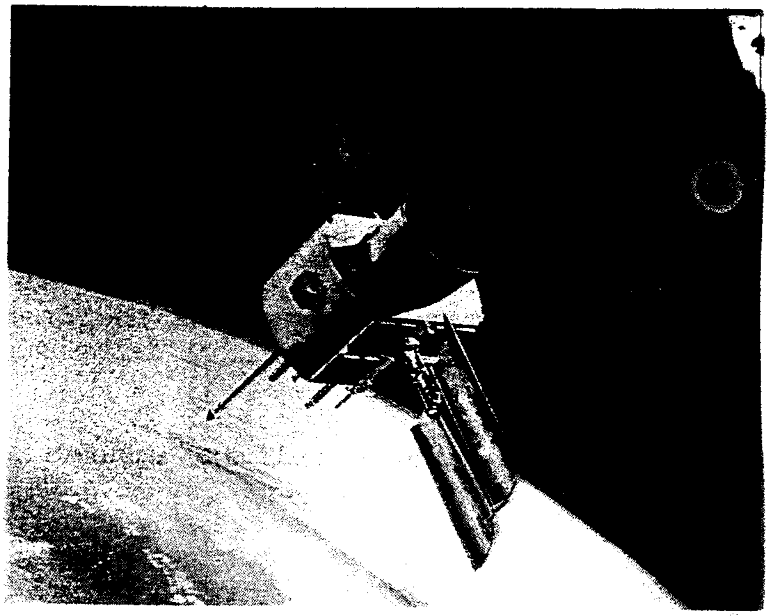
Five Years of Continuous Observations in the SWEPOS Network

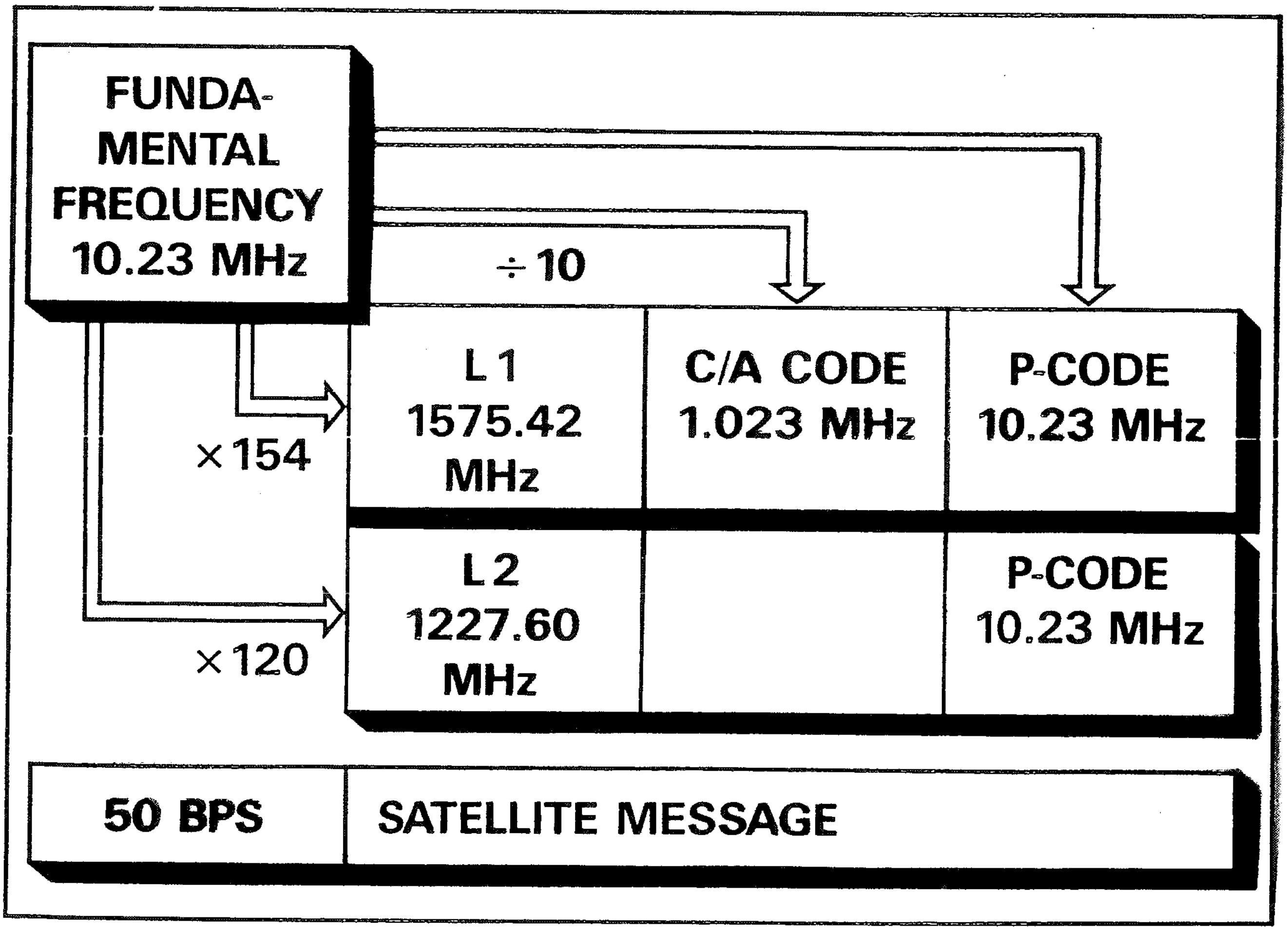
Jan Johansson
Onsala Space Observatory
Chalmers University of Technology
SE-43992 Onsala
E-mail: jmj@oso.chalmers.se

SWEPOS
Geodesy and Geophysics - BIFROST
Remote Sensing of the Atmosphere - BALTEX
High-Precision Navigation - CICERON
Time-Transfer - SP Swedish Nat. Testing & Research Inst.

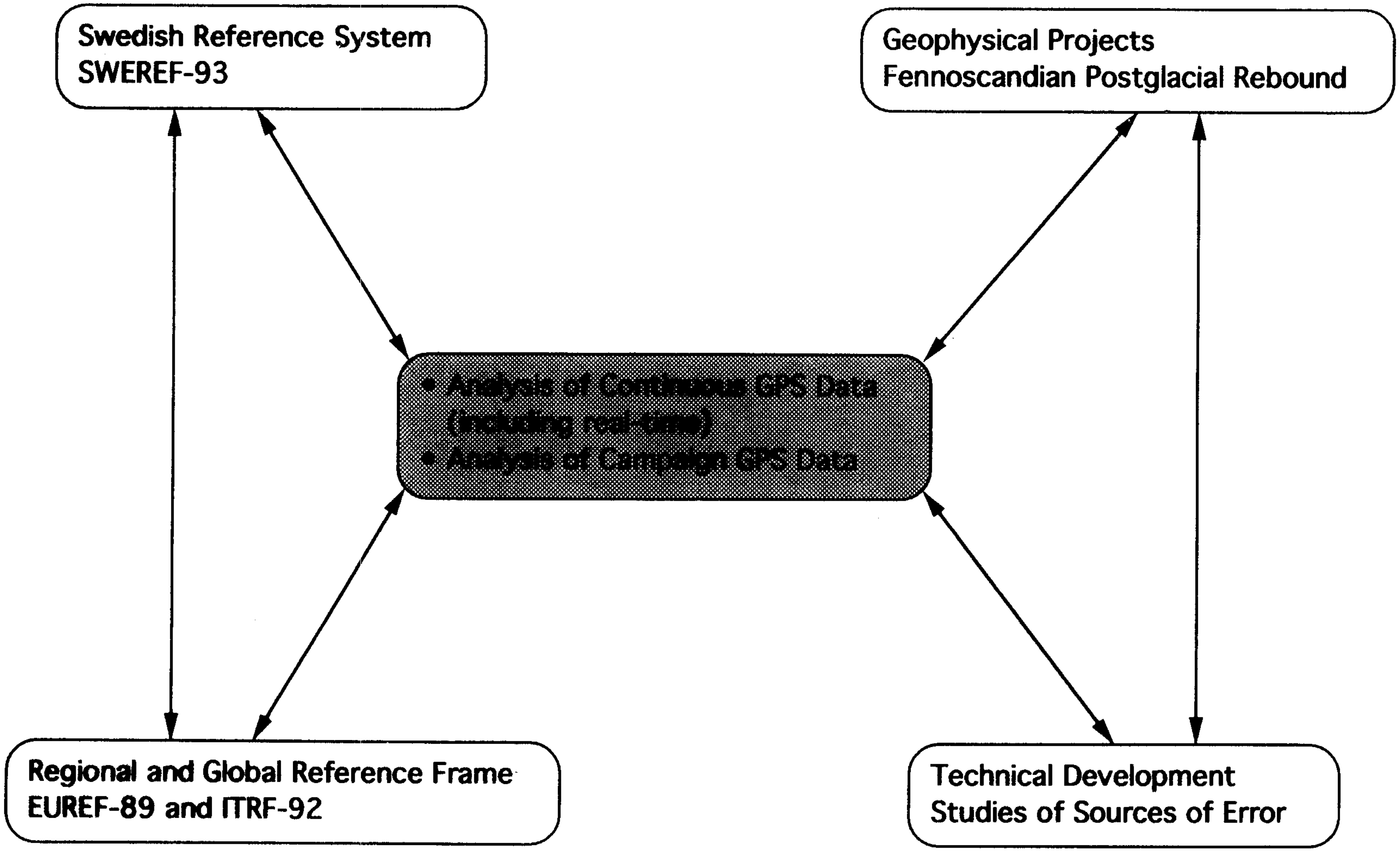
IISC-CGSIC
Gävle, 3-4 December 1998

SATELLITE SIGNAL



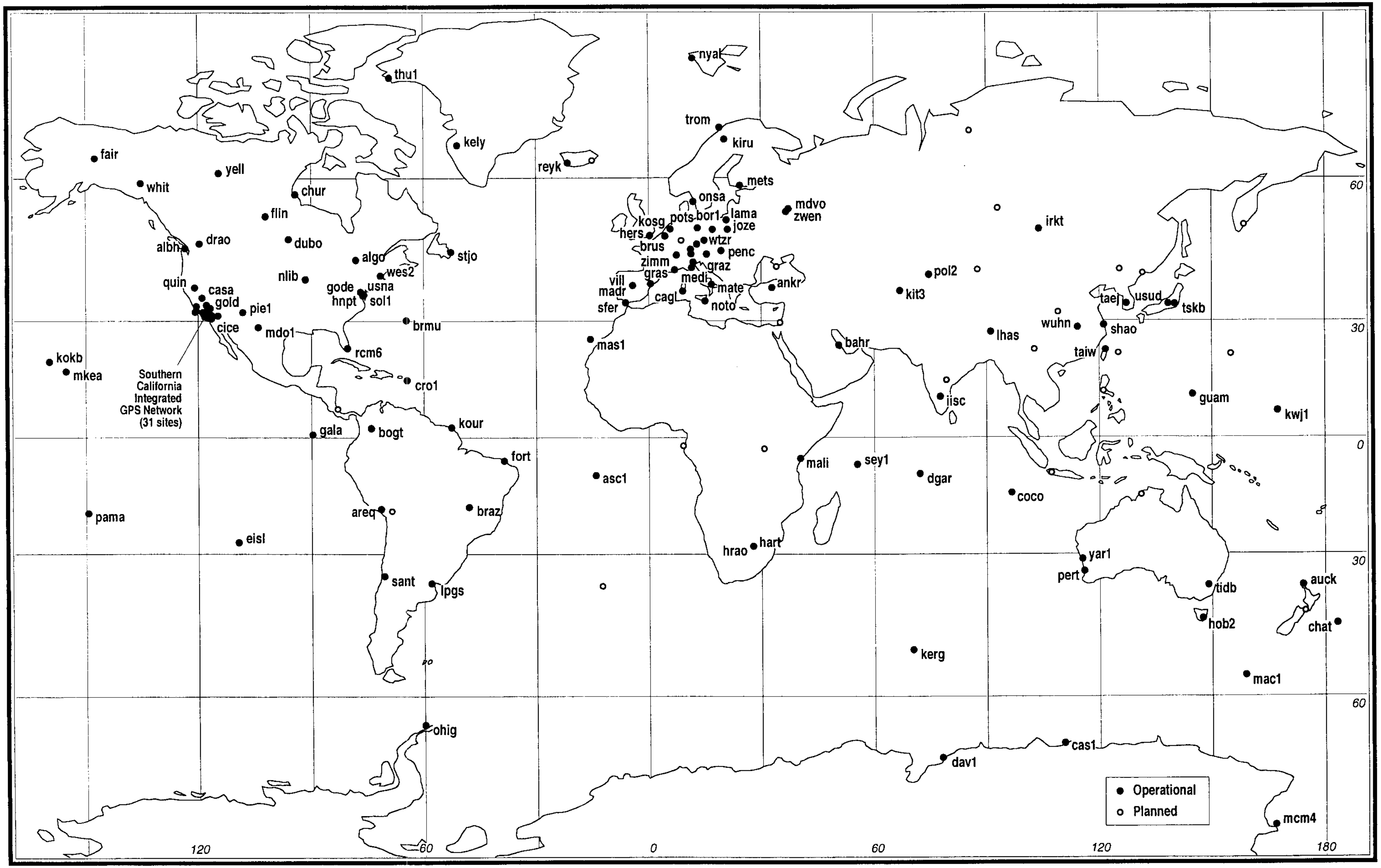


Geodesy and Geophysics: Links to GPS Analysis

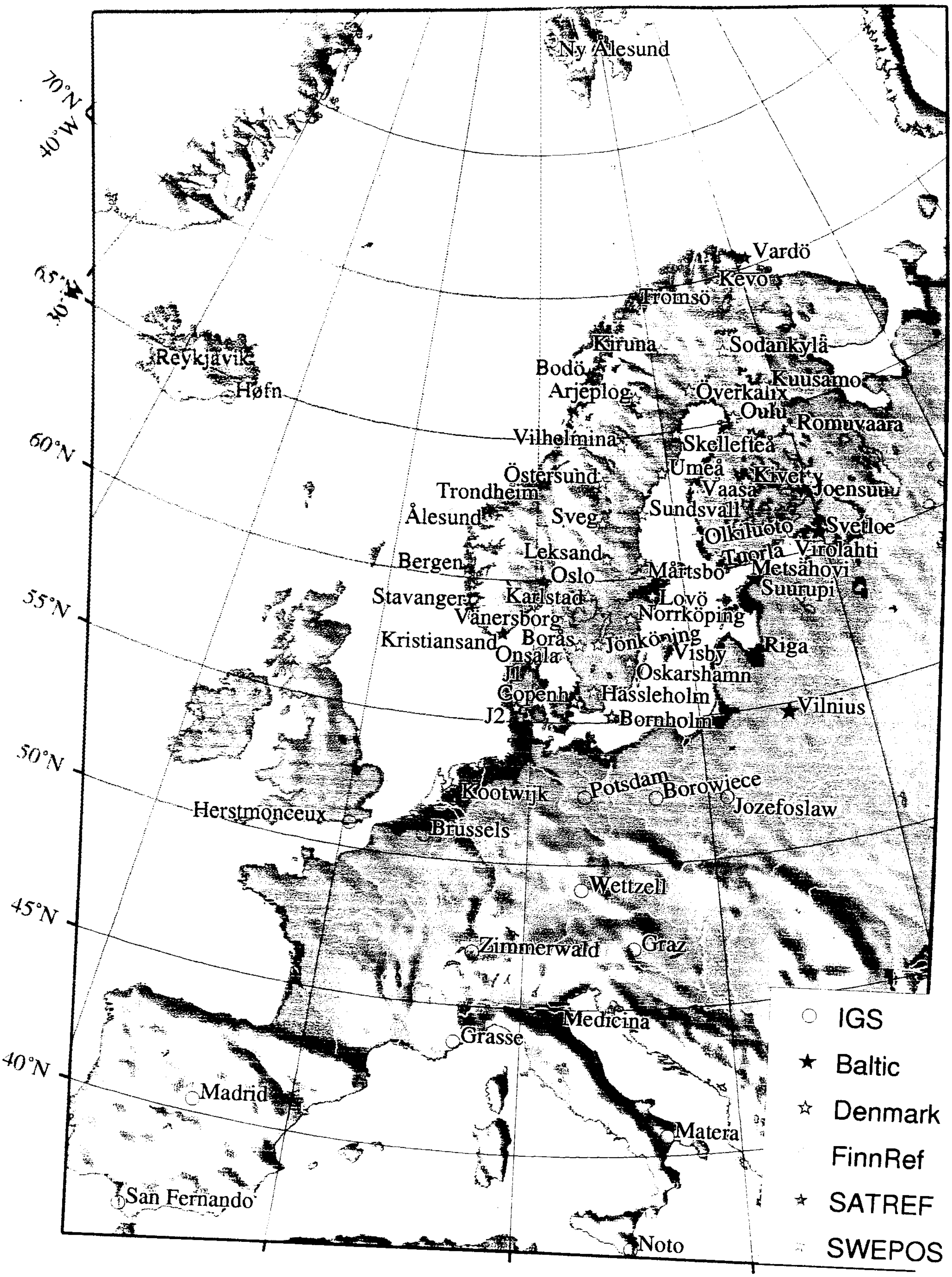


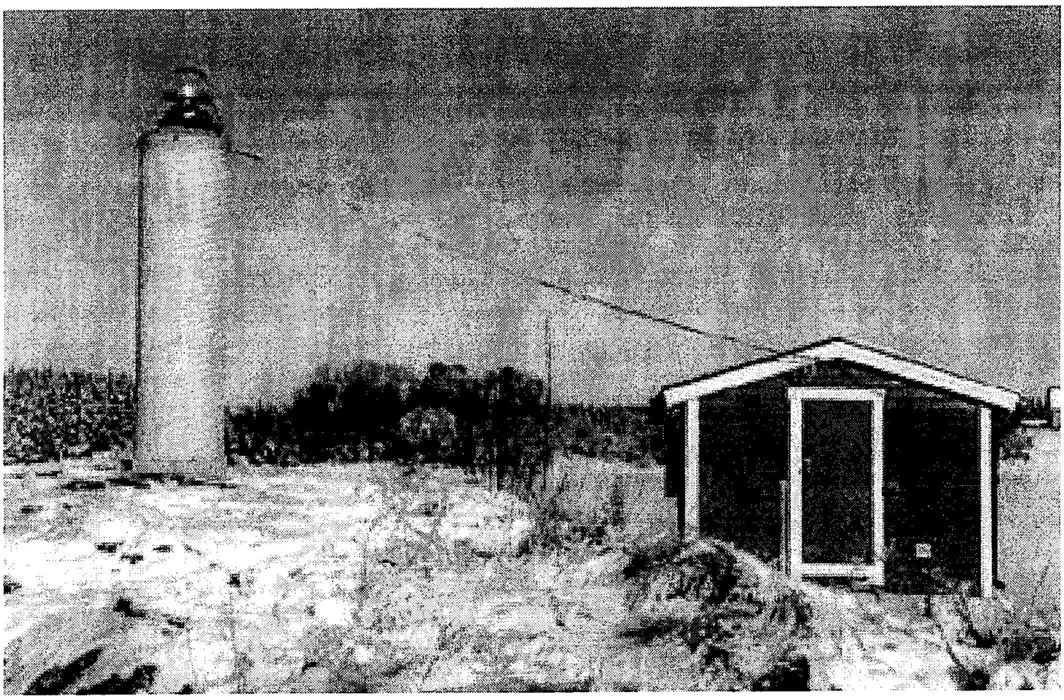
GPS TRACKING NETWORK

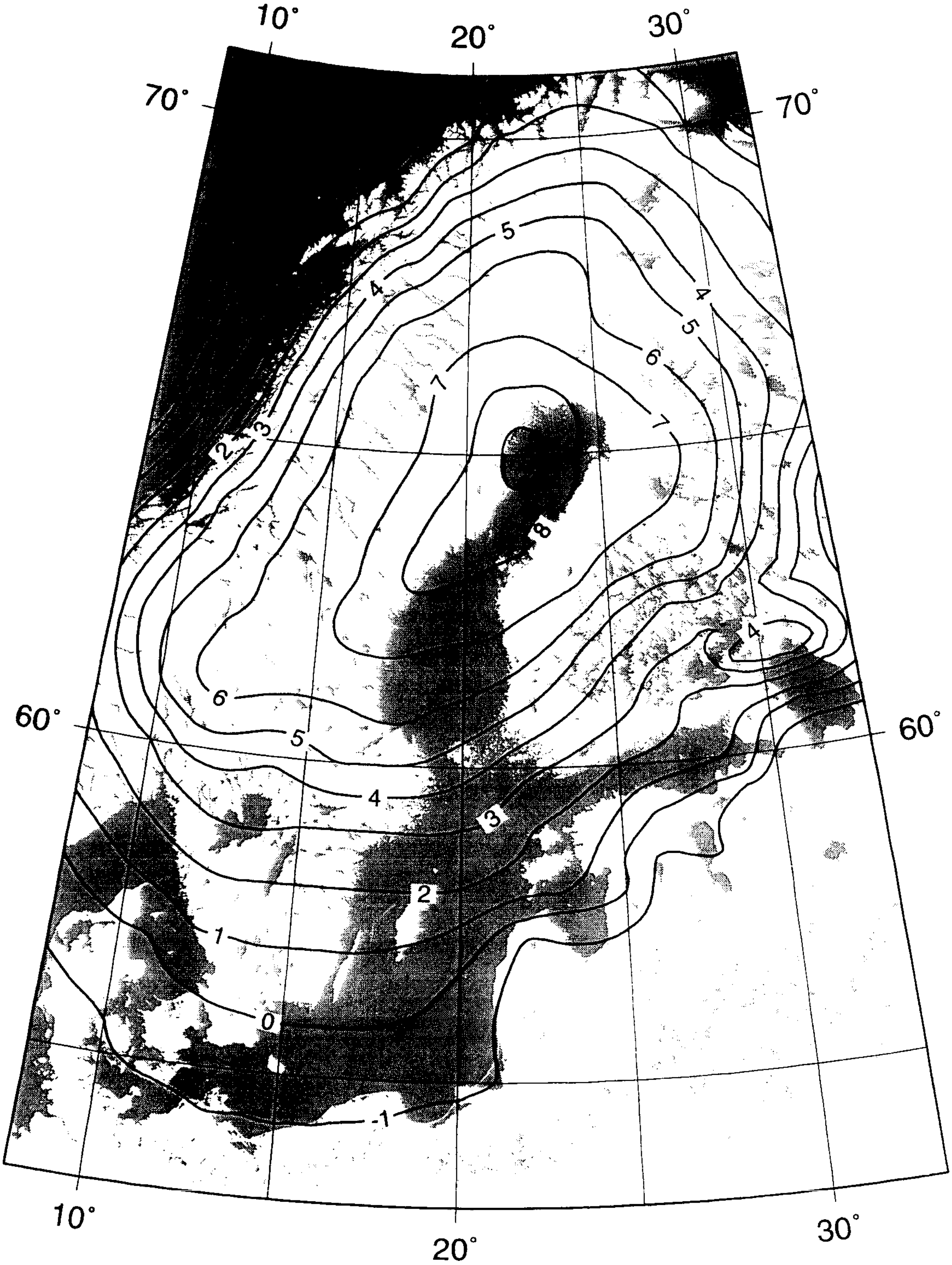
International GPS Service for Geodynamics

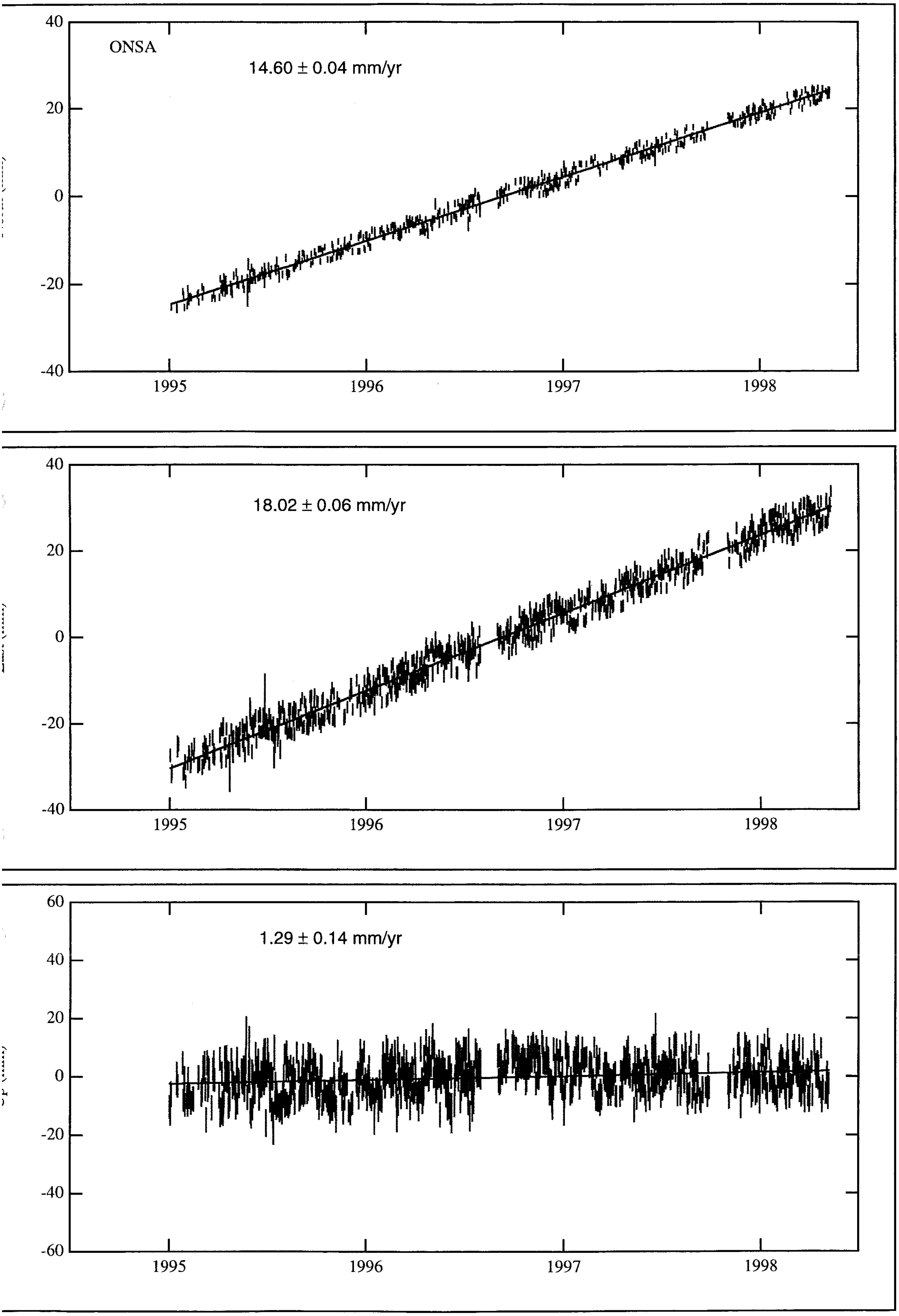


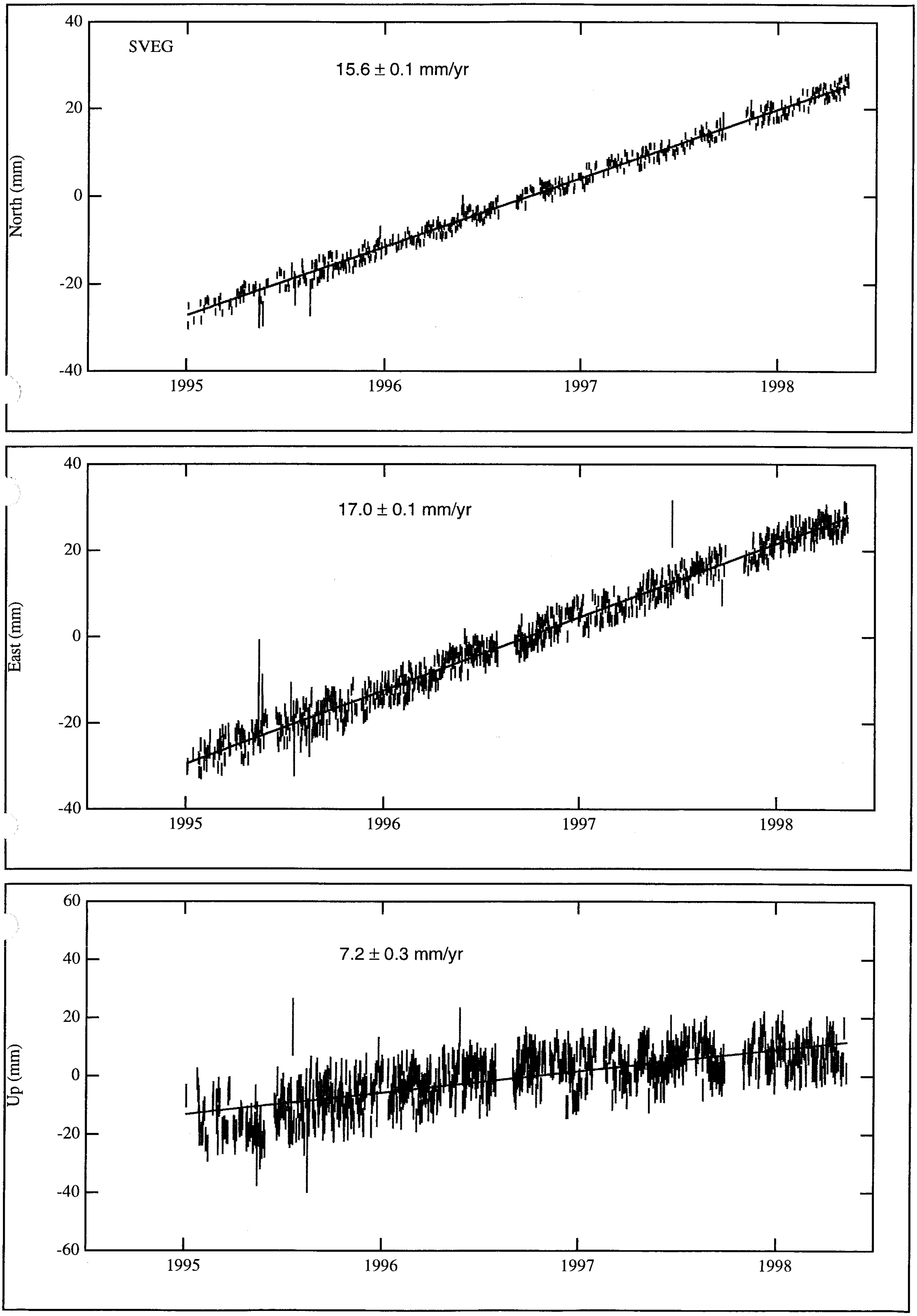
January 1997

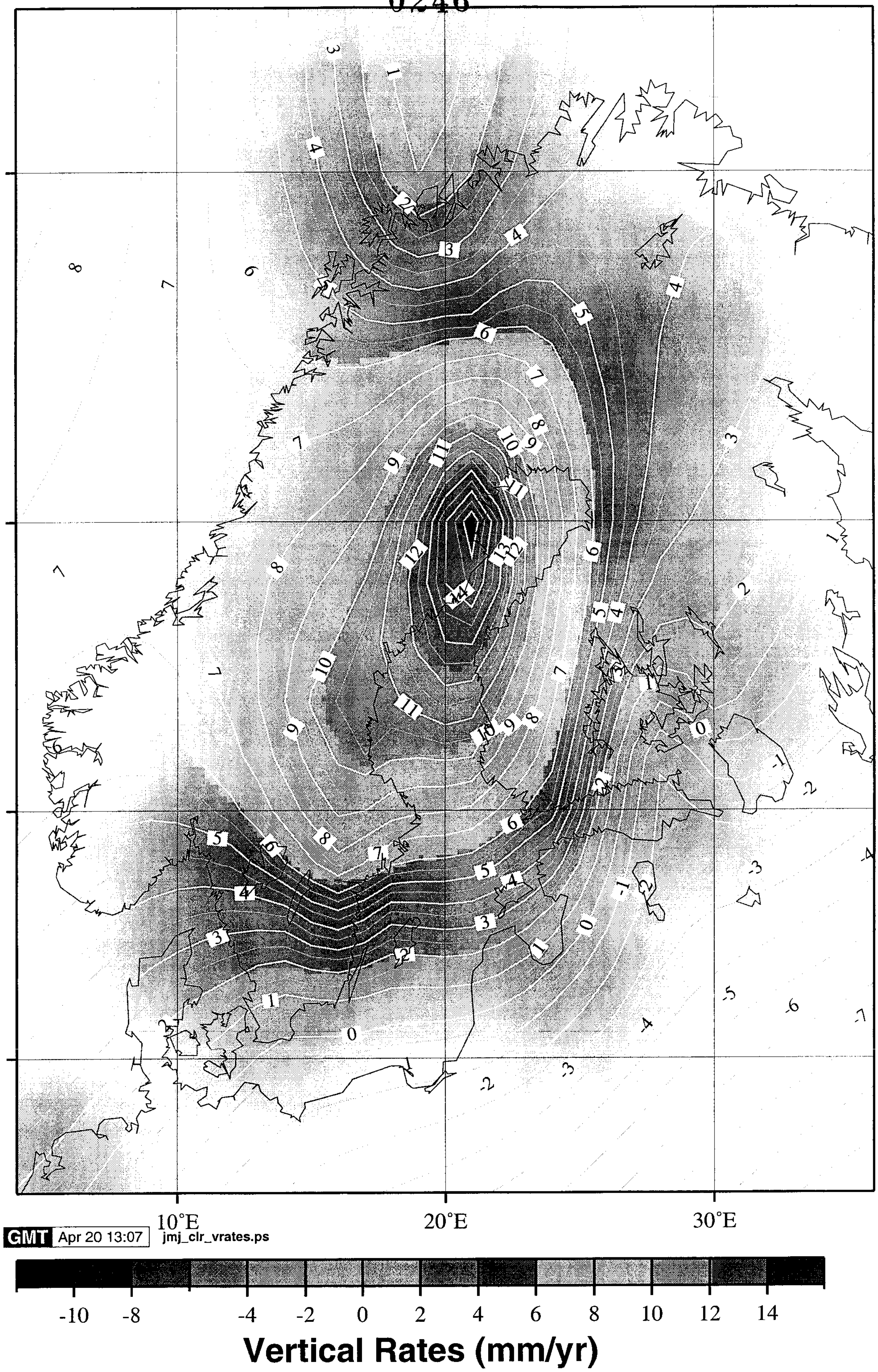

70°N
40°W
65°N
30°W
60°N
55°N
50°N
45°N
40°N
Ny Ålesund
Vardö
Kevo
Tromsö
Kiruna
Sodankylä
Reykjavik
Høfn
Bodö
Arjeplog
Kuusamo
Överkalix
Oulu
Romuvaara
Vilhelmina
Skellefteå
Östersund
Umeå
Kivetty
Trondheim
Vaasa
Joensuu
Ålesund
Sveg
Sundsvall
Olkiluoto
Svetloe
Bergen
Leksand
Tuorla
Virolahti
Mårtsbo
Metsähovi
Oslo
Suurupi
Stavanger
Karlstad
Lovö
Vänersborg
Norrköping
Kristiansand
Borås
Jönköping
Riga
Onsala
Visby
J1
Oskarshamn
Copenh
Hässleholm
Vilnius
J2
Bornholm
Kootwijk
Potsdam
Borowiece
Jozefoslaw
Herstmonceux
Brussels
Wettzell
Zimmerwald
Graz
Medicina
Grasse
Madrid
Matera
San Fernando
Noto
IGS
Baltic
Denmark
FinnRef
SATREF
SWEPOS




10°
20°
30°
70°
70°
60°
60°
10°
20°
30°
5
4
4
5
6
7
7
6
8
2
3
6
5
4
4
3
2
1
0
-1


ONSA
14.60 ± 0.04 mm/yr
40
20
0
-20
-40
1995
1996
1997
1998
18.02 ± 0.06 mm/yr
40
20
0
-20
-40
1995
1996
1997
1998
1.29 ± 0.14 mm/yr
60
40
20
0
-20
-40
-60
1995
1996
1997
1998


SVEG
15.6 ± 0.1 mm/yr
North (mm)
17.0 ± 0.1 mm/yr
East (mm)
7.2 ± 0.3 mm/yr
Up (mm)
1995
1996
1997
1998

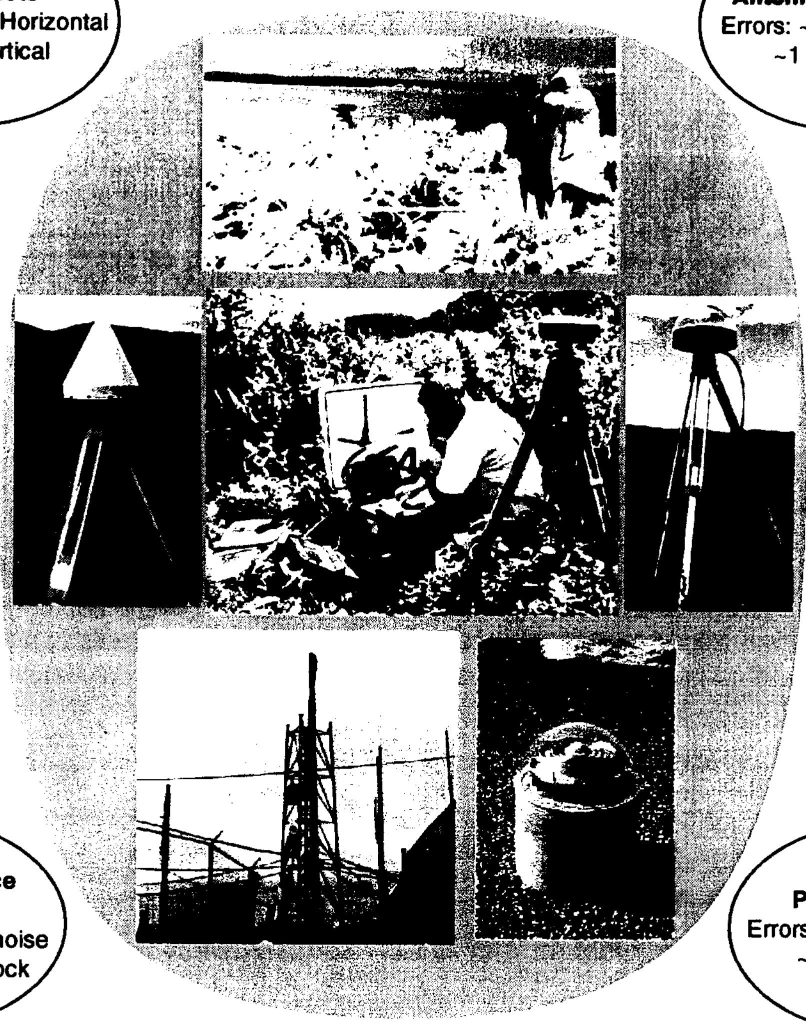

70°N
65°N
60°N
55°N
10°E
20°E
30°E
GMT Apr 20 13:07 jmj_clr_vrates.ps
-10
-8
-4
-2
0
2
4
6
8
10
12
14
Vertical Rates (mm/yr)

Equipment and Operating Environment Factors that affect Measurement Accuracy

Antenna Mixing
Errors: ~8 mm Horizontal
~90 mm Vertical

Snow Effects
Errors: < ~1 mm Horizontal
~40 mm Vertical

Antenna Consistency
Errors: ~3 mm Horizontal
~1 mm Vertical



Antenna Raydome
Errors: < 10 mm Horizontal
~30 mm Vertical

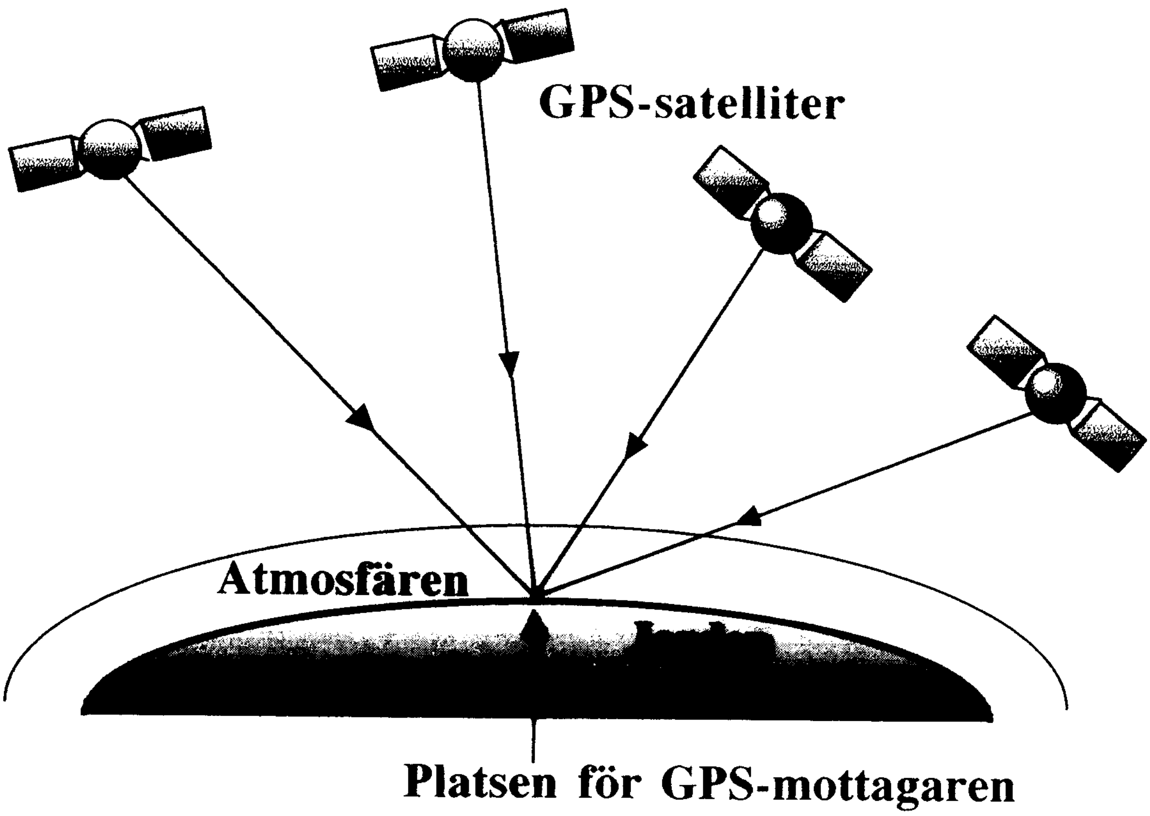
High and Low Antenna Setup Heights
Errors: < 1 mm Horizontal
~20 mm Vertical

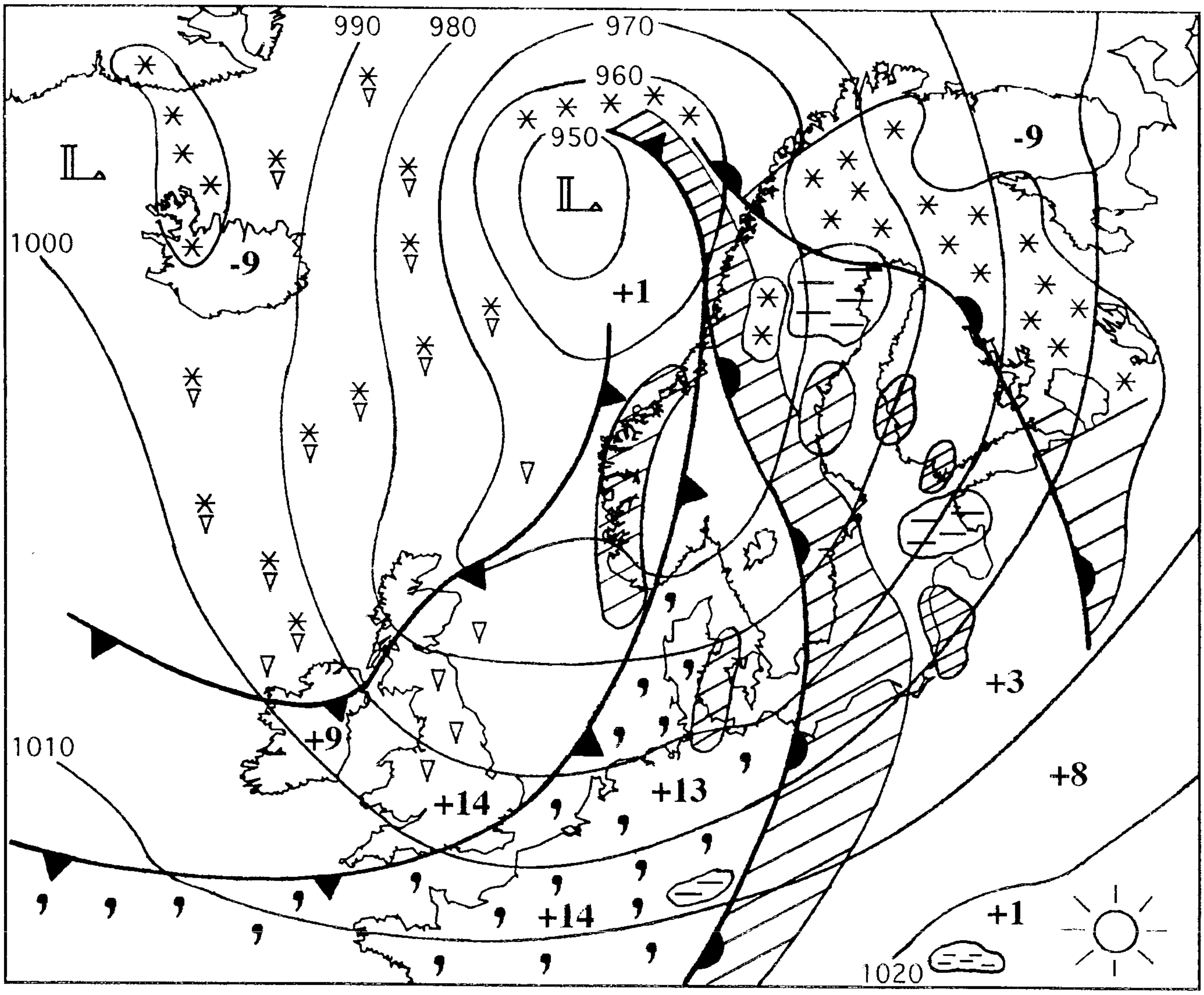
Radio Interference Problems
- Reduced Signal-to-noise
-Increased loss of lock

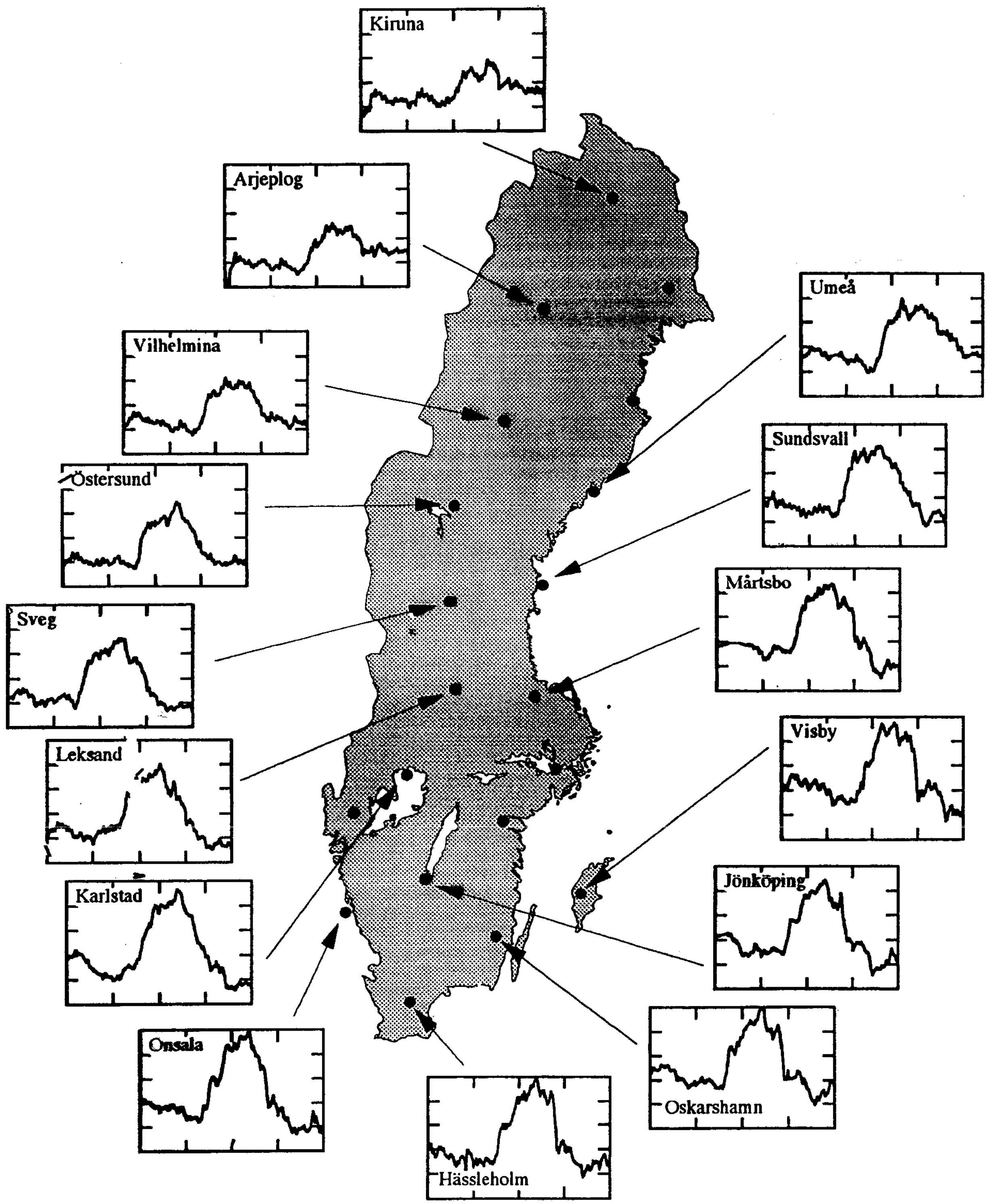
Pillar Scattering
Errors: < 1 mm Horizontal
~30 mm Vertical

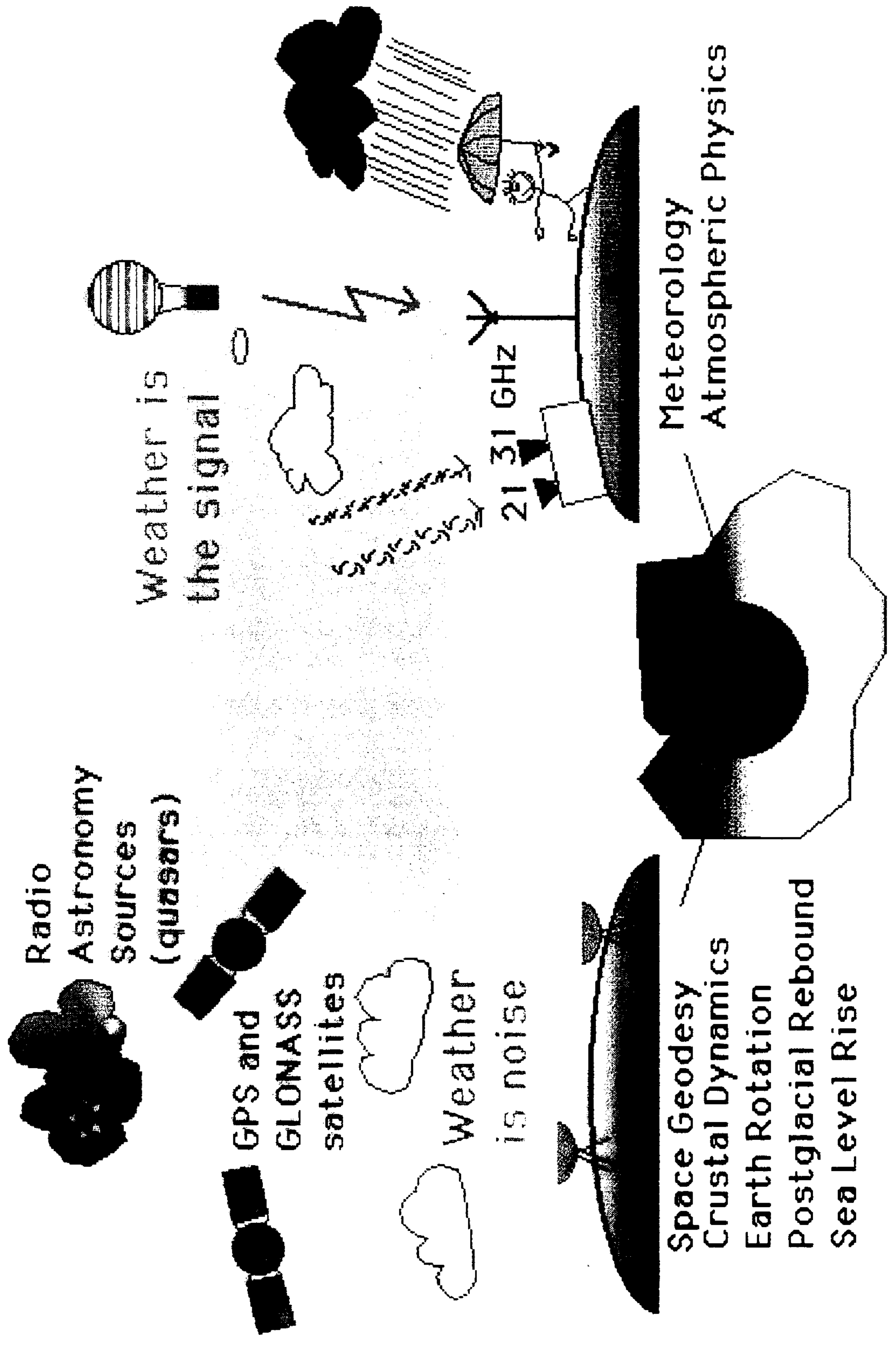
Monument Stability
Errors: Random walk noise, monument tilt

UNAVCO, March 1997

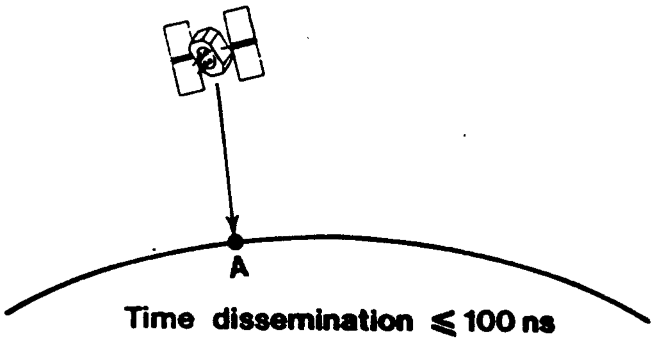

GPS-satelliter
Atmosfären
Platsen för GPS-mottagaren


990
980
970
960
950
1000
1010
1020
-9
+1
-9
+9
+14
+13
+14
+3
+8
+1

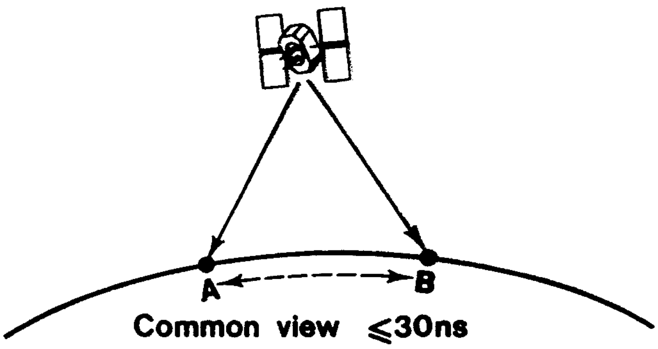

Kiruna
Arjeplog
Vilhelmina
Östersund
Sveg
Leksand
Karlstad
Onsala
Hässleholm
Oskarshamn
Jönköping
Visby
Mårtsbo
Sundsvall
Umeå


Radio
Astronomy
Sources
(quasars)
GPS and
GLONASS
satellites
Weather
is noise
Weather is
the signal
21 31 GHz
Meteorology
Atmospheric Physics
Space Geodesy
Crustal Dynamics
Earth Rotation
Postglacial Rebound
Sea Level Rise

Tidsmätning med GPS



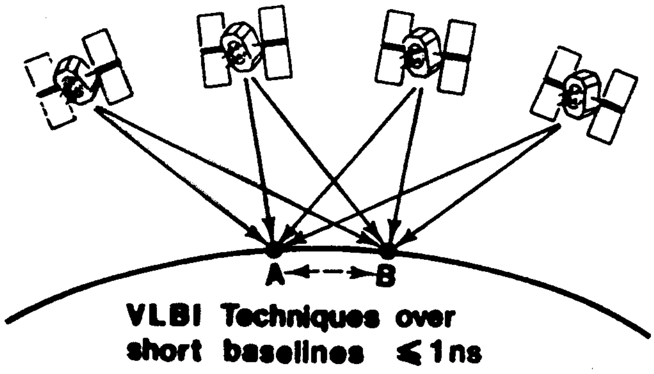
$$x_{\alpha k} = UTC(k)(t) - GPS(SV_{\alpha})(t)$$



$$x_{\alpha k1} = UTC(k1)(t) - GPS(SV_{\alpha})(t)$$

$$x_{\alpha k2} = UTC(k2)(t) - GPS(SV_{\alpha})(t)$$

$$x_{\alpha k1k2} = x_{\alpha k1}(t) - x_{\alpha k2}(t)$$

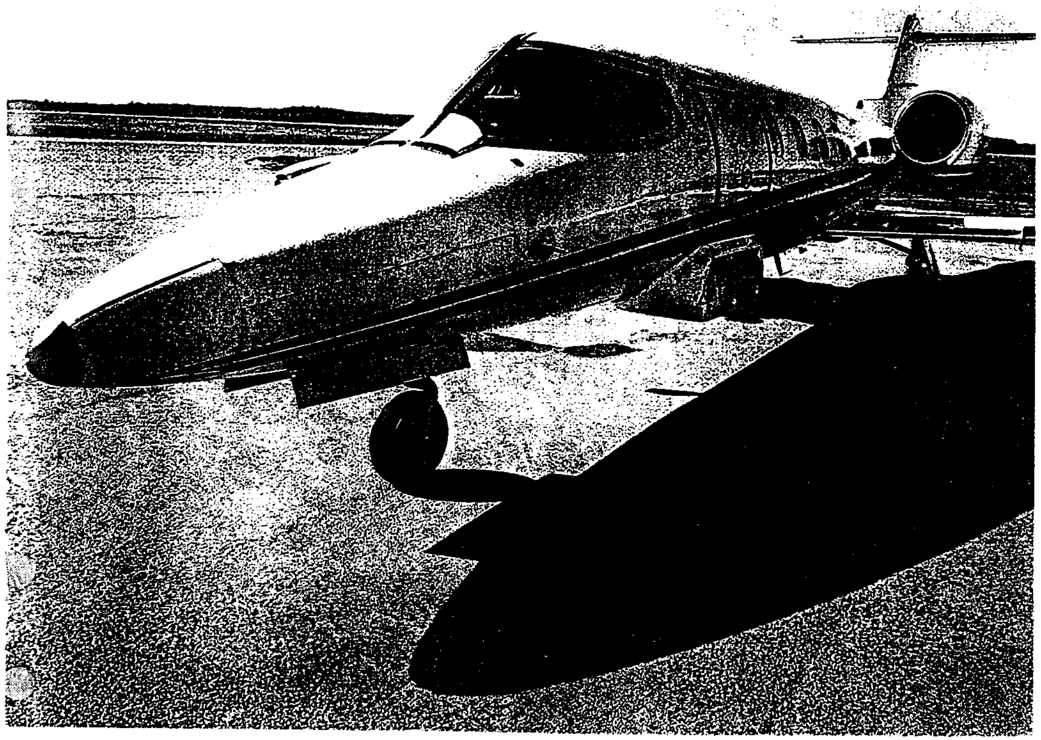


Conclusion/Summary

- GPS contriubutes to e.g
  - monitoring of global change
    - geophysics
    - sea level
    - atmosphere
  - weather forecast
  - time-transfer
  - navigation

Future

- Real time (RTK, weather forecast)
- More permanent stations
- More satellites (GPS+GLONASS) ???
- More Frequencies ???



Ingen rymdfarkost utan lilla tuffa LearJet som använts av Lantmäteriet sedan 1970. Kameraboxen sitter in ingångens underkant.

GPS-USE IN AERIAL PHOTOGRAPHY

- NAVIGATION

  IN SWEDEN EPOS
  OVERSEAS – TODAY, ABSOLUTE GPS

- POSTPROCESSED GPS - CAMERACOORDINATES FOR USE IN AERIAL TRIANGULATION

  L1/L2 RECEIVERS WITH PHOTOGRAMMETRY OPTION

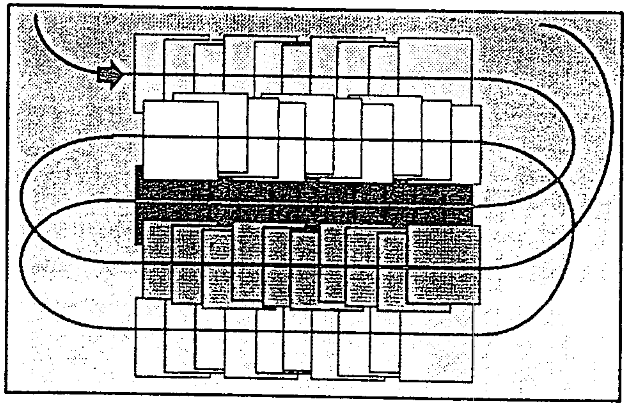
  REFERENCESTATION - SWEPOS, SWEDISH NET OF GPS-REFERENCESTATIONS

  POSITIONS ARE CALCULATED WITH FLOAT AMBIGUITIES USING DUAL FREQUENCY CODE AND CARRIER PHASE

  BASELINES UP TO 800km

  STRIPWISE GPS-PROCESSING WITH AN RELATIVE ACCURACY AT 1-2dm

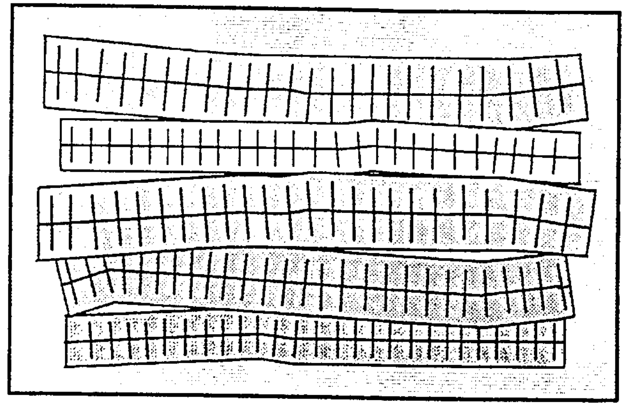
WITH GPS



- NAVIGATION SOFTWARE (CAAP-SYSTEM)
- SOFTWARE TRIGGERS THE CAMERA AT PREDEFINED EXPOSUREPOSITIONS

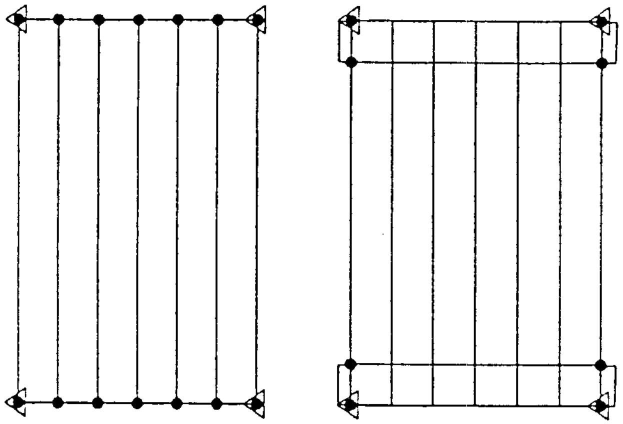
- CREW 1-2 PILOTS, 1 CAMERAOPERATOR/NAVIGATOR
- ACCURATE FLIGHT LINES
- LESS EXPOSURES
- LESS/NO REPHOTO DUE TO BAD NAVIGATION
- LESS TIME IN-FLIGHT
- PIN-POINT PHOTOGRAPHY FOR EXAMPLE MAP SHEET UPDATING, ORTHOPHOTOPRODUCTION

WITHOUT GPS



- VISUAL NAVIGATION FROM MAPS
- CREW: 1-2 PILOTS 1 CAMERAOPERATOR 1 NAVIGATOR

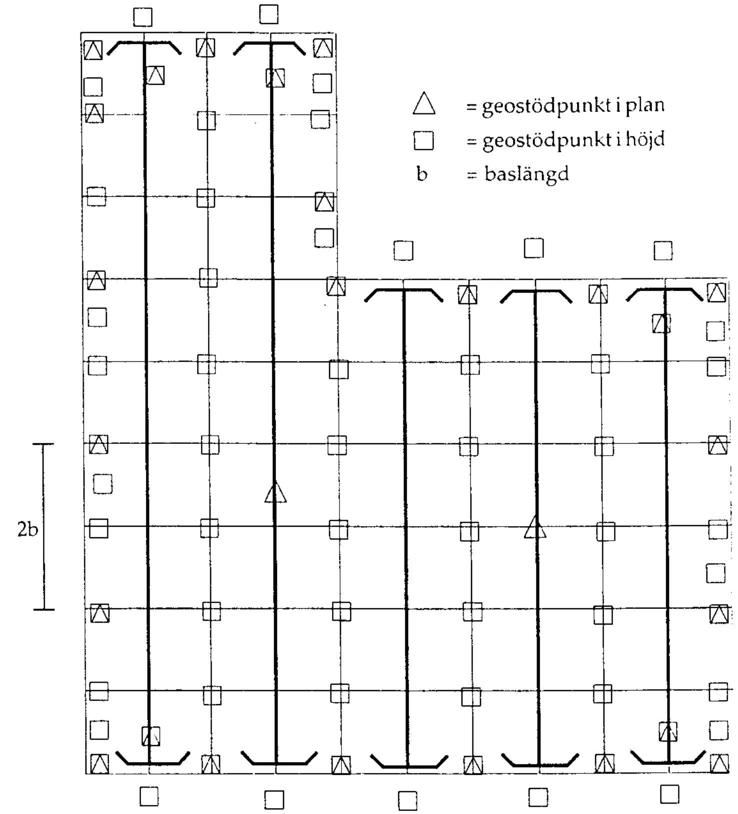
- SOMETIMES DIFFICULT TO NAVIGATE (EXAMPLE DESERT AREAS OR IN AFRICA) RESULTING IN GAPS IN THE PHOTOCOVERAGE



AERIAL TRIANGULATION WITH GPS-POSITIONS FOR EACH PROJECTION CENTRE

- THE GPS-DATA BINDS THE PROJECTION CENTRAS TOGETHER AND MAKES A VERY SOLID BLOCK, WITH HIGH RELATIVE ACCURACY
- GROUND CONTROL ONLY NEEDED IN EACH CORNER OF BLOCK , USED FOR CONNECTION TO GROUND COORDINATESYSTEM
- CROSS STRIPS OR HEIGHT CONTROL TIES THE BLOCK TOGETHER

BENEFIT
- REDUCES THE NEED FOR GROUND CONTROL



TRADITIONAL CONFIGURATION OF GROUND CONTROL

0257

National Landsurvey of Sweden
Photogrammetric division
Thomas Lithen 1996-03-01

Results of GPS-supported Aerial Photography and Aerial Triangulation over Francistown using the CAAP-system.

The National Landsurvey of Sweden (NLS) has since 1992 routinely been using real-time GPS in aerial photography, for navigation and automatic exposures at preselected points. In addition, post processed GPS has been used in the aerial triangulation process in order to significantly reduce the number of ground control.

The whole system used for aerial photography at NLS is called CAAP (Computer Assisted Aeriel Photography). The CAAP-system consists of four main parts: planning, navigation and automatic exposure, postprocessing and archiving.

The objective of this paper is to briefly introduce some parts of the CAAP-system and to show some test results from a production job done in Francistown, Botswana.

Planning of photo strips and photo centers

Photo strips and photo centers are planned in advance using the software CR21, which has been developed in-house. The main input data is the first and last coordinate pair in each strip, as well as flying height, overlap in percent and aerial camera parameters.

The resulting data files, consisting of X, Y and Height coordinates for each planned exposure point, are in ASCII format, and they can therefore, be edited by a standard editor before they are used for navigation and exposure control.

The input coordinates are normally taken from existing maps and are therefore coordinates in the the local geodetic datum using the existing map projection. The navigation module handles only Transverse Mercator coordinates (TM). If the existing map projection is different a transformation must be done to TM coordinates.

Navigation and automatic exposure

The main parts of the airborne hardware consists of an aerial camera, an Ashtech Z-XII GPS reciever with a photogrammetric module coupled to a laptop computer.
The navigation software NAVPRO, which has been developed in-house, uses the real-time satellite positions as input, as well as the pre-determined exposure points.

NAVPRO steers the aerial camera directly. When the aircraft reaches a preselected exposure point, a pulse is sent to the camera and the shutter is trigged. When the fiducial marks are exposed a pulse is sent to the GPS reciever to tag the exposure time. This accurate time tagging is the key to accurate positioning of the antenna if post-processing of GPS is done.

The satellite positions are in the geodetic datum WGS84. In order to transform these positions to the map projection used, NAVPRO needs the following information: the parameters of a seven parameter similarity transformation from WGS84 to the local datum, the local ellipsoid and the central meridian, scale factor and false origin for the Transverse Mercator projection.

Post-processing

To make this procedure possible, GPS rawdata must be recorded on the aircraft as well as on a reference station at a known position. The airborne hardware is added by an extra PC using the Ashtech software DATALOGR to collect rawdata from the same reciever as used for the navigation.

The differential postprocessing of data from the static reference station and the moving aircraft is made using the Ashtech software PNAV. The position are calculated with float ambiguities using dual frequency code and carrier phase, as the reference station normally is far away from the aircraft.

The resulting coordinates are in the WGS84 datum and must, therefore, be transformed to the local datum and mapprojection used for the aerial triangulation.

Aerial triangulation

An usual ground control requirements for block triangulation are a XYZ coordinate every fourth model for the outside strips and a height control for every fourth model for the inner strips. Using GPS-aerotriangulation, only four ground control points are needed, in theory, one in each corner and to fly a cross strip across each end of the block. In practise, the number of ground control should be doubled or trebled to guard against errors such as misidentification etc.

The adjustment of the blocks at NLS is done by bundle adjustment in the PATB-RS GPS software (from INPHO, Stuttgart, Germany) using the corrected image coordinates, ground control points, the coordinates for the antenna at each exposure point determined by GPS and the excentricity between antenna and camera.

The differential GPS observation are not used as absolute observations, instead unknown parameters for stripwise linear GPS drift corrections are introduced in the block adjustment and solved for together with all other unknowns. This implies that GPS data is mainly used for relative positioning of exposure points within a strip.

Results from two test adjustments over Francistown

The aerial photography over Francistown, Botswana was taken in the middle of october 1994. The flying height was 3000 meters which gave an image scale of 1:20000. The camera used was a Leica RC30 with a focal length of about 0.153 m together with black and white film, Kodak Double-X. The CAAP-system was used for navigation and GPS rawdata were recorded for post processing. A GPS reference station was placed at the airport in Gabarone, which is about 350 km away from Francistown.

There were four parallel strips, each of 12 images, and two cross strips of 8 images. An overlap of about 60 % along and 30% between strips were used. There were 42 premarked photo control points in the area, 35 of these were measured by GPS and was used for the test.

Two different test adjustments were made, one GPS aerotriangulation with cross strips and ground control only in the corners, and one conventional aerial triangulation without cross strips. In the GPS case, 8 control points were used , with two in each corner. For the conventional triangulation, without GPS, 12 XYZ points and 11 level points was used as photo control. The remaining photo control points were used as independent check points, see Appendix A and B.

Photogrammetric measurements and aerial triangulation

Approximate 5-7 points per image were pugged before the photogrammetric measurements. The photgrammetric measurements were made in a Zeiss Planicomp P2. The image coordinates are then corrected for lens distorsion, earth curvature and refraction.

The image coordinate accuracy was set to 4 micron and the ground control and GPS measurements were assumed to be error free. The aerial triangulation was made using 12 additional parameters as well as GPS drift parameters for each strip in the GPS case. The adjustment gave a standard devation of 4.05 micron (sigma naught) for the GPS aerotriangulation and 3.43 micron for the conventional case. Following theoretical values were obtained:

- The mean value of standard deviaton for ground points, including control points, check points and tie points were

	GPS-aerotriangulation			Conventional triangulation		
	No			No		
x	355	0.08 m	max 0.13 m	331	0.08 m	max 0.14
y	355	0.09 m	max 0.21 m	331	0.09 m	max 0.19
z	355	0.15 m	max 0.28 m	331	0.16 m	max 0.33

- The mean value of standard deviaton for projection centers were

	GPS-aerotriangulation			Conventional triangulation		
	No			No		
x	64	0.08 m	max 0.17 m	48	0.17 m	max 0.31
y	64	0.12 m	max 0.19 m	48	0.20 m	max 0.33
z	64	0.07 m	max 0.12 m	48	0.08 m	max 0.17

Check of coordinates from aerial triangulation versus ground control survey

A comparison between coordinates from a ground surveying and coordinates from the block adjustment for the premarked check points gave the following RMS

	GPS-aerotriangulation			Conventional triangulation		
	No			No		
x	27	0.11 m	max 0.31 m	23	0.07 m	max 0.15
y	27	0.08 m	max 0.22 m	23	0.10 m	max 0.26
z	27	0.11 m	max 0.25 m	12	0.12 m	max 0.21

These values are in compliance with the theoretical values for the ground control, which implies that the theoretical values for the projection centers should be a good estimate of the "real" accuracy as well.

Check of coordinates from aerial triangulation versus GPS for the projection centers

The coordinates for the projection centers from the GPS aerotriangulation have, as shown earlier, an accurracy of about 0.1 m and following tests were made:

- Comparison between planned coordinates and coordinates from the block adjustment for 64 projection centers

RMS x	12.29 m	max	30.86 m
RMS y	20.71 m	max	49.91 m
RMS z	19.91 m	max	32.32 m

This test shows how accurate NAVPRO, using GPS in stand alone mode without corrections, can pinpoint pre-determined exposure points. It should be mentioned that the maximum errors of GPS with a single reciever could be up to 100 m due to the fact that Selective Availability is switched on.

- Comparison between postprocessed GPS coordinates obtained from PNAV and coordinates from the block adjustment for 64 antenna positions:

RMS x	3.03 m
RMS y	2.87 m
RMS z	1.31 m

This test shows the total effect of using PNAV, calculating differential kinematic GPS over long distances, inaccuracy in the local network over long distances and inaccuracy in the datum transformation.

A transformation of the horizontal component was made using two translations, rotation and a scale factor in order to remove the effect of inaccuracies in the local network and datum transformation, and to see the accuracies between strips using PNAV:

RMS x	0.33 m
RMS y	0.30 m

Conclusions

The main reason for using GPS is the improved control over the camera position during navigation and the large potential saving in cost of ground control for aerial triangulation. The example above shows that the method of GPS-aerotriangulation in the special form of cross strips and linear GPS drift corrections is operational today, even if the reference station is far away. There is no critical need to wait for more refined GPS hardware and procedures to come.

References

Ackerman, F (1992) Operational Rules and Accuracy Models for GPS-Aerotriangulation
IAPRIS, comm III, Washington DC, 1992, VOL XXIX, part B3, pp 691-700.

Burman, H, Torlegård, K (1994) Empirical Results of GPS-Supported Block Triangulation.
OEEPE Official Publication No 29, ISSN 0257-0505.

Moffit, F H, Mikhail, E M (1980) Photogrammetry, Third Edition
Harper & Row 1980, ISBN 0-700-22517-X.

Appendix A

Block Francistown, Botswana

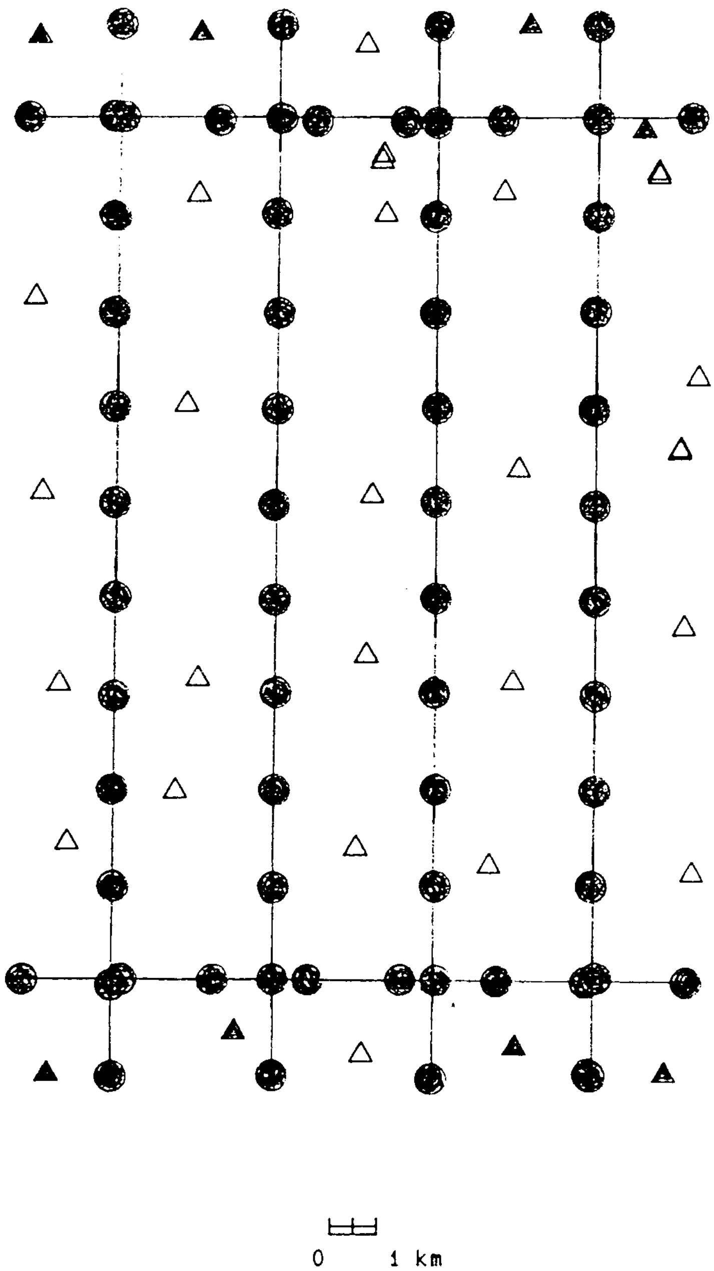
GPS Aerotriangulation

Scale 1:150000

▲ 8 Photo Control Points, XYZ

△ 27 Check Points, XYZ

● 64 Projection Centers



Appendix B

Block Francistown, Botswana

Conventional Triangulation

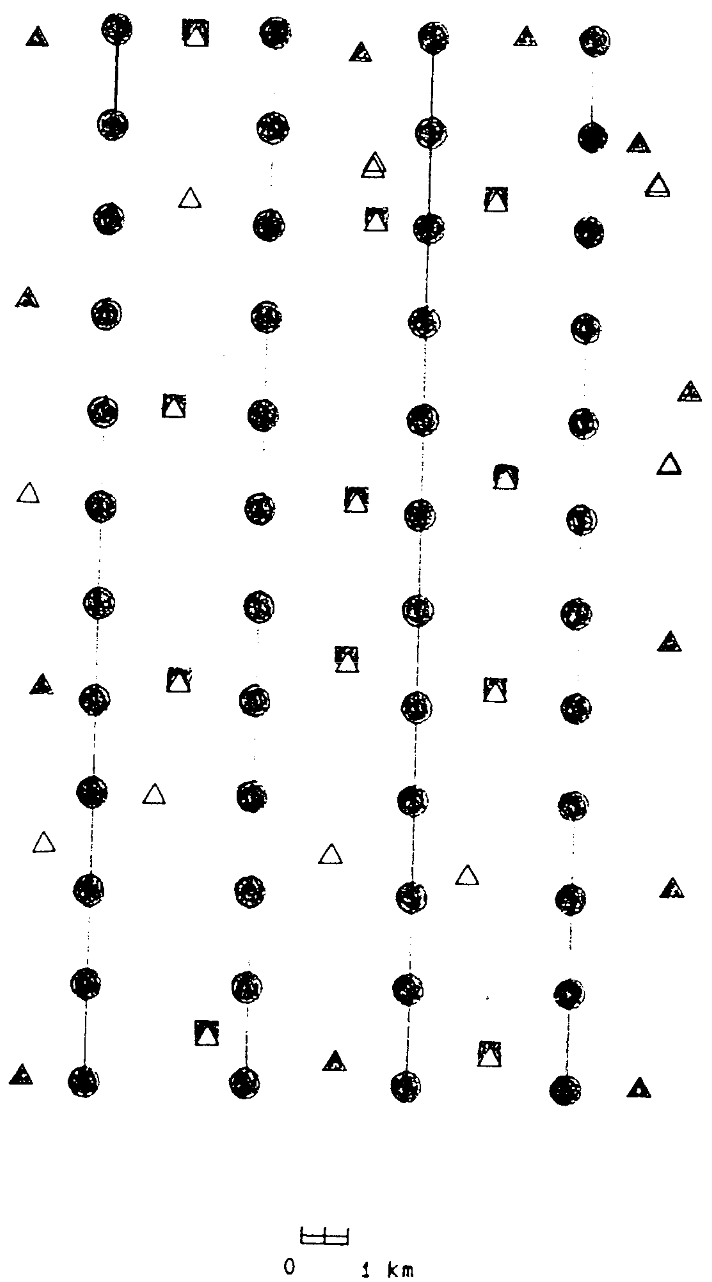
Scale 1:150000

▲ 12 Photo Control Points, XYZ

⧅ 11 Photo Control Points, Z and Check Points, XY

△ 12 Check Points, XYZ

● 48 Projection Centers



CENTRAL EUROPEAN INITIATIVE
WORKING GROUP ON SCIENCE AND TECHNOLOGY
SECTION C "GEODESY"

00-661 Warszawa, Pl. Politechniki 1
Tel.: (48-22) 6228515; Fax: (48-22) 6210052;
E-mail: sledzinski@gik.pw.edu.pl
http://www.gik.pw.edu.pl/cei-section c

RESULTS AND ACHIEVEMENTS OF THE LONG-TERM COOPERATION IN GEODESY AND GEODYNAMICS GAINED BY THE SIXTEEN CEI (Central European Initiative) COUNTRIES

Janusz Śledziński
Warsaw University of Technology
Institute of Geodesy and Geodetic Astronomy

International Coordinator of the CEI WG Science and Technology Section C "Geodesy"
Chairman of the IAG Subcommission
"Geodetic and Geodynamic Programmes of the Central European Initiative (CEI)"
Co-Chairman of the CEI Project CERGOP
Member of the Steering Committees of the CEI Projects CERGOP and UNIGRACE

Report presented to the 7th European Meeting
of the International Information Sub-Committee (IISC)
of the Civil GPS Service Interface Committee (CGSIC)

Gävle, Sweden
3-4 December 1998

RESULTS AND ACHIEVEMENTS OF THE LONG-TERM COOPERATION IN GEODESY AND GEODYNAMICS GAINED BY THE SIXTEEN CEI (Central European Initiative) COUNTRIES

Prof. Dr.-Ing. habil. Janusz Śledziński

International Coordinator of the CEI WG Science and Technology Section C "Geodesy"
Chairman of the IAG Subcommission
"Geodetic and Geodynamic Programmes of the Central European Initiative (CEI)"
Member of the Steering Committees of the CEI Projects CERGOP and UNIGRACE

1. MAIN TOPICS OF COOPERATION

Intensive international cooperation of the CEI WG Science and Technology Section C "Geodesy" focused in the last time on the following topics:

* preparation of the second phase of realisation of the project CERGOP (Central Europe Regional Geodynamics Programme),
* realisation of the project UNIGRACE (Unification of Gravity Systems in Central and Eastern Europe),
* establishment of permanent satellite GPS (Global Positioning System) stations in CEI countries,
* realisation of a broad programme of activities of the Section C WG on University Education Standards,
* initialisation of international cooperation of the new Section C WG on Satellite Navigation Systems.
* continuation of cooperation between the CEI WGST Section C "Geodesy" and other international organisations: International Association of Geodesy and European Geophysical Society.

Some evident achievements and experiences gained from the international cooperation of CEI countries in above mentioned topics are shortly outlined below.

2. PROJECT CERGOP (Central Europe Regional Geodynamics Programme),

The first phase of the Project CERGOP (Central Europe Regional Geodynamics Project) that is partially supported by a finance grant of the European Union programme COPERNICUS, was completed by the end of June 1998. The programme of the second phase of the Project CERGOP-2 is now being prepared. The following countries participated in the Project: Austria, Croatia, the Czech Republic, Germany, Hungary, Italy, Romania, Poland, Slovakia, Slovenia and Ukraine. As associated country Bulgaria joined the project in 1996.
The most important achievements of the project:

* Establishment and maintenance of the Central European GPS Reference Network consisting of 31 sites on the territories of 11 countries. Four epoch monitoring satellite GPS campaigns were carried out on this network in yearly intervals in 1994, 1995, 1996 and 1997. As a result there are available the precise coordinates of all 31 sites with the accuracy of sub-centimetre level as

well as vectors of station displacements within the period 1994-1997. The geodynamic network is used for investigation of the most profound geotectonic features in the Central European region, the Teisseyre-Tornquist Zone, the Carpathians, the Bohemian Massif, the Pannonian Basin and their relation to the Alpine-Adria region. The results of research were presented at international conferences (EGS CEI Symposium G16, Nice, France, April 1998; IAG Symposium, Rio de Janeiro, Brazil, September 1997; EUREF Symposium, Bad Neuenahr, Germany, June 1998).

* Enormous and very operative work performed by nine CERGOP Study Groups carrying out research in particular fields during the whole project period. The scientific outputs of CSG-s were presented at different international conferences. Perhaps one of the most notable achievements of the study groups is the preparation and editing five monographs of five particular regions in Central Europe. The following volumes were published in the publication series REPORTS ON GEODESY edited by the Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology: The Pannonian Basin (edited by G. Grenerczy, Hungary), The Bohemian Massive (edited by P. Vyskočil, the Czech Republic), The Teisseyre-Tornquist Zone (edited by J. Liszkowski, Poland), The Northern Carpathians (edited by F. Zablotsky, Ukraine), and The Southern Carpathians (edited by D. Ioane, Romania). The monographs summarize the latest geoscience results, available for these regions, with particular emphasis on the project's objectives. There is also a sixth volume by P. Vyskočil, Czech Rep. and J.Śledziński, Poland which contains general characteristics of all regions, list of performed studies and a summary, indicating some proposals for future investigations.
* All results achieved currently by different working groups were regularly and fast published in the series REPORTS ON GEODESY IG&GA WUT, Poland). So far 19 volumes were published containing proceedings of nine CEI CERGOP Working Conferences, two CEI WGST Section C Symposia on University Education Standards, two EGS/CEI (European Geophysical Society) Symposia "Geodetic and Geodynamic Programmes of the CEI", (Vienna/Austria, 1997 and Nice/France, 1998) and a set of 6 geotectonic monographs.

New phase of the Project CERGOP-2, now being prepared, will accept all the basic objectives of the Project CERGOP-1 but will also involve the following factors: (a) adoption of new member countries, extension of the geographic area of the project (e.g. Albania, Bulgaria), (b) extension of the CEGRN by adoption of new GPS sites thus establishing the Central European Extended Geodynamic Reference Network (CEEGRN) consisting of about 60 sites, (c) the new role of the permanent stations, (d) integration processes with other regional networks (e.g. EUREF) and interaction with other, overlapping projects, (e) support local area geodynamic research, environmental studies, seismic hazard assessments, meteorology etc. in the Central European Region, etc. The working conference of the CERGOP-2 Steering Committee will be held on 14-15 December 1998 in Warsaw to discuss all aspects of the second phase of the project CERGOP and to prepare draft request to EU COPERNICUS Programme for financial support.

3. PROJECT UNIGRACE (Unification of Gravity Systems in Central and Eastern Europe)

The realisation of the CEI Project UNIGRACE (Unification of Gravity Systems in Central and Eastern Europe), that was also accepted by European Union (programme INCO COPERNICUS), started in 1998. The project consists in establishing the absolute gravity traverses from the Baltic Sea to Adriatic and the Black Sea. Twelve countries participate in the project: Austria, Bulgaria, Croatia, Czech Republic, Finland, Germany, Hungary, Italy, Poland, Romania, Slovakia and Slovenia. Five absolute gravity-meters from Austria, Finland, Germany, Italy and Poland are involved in two observation campaigns. First observation campaign was organised in 1998. The absolute gravity is measured at 10 intraplate and 7 tide gauge points. The First UNIGRACE Working Conference was held in Frankfurt a. Main (Germany) on 2-3 February 1998. All organisational and logistic problems were discussed and the time schedule of actions was accepted. The Second UNIGRACE Working Conference will be organised in February 1999 in Warsaw (IG&GA WUT).

4. NEW PERMANENT SATELLITE GPS STATIONS IN CEI COUNTRIES

The number of permanent satellite GPS stations working in CEI countries within either Programme of IGS (International GPS Service for Geodynamics), EUREF (European Reference Frame) or as reference stations of navigation systems has increased significantly in the last few years. About 40 permanent satellite stations work presently in CEI countries, next stations are planned to be established in CEI countries in the forthcoming years. It is to be noted with satisfaction that several new permanent satellite stations were established in the last time in CEI countries. One station, near Kiev began permanent observations in Ukraine, further two stations (Lviv and Uzhgorod) are being prepared to become permanent; another permanent station was established in Sofia (Bulgaria); in Italy one next permanent station become operational; German institutions assist to establish a permanent GPS station in Tirana (Albania). However, the distribution of these stations is not even: all permanent stations currently operating are located on the territory of 8 CEI countries (Austria, Bulgaria, the Czech Republic, Hungary, Italy, Poland, Slovakia and Ukraine). Eight CEI countries (Albania, Belarus, Bosnia&Herzegovina, Croatia, Macedonia, Moldova, Romania, Slovenia) have not yet established permanent satellite stations.

5. ACTIONS OF THE SECTION C WG ON UNIVERSITY EDUCATION STANDARDS

This working group organised successfully several international symposia: in 1996 an "International Symposium on Education in GPS Application to Geodesy and Geographic Information Systems (GIS)", in 1997 a symposium "International Symposium on Differential Global Positioning System in Engineering and Cadastral Measurements - Education and Practice", both held in summer time in Ljubljana, Slovenia. This working group organised also a summer seminar/workshop "Education in GPS Application to Geodesy and GIS/LIS" held in Grybów, Poland in June 1998. Participants from Austria, Germany, Hungary, Poland, Slovakia and Slovenia attended the seminar. It was recommended that in the forthcoming years the training for the international student groups on GPS satellite techniques and applications would be organised by this CEI Section C Working Group. The participants from all 16 CEI countries are invited to attend these training meetings.

6. INITIALISATION OF ACTIVITY OF THE NEW CEI SECTION C WORKING GROUP ON SATELLITE NAVIGATION SYSTEMS

In view of a great development of navigation systems (various geodetic real time and postprocessing positioning systems, DGPS, DGLONASS etc.) in many CEI countries, the CEI Section C has decided to establish a new Section Working Group on Satellite Navigation Systems. First meeting of this Working Group was held in April 1998 in Nice, France on the occasion of the EGS Symposium G16 on CEI geodetic and geodynamic programmes. The programme of the international cooperation was discussed; the main item of the plan of action of this Working Group will be preparation of an international project on development of national satellite navigation systems that would be submitted to the European Union with the request for financial support. In March 1999 this working group will organise in Trieste, Italy an international seminar/workshop on application of satellite DGPS technique for assurance of the safety of road traffic. Necessary funds for organisation of this seminar and for covering accommodation costs of some participants are already available.

7. COOPERATION BETWEEN CEI SECTION C AND IAG (International Association of Geodesy)

International Association of Geodesy (IAG) created in 1996 a Subcommission "GEODETIC AND GEODYNAMIC PROGRAMMES OF THE CEI" in order to establish a better cooperation and coordination of the scientific projects related to the area of Central Europe. This Subcommission was created within the IAG Commission VII "Recent crustal movements" (chaired by Prof. Dr. T. Tanaka, Japan), Section V "Geodynamics" (chaired by Dr. M. Feissel, France) as a result of the request of the International Coordinator of the CEI Section C "Geodesy". The Chairman of the Subcommission was elected Prof. Dr. J. Śledziński (Poland). The charter duties of the Subcommission are the following: (a) coordination and/or integration of the international geodetic and geodynamic programmes supported by IAG and CEI, (b) creation of close links between running projects of IAG and those of CEI (e.g. CEI CERGOP - Central Europe Regional Geodynamics Project and IGS and EUREF, use of CEI permanent GPS stations within IGS and other programmes for maintenance of the ETRF and ITRF, etc.), (c) initialisation of common geodetic and geodynamic projects for the region of Central and Eastern Europe, (d) fostering the cooperation among universities and research centres from Central Europe and Western countries in the field of geodesy and geodynamics, promoting actions contributing to the development of innovative technologies and participation of CEI scientists in international IAG research programmes.

The exhaustive Progress Report on activities of the IAG Subcommission "Geodetic and Geodynamic Programmes of the CEI (Central European Initiative)" was presented by the chairman at the IAG Scientific Assembly, Rio de Janeiro, Brazil, 3-9 September 1997. The next Progress Report on CEI projects in Central and Eastern Europe and on CEI-IAG cooperation in geodesy and geodynamics will be prepared for the 22nd General Assembly of the International Union of Geodesy and Geophysics that will be held in Birmingham, UK, on 19-30 July 1999.

8. COOPERATION BETWEEN CEI SECTION C "GEODESY" AND EGS (European Geophysical Society) SECTION 2 "GEODESY"

The cooperation was initiated in 1996. It was decided that since there are many projects of common interest for both CEI and EGS, during the next General Assemblies of the European Geophysical Society there would be organised special symposia devoted to the geodetic and geodynamic programmes of the CEI. In 1997 (22nd General Assembly of the EGS) the Symposium G14 "Geodetic and Geodynamic Programmes of the CEI" was held in Vienna, Austria, 21-25 April 1997; in 1998 (23rd General Assembly of the EGS) the Symposium G16 "Geodetic and Geodynamic Achievements of the CEI" was held in Nice, France, 20-24 April 1998. Next EGS "CEI Symposium" will be held in April 1999 in The Hague, The Netherlands. The Convener of all symposia is Prof. Dr. J. Śledziński, Poland, Co-Convener - Prof. Dr. J. Kostelecky, Czech Republic.

In oral and poster sessions there are presented papers on EUREF campaigns in CEI countries, on CEI Projects CERGOP and UNIGRACE, activities of the CEI study groups, contribution of permanent GPS stations in CEI countries to international programmes, etc. At the Symposium G16 in 1998 forty five papers prepared by about ninety authors were presented. The CEI Section C will take an active part in all next EGS General Assemblies.

9. UPDATED PLAN OF NEAR-TERM GPS RELATED ACTIONS FOR 1999

(1) CERGOP-2 Steering Committee meeting in Warsaw to prepare a draft application to European Union with request for financial support for CERGOP-2. The meeting will be organised by the Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology on 14-15 December 1998. The responsible and contact person is Prof. Janusz Śledziński.

(2) The publication of the proceedings of all meetings, conferences and symposia organised by the CEI WGST Section C "Geodesy" will be the duty of the Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology. So far, 21 volumes of proceedings and results of scientific works done by the CEI WGST Section C members were edited and published in the Institute's series REPORTS ON GEODESY. The responsible person is Chief Editor Prof. Janusz Śledziński.

(3) Continuation of the geotectonic studies based on GPS surveys on the Central European regions within the CEI WGST Section C Study Group "Analysis of the region of Central Europe". Preparation of further geotectonic monographs. Scope of work coincides with the Project CERGOP-2 objectives.

(4) Organisation of the subsequent satellite GPS CERGOP/EXTENDED SAGET campaign in May-June 1999. The guidelines to be observed by all CERGOP stations will be prepared in due time by the CERGOP Steering Committee under the leadership of the Project Coordinator Dr. P. Pešec, Austria. The observation data will be processed by all eight CERGOP Processing Centres. As CERGOP Data Centre will serve Graz-Lustbühel Observatory, Austria.

(5) Organisation of the EGS G4 Symposium " Geodetic and Geodynamic Programmes of the CEI", The Hague, The Netherlands, 19-23 April 1999. Preparation of progress reports and papers with current results achieved in realisation of the CEI WGST Section C projects. Responsible persons: Convener of the Symposium Prof. J.Śledziński, Poland and Co-Convener Prof. J. Kostelecký, Czech Republic.

(6) Organisation of the CEI Section C international seminar/workshop in Trieste, Italy, March 1999 on application of satellite positioning systems to assurance of the safety of road traffic. The responsible persons: Prof. G. Manzoni, Trieste, Italy and Prof. S. Oszczak, Olsztyn, Poland.

To assure more effective and quick dissemination of information on activities of the CEI WGST Section's C "Geodesy" different working groups there are opened Web Home Pages. The address is the following:

http://www.gik.pw.edu.pl/cei-section c

Several poster sheets presented in the following pages of this paper give some supplement facts on Central European Initiative WGST Section C "Geodesy" and the realisation of its scientific programme.

RESULTS OF THE LONG-TERM COOPERATION IN GEODESY AND GEODYNAMICS GAINED BY SIXTEEN CEI COUNTRIES

Janusz Śledziński
Chairman and International Coordinator of the WGST CEI Section C "Geodesy"
Chairman of the IAG Subcommission "Geodetic and Geodynamic Programmes of the CEI"
Co-Chairman of the CEI Project CERGOP

Warsaw University of Technology
Institute of Geodesy and Geodetic Astronomy

00-661 Warszawa, Pl. Politechniki 1
Tel.: (48-22) 6228515; Fax: (48-22) 6210052; E-mail: sledzinski@gik.pw.edu.pl
Web Home Page: http://www.gik.pw.edu.pl/cei-section-c

Paper presented at the 7th European Meeting of the Civil GPS Service Interface Committee, International Information Subcommittee (CGSIC/IISC)
Gävle, Sweden, 3-4 December 1998

CEI MEMBER STATES

(16 countries, status 1.11.1998)

1. Albania
2. Austria
3. Belarus
4. Bosnia & Herzegovina
5. Bulgaria
6. Croatia
7. Czech Republic
8. Hungary
9. Italy
10. Macedonia
11. Moldova
12. Poland
13. Romania
14. Slovakia
15. Slovenia
16. Ukraine

CONCISE HISTORY OF THE CEI

Organisation established in 1989 as

QADRAGONALE

(Austria, Hungary, Italy, Yugoslavia)

and then transformed to:

PENTAGONALE (1990)

(Austria, Hungary, Italy, Yugoslavia, Czechoslovakia)

HEXAGONALE (1991)

(Austria, Hungary, Italy, Yugoslavia, Czechoslovakia, Poland)

IN 1992 HEXAGONALE
renamed as
CENTRAL EUROPEAN INITIATIVE (CEI)

CEI COOPERATION

Objectives:

* to initiate the scientific, economic and cultural cooperation between the countries of Central Europe
* to strengthen the stabilisation within the region of Central Europe
* to promote all-European integration processes
* to help the Central and Eastern European countries in entering the integrated world by adjusting their multilateral relations to European Union's standards

CEI WORKING GROUPS and chairmanship

1. Agriculture (Poland)
2. Civil Protection (Italy)
3. Combating Organised Crime (Italy and Slovakia)
4. Culture and Education (Slovakia)
5. Drug Law Enforcement (Slovakia)
6. Energy (Slovenia)
7. Environment (Austria)
8. Human Dimension (Austria)
9. Human Resources Development and Training (Czech Rep.)
10. Information and Media (Austria)
11. Migration (Hungary)
12. Minorities (Hungary and Romania)
13. Rehabilitation of Bosnia&Herzegovina and Croatia (Bosnia& Herzegovina and Croatia)
14. Science and Technology (Italy)
15. Small and Medium Size Enterprises (Slovenia)
16. Statistics (Austria)
17. Tourism (Croatia)
18. Transport (Italy)
19. Youth Exchange (Macedonia)

CEI WORKING GROUP on SCIENCE AND TECHNOLOGY (WGST)

EARTH SCIENCE COMMITTEE

Section A "Geology"

Section B "Geophysics"

Section C "Geodesy"

CEI WGST SECTION C "GEODESY"

FORMAL STRUCTURE OF WORK

* WORKING GROUP ON INTERCONNECTION OF GEODETIC NETWORKS;
* WORKING GROUP ON GIS/LIS;
* WORKING GROUP ON UNIVERSITY EDUCATION STANDARDS;
* WORKING GROUP ON SATELLITE NAVIGATION SYSTEMS;
* PROJECT CERGOP;
* PROJECT UNIGRACE

CERGOP

(CENTRAL EUROPE REGIONAL GEODYNAMICS PROJECT)

MAIN OBJECTIVES

* to integrate the geodynamic research in the region of Central Europe based on high accuracy space geodetic surveys and an integrated geodynamic network
* to provide a precise geodetic frame - CEGRN (Central European GPS Reference Network) - for
  * * studies on geodynamics of Central European areas of
    - Pannonia Basin,
    - Carpathian Belt,
    - Bohemian Massif
    - Teisseyre-Tornquist Zone,
    - Subalpine Region
  * * connection of local geodynamic networks established on the territory of participating countries

C E R G O P

PROJECT MANAGEMENT:

PROJECT ACTIONS ARE COORDINATED BY IPWG
(INTERNATIONAL PROJECT WORKING GROUP)
COMPOSED OF
PROJECT CHAIRMAN, PROJECT CO-CHAIRMAN
AND NATIONAL INVESTIGATORS (REPRESENTATIVES)

PROJECT CHAIRMAN: ISTVÁN FEJES (HUNGARY)
PROJECT CO-CHAIRMAN: JANUSZ ŚLEDZIŃSKI (POLAND)

MEMBER COUNTRIES AND NATIONAL INVESTIGATORS:

AUSTRIA	P.PESEC	POLAND	J.ŚLEDZIŃSKI
CROATIA	M.SOLARIĆ	ROMANIA	D.GHIȚĂU
CZECH REP.	J.ŠIMEK	SLOVAKIA	M.MOJZEŠ
GERMANY	E.REINHART	SLOVENIA	F.VODOPIVEC
HUNGARY	I.FEJES	UKRAINE	F.ZABLOTSKY
ITALY	C.MARCHESINI		

C E R G O P

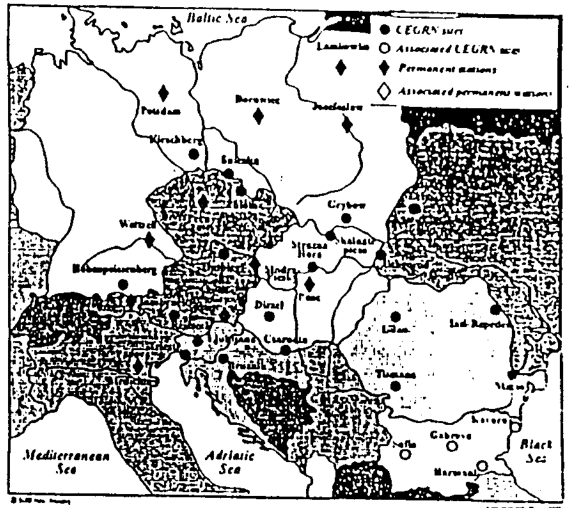
CERGOP GPS OBSERVATION CAMPAIGNS:

1994, May 2-6, (zero epoch)
1995, May 29 - June 3
1996, June 10-15
1997, June 4-10

* CERGOP DATA CENTRE: GRAZ (AUSTRIA)
* CERGOP PROCESSING CENTRES:

GRAZ (AUSTRIA)
IG&GA WUT WARSAW (POLAND)
FÖMI SGO PENC (HUNGARY)
VUGTK PECNY (CZECH REP.)
IfAG FRANKFURT (GERMANY)
STU BRATISLAVA (SLOVAKIA)
ISA MATERA (ITALY)
ZAGREB (CROATIA)

CERGOP DATA ARE AVAILABLE FREE FOR GEODYNAMIC STUDIES TO ALL SCIENTIFIC INSTITUTIONS



Sites of the Central European GPS Geodynamic Reference Network (CEGRN)

EXTENDED SAGET vs. CEGRN

	EXTENDED SAGET	CEGRN
Area	countries from Scandinavia to Mediterranean Region	CEI countries
Number of points	unlimited	limited to 31 stations
Stations	no any restriction in station distribution; any new station is accepted	only accepted stations
Campaigns	1992, September 7-11 1993, August 2-6 1994, May 2-6 1995, May 29 - June 3 1996, June 10-15 1997, June 4-10 1998, Juni 27 - July 1	1994, May 2-6, (z-ep) 1995, May 29 - June 3 1996, June 10-15 1997, June 4-10
Duration of campaigns	5 days	5 days
Responsible processing centre(s)	IG&GA WUT	IG&GA WUT (PL) FÖMI PENC (H) GRAZ (A) VUGTK (CZ) IfAG (D) STU (SQ) ISA (I) ZAGREB (Cr)
Software used	BERNESE	BERNESE

CERGOP STUDY GROUPS

CSG 1. cancelled
CSG 2. CERGOP site quality monitoring
CSG 3. CERGOP reference frame
CSG 4. Standardisation of Data and Processing Centres
CSG 5. Permanent and epoch GPS CERGOP stations
CSG 6. CEGRN and height determination
CSG 7. CERGOP gravity network
CSG 8. Geotectonic analysis of the region of Central Europe
CSG 9. cancelled
CSG10. Monitoring of recent crustal movements in Eastern Alps with GPS
CSG11. Threedimensional plate kinematics in Romania

CERGOP MAIN ACHIEVEMENTS
(1)

* Establishment and maintenance of the Central European GPS Reference Network (CEGRN) of the highest accuracy level consisting of 31 sites located on the territory of 11 Central European countries. The results of the processing of the CEGRN indicate that an overall site position accuracies of
  2-4 mm in horizontal coordinates, and
  4-8 mm in vertical coordinates
  have been achieved.

* The sub-centimetre accuracy of the position of the CEGRN stations gave possibility to obtain significant kinematic results about intraplate tectonic motions in Central Europe.

CERGOP MAIN ACHIEVEMENTS
(2)

* Eleven CEGRN stations are permanent GPS stations providing continuous monitoring capabilities for tectonic studies;

* All 11 permanent CEGRN stations are incorporated to the permanent EUREF network;

* 10 CEGRN stations are permanent IGS stations;

CLOSE LINKS BETWEEN CEGRN AND EUREF

CONTRIBUTION TO THE MAINTENANCE OF EUREF

CEGRN SUBNETWORK OF EUREF

CERGOP MAIN ACHIEVEMENTS
(3)

* CEGRN is used as reference network for local area deformation studies.

  Some examples:

** geodynamic studies in the Vrancea area (Romania);
** Tatra Mountains without borders (Slovakia-Poland);
** Monitoring of recent crustal movements in the Eastern Alps;
** geodynamic test field Grybów (Poland);
** geodynamic studies in the Pieniny region (Poland-Slovakia);
** project Morava (Slovakia-Czech Republic);
** geodynamic studies of the Sudety Region (Poland-Czech Rep.);
** geodynamic reference network HGRN of Hungary (Hungary);
** geodynamical research in Bulgaria (Bulgaria);
etc.

CERGOP MAIN ACHIEVEMENTS
(4)

* Establishment and launching the operation of 8 processing centres
  * Bratislava, Slovakia;
  * Frankfurt, Germany;
  * Graz, Austria; (also serve as Data Centre)
  * Matera, Italy;
  * Pecny, Czech Republic;
  * Penc, Hungary;
  * Warsaw, Poland
  * Zagreb, Croatia.
* Several CERGOP Processing Centres (Frankfurt, Pecny, Warsaw) serve also as EUREF Analysis Centres.

CERGOP MAIN ACHIEVEMENTS
(5)

* Publication of 6 volumes of geotectonic Monographs. Work done in the frame of CERGOP Study Group 8 "Geotectonic analysis of the region of Central Europe"
  * Bohemian Massif (edited by P. Vyskočil),
  * The Teisseyre-Tornquist Zone (edited by J. Liszkowski),
  * Pannonian Basin (edited by G. Grenerczy),
  * Northern Carpathians (edited by F. Zablotsky),
  * Southern Carpathians (edited by D. Ioane).
  * Summary and proposals for future investigations (edited by P.Vyskočil and J.Śledziński)

All volumes published in the series REPORTS ON GEODESY edited by Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology.

FUTURE PLANS: NEW PHASE OF CERGOP 2
(1)

* Extension of the geographic area of the project; new member countries will participate in the project;
* Extension of the CEGRN, adoption of new sites up to about 60 stations;
* Use of the new role of the permanent stations;
* The proliferation of local area deformation studies based on the CEGRN; provide a reliable 3D tectonic velocity field covering the Central European Region;
* Geophysical interpretation of the three dimensional velocity field;

FUTURE PLANS: NEW PHASE OF CERGOP 2
(2)

* Integration processes with other regional networks (e.g. EUREF); interaction with other overlapping projects;
* Investigation of the geotectonic features in the Central European Region, in particular:

  Bohemian Massif,
  the Teisseyre - Tornquist Zone,
  Pannonian Basin,
  the Carpathians,
  the Subalpine Region (Alpine - Adria Region),
  Moesian Platform,
  the Balkanides.

CEI SECTION C WORKING GROUP ON UNIVERSITY EDUCATION STANDARDS

ACTIONS:

* INTERNATIONAL SYMPOSIUM
  "EDUCATION IN GPS APPLICATION TO GEODESY AND GEOGRAPHIC INFORMATION SYSTEMS (GIS)"
  LJUBLJANA, SLOVENIA, 18-21 SEPTEMBER 1996

* INTERNATIONAL SYMPOSIUM
  "DGPS IN ENGINEERING AND CADASTRAL MEASUREMENTS - EDUCATION AND PRACTICE"
  LJUBLJANA, SLOVENIA, 25-27 AUGUST 1997

* WORKSHOP
  "EDUCATION IN GPS APPLICATION TO GEODESY AND LIS/GIS"
  GRYBÓW, POLAND, 22-25 JUNE 1998

COOPERATION LINKS CEI SECTION C - EGS
(European Geophysical Society)

* * * * * * *

XXII General Assembly of the EGS: Symposium G14
"Geodetic and Geodynamic Programmes of the CEI",
Vienna, Austria, 21-25 April 1997.

XXIII General Assembly of the EGS: Symposium G16
"Geodetic and Geodynamic Achievements of the CEI",
Nice, France, 20-24 April 1998.

XXIV General Assembly of the EGS: Symposium G4
"Geodetic and Geodynamic Programmes of the CEI",
The Hague, The Netherlands, 19-23 April 1999.

CEI WGST SECTION C WORKING GROUP ON SATELLITE NAVIGATION SYSTEMS

International CEI Section C seminar/workshop "GPS in road and mountain safety" Trieste, Italy, 9-11 March 1999

Organisers: Prof. G. Manzoni, Trieste, Italy and Prof. S. Oszczak, Olsztyn, Poland.

General topics: vehicle navigation and control, anticollision alert, safety messages to drivers, robbery alert, road rescue, mountain rescue, landslide monitoring, civil engineering structure control, road centimetre accuracy surveys, DGPS and DGLONASS, RTK techniques, EGNOS terrestrial applications.

IAG Subcommission:
"GEODETIC AND GEODYNAMIC PROGRAMMES OF CEI"
Chairman: Prof. Dr. Janusz Śledziński, Poland

established in 1996 within

COMMISSION VII "RECENT CRUSTAL MOVEMENTS"
chaired by Prof. Dr. T. Tanaka, Japan

of the

Section V "GEODYNAMICS"
chaired by Dr. M. Feissel, France

0277

A SIMPLE WAY OF TRANSFORMING COORDINATES BETWEEN GEODETIC REFERENCE FRAMES.

B-G Reit

The National Land Survey of Sweden
SE-801 82 Gävle, Sweden
Fax +46 26 61 06 76
E-mail bo-gunnar.reit@lm.se

Abstract

A simple method is developed which makes it possible to introduce a rigorously defined global reference frame without being forced to abandon the plane grid system in use. The method utilizes the Transverse Mercator projection and can replace the 7-parameter transformation in most everyday work within surveying and mapping.

Introduction

The never-ceasing progress in computer technology has made the use of digital maps widespread. The advent of GPS has undoubtedly meant a revolution to geodesy. Many countries are changing to a global reference frame as a national standard. This often leads to lengthy computations involving several consecutive transformation steps. Not all GIS systems have algorithms implemented for transformation between geodetic datums. A typical sequence of transformations might look like

$$(\varphi, \lambda)_{global} \leftrightarrow (X, Y, Z)_{global} \leftrightarrow (X, Y, Z)_{national} \leftrightarrow (\varphi, \lambda)_{national} \leftrightarrow (x, y)_{national} \leftrightarrow (x, y)_{local} \quad (1)$$

Fortunately there is a simple way of shortening the above sequence. The following sections describe a method which can be applied in a number of situations.

The Method

The method is based on the following assumption:

Given a geodetic datum A and a plane rectangular system of another datum B, it is possible to find a set of projection parameters (using the same projection as used for the given plane coordinates of datum B) to define a plane system of datum A, which approximates the plane system of datum B.

The idea is that possible deficiancies in scale and orientation of the plane system B can be modelled by a suitable choice of projection parameters. Commonly used projections with non-zero convergence of meridians like the Transverse Mercator (Gauss-Krüger) and the Lambert Conformal Conic (Conical Orthomorphic) rotate the plane system when the central meridian is changed. However, a badly oriented Mercator system cannot be well modelled as the convergence of meridians of this projection equals zero. Also for areas situated on both sides of the equator the method will not be able to model a rotation as the convergence of meridians changes sign at the equator in most projections.

Apart from some unrealistic cases, the plane system A will never be coincident with the plane system B in a strict mathematical sense. The discrepancy between the systems is caused by difference in curvature of the ellipsoids and by tilting and displacement of the ellipsoids relative each other. However, the effects of these differences will in most cases be quite moderate.

If the differences between the plane systems are acceptable, (1) can be reduced to one simple transformation step

$$(\varphi,\lambda)_{\text{global}} \leftrightarrow (x,y)_{\text{local}} \qquad (2)$$

For the Transverse Mercator (Gauss-Krüger) projection an algorithm has been developed, which can be used for computation of the parameters of the projection. In short the procedure is as follows. The prerequisites are: A set of control points with known coordinates $(\varphi,\lambda)_A$ and $(x,y)_B$ and the equatorial radius and the flattening of the ellipsoid of datum A. Notice that the ellipsoid of the plane system is not needed in the computations. The northing and easting are functions of latitude and longitude but also of the the projection parameters:

$$x = f(\varphi,\lambda,\lambda_0,k_0,N_0,E_0) \qquad (3a)$$

$$y = g(\varphi,\lambda,\lambda_0,k_0,N_0,E_0) \qquad (3b)$$

where k_0 is the scale factor along the central meridian λ_0 and N_0 and E_0 are the false northing and easting respectively.

Equations (3a) and (3b) are linearised by Taylor expansion around approximate values of the sought parameters. Each control point will give rise to two linear equations of a linear equation system. The system is solved by the method of least squares to estimate corrections to the approximate values. The whole procedure is iterated if necessary.

Accuracy

The method has been tested in a number of examples. The plane coordinates in all examples below are obtained by using the Transverse Mercator projection.

Example 1

Sweden, transformation between the national map grid $(x,y)_{RT\ 90\ 2.5\ gon\ V}$ and global geodetic coordinates $(\varphi,\lambda)_{SWEREF\ 93}$, [1, 2]. Area under consideration: $56° < \varphi < 68°$ and $12° < \lambda < 23°$ (covering most of Sweden). Number of control points: 20.

Control points in this case have been the stations of the permanent Swedish GPS network. The maximum radial (2D) difference, in any of the control points, between the grid coordinates of the global reference frame and the original coordinates of the national grid amounts to 0.126 m. The r.m.s. of the differences is 0.066 m (2D).

The parameters have been checked in 70 other stations of the triangulation network giving a maximum difference of 0.243 m and r.m.s. 0.081 m.

All differences in this example include the errors in the first order triangulation and the GPS positional errors.

Example 2

Sweden, transformation between the local grid *(x,y)* of the city of Borås and global geodetic coordinates $(\varphi,\lambda)_{SWEREF\ 93}$. Area under consideration: 50 by 61 km. Number of control points: 17.

Maximum difference (2D) in any control point 0.008 m, r.m.s. 0.004 m. No measuring errors included.

Example 3

Finland, transformation between the national grid $(x,y)_{KKJ}$ and global geodetic coordinates $(\varphi,\lambda)_{EUREF89}$. Area under consideration: 60°<φ<70° and 19.5°<λ<31.5° (covering to the most part of Finland). Number of control points: 144.

Coordinates of the control points used for computation of the projection parameters are obtained through transformation of a uniform grid of points from the global system to the plane system KKJ according to sequence (1); cf. Matti Ollikainen **[3]**.

Maximum difference (2D) in any control point 0.089 m., r.m.s. 0.027 m. No measuring errors included.

Example 4

Australia, transformation between the national grid $(x,y)_{AMG84\ UTM\ 50}$ and global geodetic coordinates $(\varphi,\lambda)_{GDA}$. Area under consideration: -35°<φ<-20° and 114°<λ<120° (covering the part of Australia within UTM zone 50). Number of control points: 112.

Coordinates of the control points used for computation of the projection parameters are obtained by transformation of a uniform grid of points from the global system to the plane system according to sequence (1). The transformation has been described in detail by W. Featherstone **[4]**.

Maximum difference (2D) in any control point 1.048 m, r.m.s. 0.499 m. No measuring errors included.

Discussion

Obviously the method makes the 7-parameter transformation superfluous in most cartographic applications. For instance UTM coordinates of local datums can easily be transformed to UTM coordinates of a global reference frame.

What is more important, the method offers a simple and smooth way of replacing local datums by a global reference frame. For historical reasons, many national datums have a rather fuzzy definition. These countries might benefit from switching to a modern global reference frame.

For example, in Sweden the national datum is based on the Bessel 1841 ellipsoid. No specific datum point exists and the definition of the national geoid may be questioned. In addition, more than one hundred cities and municipalities in Sweden use their own systems. Most of these systems exist only as plane grid systems, lacking a rigorous tie to a geodetic reference frame.

Introducing a new geodetic reference frame automatically give rise to the question: What plane grid should be used for surveying and mapping? Replacing the grid system often leads to new map sheet divisions, updating of the positional information in all databases a.s.o., operations that are very costly and time consuming. For example, the total investments in large scale maps and geographic and cartographic databases in Sweden amount to billions of pounds.

The following scenario illustrates how the proposed method could be utilized.

Like most countries in western Europe, Sweden has made a densification of the European reference frame EUREF 89. Coordinates have been computed for the 21 stations of the permanent GPS network. These coordinates constitute the Swedish densification under the name SWEREF 93.

By the suggested method, Transverse Mercator projection parameters can be defined, which map the geodetic coordinates of SWEREF 93 of the GRS 80 ellipsoid to plane grid coordinates being very close to the plane system RT 90 2.5 gon V, based on the Bessel ellipsoid now in use. The maximum difference is estimated at 0.25 m. Being coincident with RT 90 2.5 gon V on the 0.25 meter level, the new system can be used for the national map series, without causing any additional costs neither to the map users nor to the map producers.

For cities and municipalities like Borås, further densifications of SWEREF 93 should be made, using state of the art GPS technique. In a similar way as for the national grid, a new accurate local plane system can be introduced. From example 2, one can deduce that any deviations between the new system and the old plane system is most probably caused by bad geometry inherent in the old system. As stated before, all existing databases, digital maps a.s.o. can be retained.

Summing up

The method makes it possible to introduce a well defined global datum without any costly revisions of the plane system used for presentation and everyday work in surveying and mapping. Not being forced to use the 7-parameter transformation, will relieve cartographers and users of GPS, GIS a.s.o. of the necessity of taking an advanced course in geodesy.

References

1. Reit, B.-G., 1995. SWEREF 93 - a Swedish Reference System for GPS. *Reports of the Finnish Geodetic Institute,* No. 95:4 (Editor M. Vermeer): 139-144.

2. Reit, B.-G., 1995. Swedish Coordinate Systems. *Reports of the Finnish Geodetic Institute,* No. 95:4 (Editor M. Vermeer): 145-150.

3. Ollikainen, M., 1995. The Finnish Geodetic Coordinate Systems and the Realisation of the EUREF-89 in Finland. *Reports of the Finnish Geodetic Institute,* No. 95:4 (Editor M. Vermeer): 151-166.

4. Featherstone, W., 1996. An Updated Explanation of the Geocentric Datum of Australia (GDA) and its Effects Upon Future Mapping. *The Australian Surveyor,* **[2]**: 121-130.

Numerical example 1

Transformation between the national map grid $(x,y)_{RT\ 90\ 2.5\ gon\ V}$ and the global geodetic reference frame $(\varphi,\lambda)_{SWEREF\ 93}$.

Area under consideration: 56°<φ<68° and 12°<λ< 23° (covering most of Sweden).

Number of control points: 20

Ellipsoid	GRS 80

Projections parameters (Transverse Mercator):

Central meridian	15° 48' 22.614069"
Scale	1.00000564208
False northing	-667.939 m
False easting	1500064.071 m
Latitude of origin	0.000°

Residuals (network distortions incl.)

Station	dx[m]	dy[m]
ARJE	.010	-.021
BURE	-.063	.027
SKEL	-.043	.027
HASS	.076	.001
JONK	-.046	.005
KARL	.004	-.015
KIRU	.123	-.010
KLIN	.088	-.058
LEKS	-.006	.023
LOVO	.053	.014
MART	-.007	-.025
NORR	-.037	-.023
ONSA	-.035	.101
OSKA	.019	-.032
OSTE	-.067	-.056
OVER	.066	.104
SUND	-.024	-.020
SVEG	-.035	-.027
UMEA	-.036	-.001
VANE	-.015	.021
VILH	-.027	-.034
R.m.s.	.052	.041
Max	.123	.104
R.m.s., 2D	.066	

Numerical example 2

Transformation between the local grid (x,y) of the city of Borås and the global geodetic reference frame $(\varphi,\lambda)_{SWEREF\ 93}$.

Area under consideration: 50 by 60 km.

Number of control points: 17

Ellipsoid	GRS 80

Projections parameters (Transverse Mercator):

Central meridian	13° 33' 48.381579"
Scale	1.00000527297
False northing	-6360553.580 m
False easting	100452.148 m
Latitude of origin	0.000°

Residuals (network distortions not incl.)

Station	dx[m]	dy[m]
772160	-.001	.000
762851	.000	.001
772470	-.003	.000
772280	-.001	-.002
762770	.002	.002
762710	-.004	.001
772100	-.001	-.003
772330	.000	.000
772650	-.002	.003
773400	-.006	-.003
771680	.008	-.003
772611	.004	.001
772091	.001	-.003
762792	.004	-.001
762791	.004	-.001
762641	-.002	.004
762731	-.002	.003
R.m.s.	.003	.002
Max	.008	.004
R.m.s., 2D	.004	

0282

STATE LAND SERVICE OF LATVIAN REPUBLIC
NATIONAL SURVEYING CENTRE

GPS IN LATVIA: PAST, PRESENT AND FUTURE

1994-1998

REPORT PRESENTED TO THE 7TH EUROPEAN MEETING OF THE INTERNATIONAL INFORMATION SUB-COMMITTEE (IISC) OF THE CIVIL GPS SERVICE INTERFACE COMMITTEE (CGSIC)

GÄVLE, SWEDEN
DECEMBER 3-4, 1998

Jevgenijs Vasiljevs

Geodesy Department
Technical Information and Standards Division

Tel: 371-7213628 Fax: 371-7227858
E-mail: zee@lzkc.org.lv

GPS IN LATVIA: PAST, PRESENT AND FUTURE

1994-1998

ABSTRACT

As a result of EUREF.BAL92 campaign the coordinates of 4 GPS points had been defined in the territory of Latvia. This campaign was the beginning of large-scale works for creation of geodetic network using of Global Positioning System.
The GPS works of period 1992-1993 are described in the report [1] that was presented for the *Proceedings, NorFA Urgency Seminar, Espoo, Finland, June 27-29,1994.*
In this report are considered GPS works and its applications of period 1994-1998 that have been conducted by Latvian specialists of National Surveying Centre of State Land Service. The National Surveying Centre was founded in 1994. The Geodetic Network Division of Geodesy Department of aforesaid Centre have occupied with tasks of creation and development of National Geodetic Network.

1. PAST: THE TRANSFORMATION OF COORDINATES OF TRIANGULATION POINTS.

1.1. THE STATUS OF TRIANGULATION AND LOCAL NETWORKS.

At the beginning of 1994 there were 5433 different orders triangulation points in the Latvia (Figure 1). These points were created in the period of 1924-1980. The coordinates of triangulation points had been published in the "Catalogues of coordinates of triangulation points for the sheet of map of scale 1: 200 000" in 1980.

Table 1. Characteristics of triangulation

Order	Account of points	Relative accuracy	Length of baseline (km)	Precision in catalogue (m)
group A				
1	193	1: 400 000	20-50	0.01
2	772	1: 300 000	7-15	0.01
3	794	1: 200 000	5-8	0.01
4	245	1: 100 000	2-5	0.01
group B				
2	75			0.1
3	717			0.1
4	2077			0.1
SGS-30	560			1

Catalogues contain the plane coordinates X and Y of points to within 0.01 m, 0.1 m and 1 m depending on order of network in Coordinate System Pulkovo 1942 (Krasovsky ellipsoid, Gauss-Kruger Transversal Cylindrical projection) and the vertical (normal) coordinates H to within 0.001 and 0.1 m in Baltic Height System 1977 that was defined by geometrical leveling of I-IV classes and trigonometric leveling.

By November 01, 1991 State Enterprise of Projection and Information "MELIORPROJEKTS" had completed non-instrumental inspection of 1819 triangulation points of 1st, 2nd and 3rd orders.

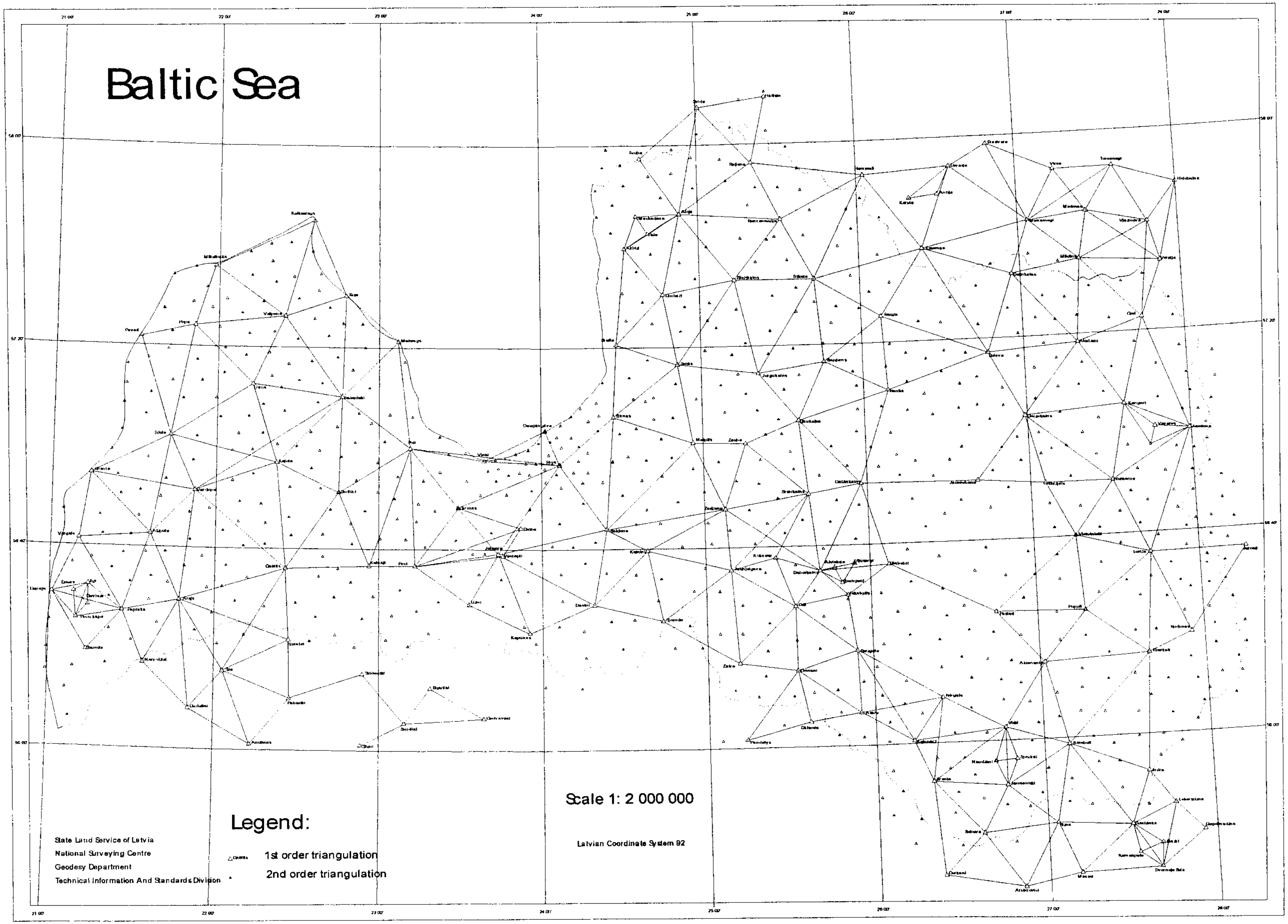


Figure 1. 1st and 2nd orders of triangulation, 1980.

Table 2. The Summary of inspection of triangulation points

Status	The quantity of points	Rate (per cent)
existed	977	53,7
not found	708	38,9
destroyed	134	7,4
Total	*1819*	*100 %*

It may be possible to suppose preservation of stated proportion (ratio) in Table 2 for all triangulation points. Thus, by analogy with these data next quantities will be take place:

Table 3. Supposed quantities of points

existed	2918
not found	2113
destroyed	402
Total	5433

The most part of triangulation points has from two to four underground centres, therefore, it can be restored by instrumental methods.

Besides that, local networks have existed in the more than 232 populated areas: 76 towns and 156 settlements.

These networks intended for topographic surveys and guaranteeing of building. All these networks was calculated as local systems, and only part of its (town systems) has reliable tie to state geodetic (triangulation) networks that allows to readjust or to transform local systems to the state geodetic coordinate system.

Aggregate quantity of points of local systems is approximately 13000. Overwhelming majority of local systems had been creating from 1975 to 1990. At present 25-50% of points have destroyed as a result of intensive building.

1.2. TRANSFORMATION OF THE TRIANGULATION.

At the beginning of 1994 necessity had arisen to regulate all existing geodetic networks for the realization of all geodetic works in the united coordinate system-Latvian Coordinate System-92 (LCS 92) and plane Transverse Mercator projection (with axis meridian=24° and scale factor on it=0.9996), because the large-scale geodetic works had expected for the conducting of the land reform in Latvia.

Taking into consideration that process of creation of completely new GPS network is not quick, it had been solved to implement this task by two ways:

1. to transform existing triangulation and local networks (as far as possible) into LCS-92 TM coordinate system;
2.
   b) after this and simultaneously to create uniform GPS network of 2nd order (G2);
   c) after this (and simultaneously) to create 3rd order GPS networks (G3) there, where G3 networks will have served for base of topographic and cadastral surveys etc.

In 1995 first part of this tack had solved by Geodesy Institute of Riga Technical University.[2].

1.2.1. GPS MEASUREMENTS IN GEODETIC (TRIANGULATION) NETWORK

As a result of GPS works in 1992-1993, 1st order of GPS network (G1) and the part of 2nd order (G2) had been calculated in coordinate system LCS-92 (fig.1). On the whole, triangulation points had been used for the creation of GPS network points (Table 4).

G1 points were the base of transformation of triangulation.
G2 points ensured the control and the estimation of accuracy.

Table 4. Matching GPS and triangulation points.

GPS order/ total points	Triangulation points (by orders)										
	1	2	3	4	2B	3B	4B	SGS-30	1.cat.	Metro triang.	local systems
G1/44	42*	2									
G2/178	1	56	32	11	3	10	19	9	1	14	8

* - point Rîga (M1884) - satellite tracking station

1.2.2. GEOMETRIC TIES OF G1 NETWORK

The concordance of transformation base points had been verified by the comparison of geometric ties of these points: lengths of baselines.

Considering that vertical deviation of Krasovsky ellipsoid and GRS80 ellipsoid is from 20 to 28 meters, baselines from Krasovsky ellipsoid had been reduced to GRS80 ellipsoid:

$$s' = s \bullet \left(1 - \frac{\Delta_\xi}{R}\right) \quad (1)$$

where $\Delta_\xi = \xi_{GRS80} - \xi_{KR}$,
ξ_{GRS80} and ξ_{KR} - - heights of corresponding geoid.
R - average radius of curvature (6387km).

The differences of geoid heights had been defined to within 2m (Table 5) for the guaranty of the reduction of lines with relative precision to within 1: 3 000 000.

Table 5. The differences of geoid heights.

Longitude (L°)	Δ_ξ (m)
21-22	27
22-24	25
24-27	23
27-28	20

The differences of the geometric ties:

$$\Delta s = s' - s_{GRS80},$$

where s_{GRS80} - the lengths of baselines defined in G1 network,

in G1 network had testified that the concordance of coordinates was good in the most part of territory: approximately 1: 500 000 (Table 6).

Considerable deviations were observed for the 7 points of G1 network: Aloja, Baldone, Jaunjelgava, Kalnâji, Kombuïi, Íirbiþi and Strante.

Table 6. The baselines and its differences.

Baseline points		The length of baseline			Δ_s (cm)
		s	s'	s_{LCS92}	
Aloja	Iirbiþi	24317.597	24317.509	24317.670	-16
Aloja	Rencçnmuiþa	37871.609	37871.473	37871.374	10
Aloja	Rûjiena	32996.431	32996.312	32996.215	10
Arâjs	Kabile	62352.107	62351.853	62351.388	47
Arâjs	Kalnâji	72183.205	72182.911	72182.037	87
Arâjs	Slamste	39272.618	39272.452	39272.324	13
Arâjs	Vçrgale	43726.926	43726.741	43726.557	18
Baldone	Dâviòi	28322.520	28322.418	28322.648	-23
Baldone	Jaunjelgava	49028.688	49028.511	49028.362	15
Baldone	Mâlpils	45721.083	45720.918	45720.772	15
Baldone	Rîga	31635.159	31635.045	31634.966	8
Dalbe	Baldone	32275.836	32275.715	32275.817	-10
Dalbe	Dâviòi	39563.727	39563.578	39563.516	6
Dalbe	Kalnâji	58761.663	58761.433	58761.365	7
Dalbe	Rîga	26218.369	26218.270	26218.367	-10
Dalbe	Ûziòi	34267.175	34267.041	34266.851	19
Gruþukalns	Alodzçni	33568.254	33568.149	33568.124	2
Gruþukalns	Kangari	37105.461	37105.345	37105.491	-15
Gruþukalns	Nesaules	50074.341	50074.161	50074.123	4
Gruþukalns	Rauza	64845.405	64845.171	64845.137	3
Gruþukalns	Slapjums	77389.085	77388.806	77388.852	-5
Gruþukalns	Zvidziena	27065.256	27065.159	27065.245	-9
Indra	Behova	65600.487	65600.261	65600.335	-7
Indra	Dzerkaïi	43712.645	43712.508	43712.467	4
Jaunjelgava	Dâviòi	52932.395	52932.204	52932.341	-14
Jaunjelgava	Mâlpils	49107.302	49107.125	49106.891	23
Jaunjelgava	Ormaòi	44424.999	44424.839	44425.165	-33
Jaunjelgava	Sestukalns	40549.964	40549.818	40549.641	18
Jaunjelgava	Silabebri	58915.064	58914.852	58915.099	-25
Kabile	Kalnâji	51436.618	51436.417	51435.932	48
Kabile	Poïi	50337.718	50337.521	50337.061	46
Kabile	Usma	30206.577	30206.459	30206.461	-0.2
Kalniðíi	Behova	42819.610	42819.456	42819.430	3
Kalniðíi	Kombuïi	57632.092	57631.893	57632.096	-20
Kalniðíi	Ormaòi	50548.437	50548.255	50548.058	20
Kalniðíi	Pastari	56734.687	56734.483	56734.445	4
Kangari	Alodzçni	28558.005	28557.916	28558.096	-18
Kangari	Zvidziena	52946.175	52946.001	52946.048	-5
Kombuïi	Behova	45852.983	45852.825	45852.856	-3
Kombuïi	Dzerkaïi	45243.159	45243.017	45243.027	-1
Kombuïi	Indra	31145.728	31145.630	31145.465	17
Kombuïi	Pastari	55715.621	55715.429	55715.503	-7
Ludza	Dzerkaïi	36929.050	36928.934	36928.942	-1
Ludza	Kangari	55278.320	55278.147	55278.281	-13
Ludza	Pastari	61765.353	61765.150	61765.141	1
Ludza	Zvidziena	57861.483	57861.293	57861.350	-6
Mâlpils	Rîga	53933.824	53933.630	53933.592	4
Mâlpils	Senks	29337.306	29337.200	29337.140	6
Mâlpils	Sestukalns	46920.213	46920.044	46920.212	-17

continued from previous page

Baseline points		The length of baseline			Δ_s (cm)
		s	s'	s_{LCS92}	
Mâlpils	Stirnas	31388.464	31388.351	31388.298	5
Mçrsrags	Kabile	63722.408	63722.159	63721.806	35
Mçrsrags	Kolka	54312.287	54312.074	54312.017	6
Mçrsrags	Poïi	39590.475	39590.475	39590.094	23
Mçrsrags	Usma	56594.189	56593.967	56593.585	38
Mçrsrags	Viòíi	54296.965	54296.752	54296.465	29
Nesaules	Sestukalns	35977.604	35977.474	35977.678	-20
Nesaules	Slapjums	43542.003	43541.846	43541.988	-14
Nesaules	Zvidziena	43266.775	43266.619	43266.533	9
Pastari	Dzerkaïi	58772.822	58772.629	58772.637	-1
Pastari	Zvidziena	46266.925	46266.758	46267.013	-25
Pavâri	Kolka	77203.350	77203.036	77202.856	18
Pavâri	Strante	53557.699	53557.473	53557.129	34
Pavâri	Usma	45352.627	45352.435	45352.315	12
Pavâri	Valpene	54246.919	54246.698	54246.521	18
Pavâri	Vârdupe	60132.733	60132.479	60132.341	14
Poïi	Kalnâji	46140.487	46140.306	46140.152	15
Poïi	Viòíi	27916.369	27916.260	27916.138	12
Rauza	Alodzçni	73812.258	73811.992	73812.109	-12
Rencçnmuiþa	Rauza	51595.521	51595.335	51595.377	-4
Rencçnmuiþa	Rûjiena	23479.066	23478.981	23478.897	8
Senks	Aloja	55378.442	55378.243	55378.434	-19
Senks	Íirbiþi	46956.631	46956.462	46956.741	-28
Senks	Rencçnmuiþa	66113.684	66113.446	66113.579	-13
Silabebri	Kalniðíi	65893.590	65893.353	65893.199	15
Silabebri	Nesaules	40513.785	40513.639	40513.708	-7
Silabebri	Ormaòi	52002.010	52001.823	52001.963	-14
Silabebri	Pastari	43472.648	43472.491	43472.417	7
Silabebri	Sestukalns	39605.981	39605.838	39605.898	-6
Silabebri	Zvidziena	53048.272	53048.081	53048.145	-6
Slapjums	Mâlpils	57525.355	57525.148	57525.240	-9
Slapjums	Rauza	27196.001	27195.903	27195.919	-2
Slapjums	Recçnmuiþa	54827.908	54827.711	54827.752	-4
Slapjums	Senks	54822.218	54822.021	54822.080	-6
Slapjums	Sestukalns	49028.012	49027.835	49027.990	-15
Stirnas	Íirbiþi	62090.404	62090.180	62090.431	-25
Stirnas	Rîga	29227.913	29227.808	29227.815	-1
Stirnas	Senks	31016.897	31016.785	31016.772	1
Stirnas	Viòíi	51243.244	51243.059	51243.066	-1
Ûziòi	Dâviòi	47166.687	47166.510	47166.498	1
Ûziòi	Kalnâji	40267.026	40266.868	40266.879	-1
Valpene	Kolka	36562.523	36562.380	36562.334	5
Valpene	Mçrsrags	43309.477	43309.307	43309.116	19
Valpene	Usma	27947.912	27947.803	27947.637	17
Vârdupe	Arâjs	40954.679	40954.506	40954.190	32
Vârdupe	Kabile	32205.700	32205.574	32205.427	15
Vârdupe	Strante	39115.031	39114.866	39114.715	15
Vârdupe	Usma	44509.358	44509.177	44509.123	5
Vârdupe	Vçrgale	46662.436	46662.239	46662.058	18
Vçrgale	Slamste	41199.002	41198.828	41198.640	19

continued from previous page

Baseline points		The length of baseline			Δ_s (cm)
		s	s'	s_{LCS92}	
Vçrgale	Strante	24570.915	24570.811	24570.983	-17
Viòíi	Dalbe	28399.331	28399.220	28399.070	15
Viòíi	Kalnâji	58130.560	58130.332	58130.097	24
Viòíi	Rîga	25281.124	25281.025	25280.957	7

1.2.3. THE ANALYSIS AND ELIMINATION OF COORDINATES CONTRADICTIONS.

Possible reasons of network contradictions:
- displacements of centre of points; (local contradiction)
- measurement errors of triangulation networks.

The ways of accurate definition of situation:
1) to find lower centre of points and to define dislocation of upper centre;
2) to make the GPS measuring and to define geometric ties to the nearest triangulation points.

State Land Service of Latvia had bought four GPS Trimble 4000SSE receivers in the September 1994. These GPS receivers were used in the earliest projects for the execution of accurate definition by 2nd way ("Strantes" and "Jaunjelgavas" projects). In all cases local nature of contradictions had been corroborated by the differences of geometric ties. The alteration of mark had been stated by the relation to nearest corresponding points of G1 network. It had testified the concept about dislocation of upper centres and non-correspondence of the present location of marks to the its coordinates in coordinate system Pulkovo42.
Taking by analogy that the deformations of other points were local, in all probability too, new Pulkovo42 coordinates had been computed for all 7 contradiction points.

1.3. TRANSFORMATION METHOD.

1.3.1. THE MODEL OF TRANSFORMATION.

At present various mathematical models are proposed for a coordinates transformation: Helmert, linear, polynomic etc. Modification can be for these models: Cartesian (X,Y,Z), on surface of ellipsoid (B,L) and on the plane (x,y). Because in the present case only normal heights of points had known sufficiently precise in coordinate system Pulkovo42, so linear transformation on the ellipsoid had been used, as meeting the dimensions of Latvia and as acceptable for the mentioned time:

$$G_2 = G_1 + AG_1 + \Delta_G, \qquad (2)$$

where $G_1 = \begin{pmatrix} B_1 \\ L_1 \end{pmatrix}$, $G_2 = \begin{pmatrix} B_2 \\ L_2 \end{pmatrix}$ - transforming and having transformed geodetic coordinates (latitude and longitude);

$A = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}$ - the matrix of transformation parameters;

$\Delta_G = \begin{pmatrix} \Delta_B \\ \Delta_L \end{pmatrix}$ - the parameters of the linear displacement to the direction of the meridian and the parallel.

1.3.2. THE REGION OF THE TRANSFORMATION.

An utilization of any transformation models can be various: for a large or small transformation region. For example, one aggregate of transformation parameters can take to the whole of State territory in one case, it can take to a limited territory in other case and it can take to a quite small part of the territory in another case. The method of least squares is usually used to determine the transformation parameters of a large region. If the number of the transformation base points is greater than 3, so in that case approximation corrections of parameters, or transformation residuals to the base points of transformation have arisen. If given coordinates of transformation base points have differed by values from the coordinates of the transformed points, so the transformation of geodetic network with the large residuals is not considered a successful transformation.

Having appraise the possible solution, the transformation by the G1 network triangles was voted the better. It eliminate completely both the uncertainty of transformation limits and the residuals, because the transformation parameters A and Δ_G are determined definitely (r=0) by 3 initial points.

Using this method, it has to verify the concordance of coordinates of base points beforehand. This verification had accomplished for the G1 network points. In cases when transformation base network has been supplemented, for example, with matching points of G2 network, so beforehand it can transform checking points by the G1 network triangles.

1.4. THE CONTROL OF THE TRANSFORMATION

GPS measurements of transformed triangulation points allow to conduct the estimation of existed geodetic network and the control of the transformation.

1.4.1. THE ACCURACY OF THE TRANSFORMATION.

The differences of transformed and GPS coordinates define the accuracy of the transformation confidently (Table 7). The accuracy of transformation depend on the accuracy of transforming points mainly. The differences of transformed and GPS coordinates of matching triangulation points of 3rd and 4th orders (Table 8) are similar to the differences that have been obtaining by the transformation inside the G1 network triangles (Table 9).
Statistic analysis of the G2 network transformation data allows to conclude next:

1. Having been computed by the transformation according to the G1 network triangles, triangulation points are determined in the new coordinate system by the next mean standard errors ellipses:

1$_{st}$ and 2$_{nd}$ orders -	0,05m
3$_{rd}$ class	0,06m
4$_{th}$ class	0,08m
B category (2nd-4th orders)	0,12m
B category SGS-30	0.50m

2. Having been transformed according to lesser triangles the improvement of the accuracy applies only to G2 network points proper. It has not an considerable influence on the aggregate of other points.

Table 7. The transformation residuals of coordinates transformed by G1 network triangles.

Point	Transformation differences B (m)	L (m)
"Rīgas" project		
Cenas	0.07	0.04
Dobeles	-0.06	-0.08
ìiboti	-0.01	-0.02
Kandava	0.03	0.01
Klapkalnciems	0.94	-0.38
Íekava	-0.01	0.05
Lîdumi	0.04	0.01
Sauðí	-0.01	0.00
Skujas	0.00	0.03
Vecâíi	0.02	0.00
Zones	0.02	-0.04
Buïïuciems_G	0.03	-0.08
Dubulti_GP	0.02	-0.07
Muls_GP	0.02	0.00
Olaine_GP	0.07	0.04
Remeikas_GP	0.07	0.00
Rîtabuïïi_GP	0.04	-0.05
Vçveri_GP	0.03	0.01
Bçrnu_slimn.	0.03	0.01
Bolderâja	0.04	-0.03
Gaiïezers	0.04	-0.02
Ilga	0.03	0.00
2.ÇCK	0.06	0.02
Imanta	0.03	0.00
Komutators	0.02	0.01
Krasta	0.05	0.00
Íengarags	0.06	0.01
Lampu_rûpn.	0.04	-0.03
Latvija	0.04	0.02
Purvciems	0.04	0.00
TEC-1	0.04	-0.01
TEC-2	0.09	0.02
Gaidas	0.00	-0.02
Iecava	-0.10	0.00
Jaunplatone	0.04	0.09
Odiòi	0.02	0.01
Popâji	0.09	0.00
Puèas	0.01	-0.14
Èierkurkalns	-0.34	-0.02
Garozes	-0.01	-0.08
Strauta	-0.08	-0.05
Streznas	-0.04	0.01
42	-2.81	-2.55
Ïitovskij	-0.08	0.00
Sabile	-0.01	-0.05
Smârde	0.05	-0.11
Vircava2	0.23	-0.05

Point	Transformation differences B (m)	L (m)
"Ventspils" project		
Alkõòi	0.09	-0.70
Âþi1	-0.12	0.10
Bezmeri	-0.07	0.04
Dâniòi	-0.03	0.09
Kalnieki	-0.02	0.05
Kalniòi	-0.03	0.08
Lepsti	0.00	0.12
Medòi	-0.02	0.14
Ozoli	0.02	0.20
Purlîdumi	-0.07	0.07
Rûgumi	-0.11	0.06
Târgale	0.02	0.11
Tetersâti	-0.07	0.06
Bebri	-0.16	0.08
Dzirnavas	-0.15	0.01
Greizis-Kalni	-0.01	0.04
Kalmeþi	0.02	0.01
Sniíeri	-0.06	0.03
Vîtoli	0.05	0.15
Bçrzciems	-0.08	0.05
Vecâ_Annahitte	0.07	0.11
Dandzîtes	0.02	-0.04
Emari	0.12	-0.01
Packule2	0.07	0.19
Tomas	0.02	-0.16
3	-1.06	-3.91
13	-0.78	0.50
108	-0.27	0.57
125	-0.58	-0.04
Dzelþi	0.05	0.26
Kâpas	0.12	0.12
Muita	0.13	0.24
pp13	0.05	0.15
"Strantes" project		
Adze	0.06	0.05
Avoti	0.00	0.02
Jûrkalne	0.02	0.03
Kalnieki	-0.02	0.05
Novadlauki	0.01	0.05
Pievika	0.06	-0.01
Sâtkalni	0.03	0.00
Feldmanis	0.02	-0.05
Gardze	-0.06	0.13
Knubi	-0.01	0.05
Laivnieki	0.22	-0.12
Gudenieki	-0.05	0.06
Sniíeri	0.10	-0.02

continued from previous page

Point	Transformation differences	
	B (m)	L (m)
"Valkas" project		
Bçrzs	0.00	0.01
Burga	-0.08	-0.01
Burtnieki	0.04	0.06
Galaturi	0.07	0.01
Kauguri	0.08	0.04
Lietnis	0.03	0.00
Mâlaiòi	0.06	0.06
Zâbaks	0.03	-0.01
Arluika	-0.03	0.00
Brenguïi	0.02	-0.02
Dindiòi	0.08	0.03
Çvele	-0.01	0.00
Jaunâmuiþa	-0.07	-0.11
Meþmuiþa	0.02	0.03
Muiþnieki	0.03	0.02
Salânieði	0.05	-0.14
Sîmaòi	0.05	0.00
Skapari	-0.01	0.03
Vireði	-0.10	-0.05
Erìeme	-0.20	-0.08
Ezeriòi	-0.10	-0.07
Kârïi	-0.10	-0.04
Smilgas	-0.03	0.01
Zalmi	-0.11	-0.04
Brikuþi	0.07	0.05
Dûíeri	-0.19	0.31
Íipji	0.12	0.04
Kaupji	-0.01	0.12
Kraòïi	-0.11	-0.14
Lamsteri	-0.06	-0.03
Roòi	-0.09	0.23
Sûcis	0.03	0.11
Teièi	-0.25	-0.03
pp8562	0.16	-0.09

Point	Transformation differences	
	B (m)	L (m)
Lancenieki	0.04	-0.02
Malarâji	-0.06	0.01
Upenieki	-0.06	-0.02
Kalçji	0.22	0.62
Pauòi	-0.49	-0.06
Rîdznieki	0.49	-0.10
Robeþi	0.39	0.45
Kalnamuiþa	-0.03	-0.02
pp73	-0.02	-0.01
"Jaunjelgavas" project		
Kalniòi	0.07	0.09
Briedâni	0.09	0.00
Grebïukalns	0.09	-0.05
Íekava	-0.01	0.05
Lielzalve	-0.11	-0.08
Menta	0.03	-0.06
Oði	0.09	0.10
Surìenieks	0.06	0.08
Visdarbi	-0.14	-0.06
Vîzentâle	0.11	0.03
Zalaki	0.04	0.00
Annas	-0.01	0.03
Beteri	0.25	0.06
Íediòi	0.10	0.02
Skrîveri	0.19	0.01
Svelnieki	0.08	0.09
Mûrmuiþa	-0.31	0.01
Buði	0.07	-0.11
Kârkli	-0.05	-0.08
Kranciems	-0.03	0.20
Rudupe	0.28	0.11
Taurkalne	0.10	-0.07
Adâmiòi	-0.02	0.03
Austrumi	0.30	-0.05
Teikulejas	-0.02	-0.16
Vallenburgas	-0.15	0.05
Zvirgzde	0.03	0.07
pp8812	0.17	-0.01

Table 8. The residuals of the coordinates transformed by the small triangles.

Points	The differences of the coordinates	
	B (m)	L (m)
"Rîgas" project		
Gaidas	0.01	-0.02
Iecava	-0.07	0.03
Jaunplatone	0.04	0.09
Odiòi	-0.05	0.03
Propâji	0.04	-0.03
Puèas	-0.05	-0.15
Garozes	0.03	-0.06
Strauta	-0.03	0.00
Streznas	-0.02	0.03
"Jaunjelgavas" project		
Annas	-0.03	0.01
Beteri	0.21	0.06
Ìediòi	0.07	-0.02
Skrîveri	0.19	0.01
Svelnieki	0.08	0.07
"Strantes project		
Feldmanis	0.02	-0.05
Garzde	-0.07	0.04
Knubi	0.00	0.02
Laivnieki	0.23	-0.13
Gudenieki	-0.09	0.00
Sniíeri	0.06	-0.03

Points	The differences of the coordinates	
	B (m)	L (m)
"Ventspils" project		
Bebri	-0.07	0.02
Dzirnavas	-0.09	-0.04
Greizis-Kalni	-0.02	-0.02
Kalmeþi	0.02	0.00
Sniíeri	0.00	0.00
Vîtoli	0.03	0.00
"Valkas" project		
Arluika	-0.03	0.00
Brenguïi	-0.03	-0.03
Dindiòi	0.10	0.04
Çvele	-0.03	0.00
Jaunâmuiþa	-0.08	-0.11
Meþmuiþa	0.01	0.02
Muiþnieki	0.01	-0.01
Silanti	0.05	-0.15
Sîmaòi	0.01	-0.01
Skapari	-0.01	0.01
Virieði	-0.10	-0.05
Ezeriòi	-0.10	-0.07
Çrìeme	-0.15	-0.08
Kârïi	-0.10	-0.04
Smilgas	0.02	0.02
Zalmi	-0.12	-0.04

1.4.2. THE THICKENING OF TRANSFORMATION BASE NETWORK.

It can possible to include any matching points of G2 network to the transformation base network, if it has been verified by the transformation according to the parameters of the G1 network triangles. The control results are the transformation residuals (the differences of transformed and GPS coordinates), that must not be larger than standard error ellipse of corresponding category multiplied by 3, exactly:

- 24 cm for the points of A category triangulation;
- 36 cm for the points of B category triangulation.

If residuals are larger (for example, Alkðòi - table 7) it is considered points has been moved somewhere else or has not been identified rightly.

In the future it is necessary to include triangulation points into G2 network only in that cases when its accuracy is required to improve.

Table 9. Comparison of coordinate residuals.

Points	Residuals by G1 triangles B (m)	Residuals by G1 triangles L (m)	Residuals by small triangles B (m)	Residuals by small triangles L (m)
"Rîgas" project				
Gaidas	0.01	-0.02	0.00	-0.02
Iecava	-0.07	0.03	-0.10	0.00
Jaunplatone	0.04	0.09	0.04	0.09
Odiòi	-0.05	0.03	0.02	0.01
Popâji	0.04	-0.03	0.09	0.00
Puèas	-0.05	-0.15	0.01	-0.14
Garozes	0.03	-0.06	-0.01	-0.08
Strauta	-0.03	0.00	-0.08	-0.05
Streznas	-0.02	0.03	-0.04	0.01
"Jaunjelgavas" project				
Annas	-0.03	0.01	-0.01	0.03
Beteri	0.21	0.06	0.25	0.06
Iediòi	0.07	-0.02	0.10	0.02
Skrîveri	0.19	0.01	0.19	0.01
Svelnieki	0.08	0.07	0.08	0.09
"Strantes project				
Feldmanis	0.02	-0.05	0.02	-0.05
Gardze	-0.07	0.04	-0.06	0.13
Knubi	0.00	0.02	-0.01	0.05
Laivnieki	0.23	-0.13	0.22	-0.12
Gudenieki	-0.09	0.00	-0.05	0.06
Sòikeri	0.06	-0.03	0.10	-0.02

Points	Residuals by G1 triangles B (m)	Residuals by G1 triangles L (m)	Residuals by small triangles B (m)	Residuals by small triangles L (m)
"Ventspils" project				
Bebri	-0.07	0.02	-0.16	0.08
Dzirnavas	-0.09	-0.04	-0.15	0.01
Greizis-Kalni	-0.02	-0.02	-0.01	0.04
Kalmeþi	0.02	0.00	0.02	0.01
Sòikeri	0.00	0.00	-0.06	0.03
Vîtoli	0.03	0.00	0.05	0.15
"Valkas" project				
Arluika	-0.03	0.00	-0.03	0.00
Brenguïi	-0.03	-0.03	0.02	-0.02
Dindiòi	0.10	0.04	0.08	0.03
Çvele	-0.03	0.00	-0.01	0.00
Jaunâmuiþa	-0.08	-0.11	-0.07	-0.11
Meþmuiþa	0.01	0.02	0.02	0.03
Muiþnieki	0.01	-0.01	0.03	0.02
Silaniti	0.05	-0.15	0.05	-0.14
Sîmaòi	0.01	-0.01	0.05	0.00
Skapari	-0.01	0.01	-0.01	0.03
Vireõi	-0.10	-0.05	-0.10	-0.05
Ezeriòi	-0.10	-0.07	-0.10	-0.07
Çrìeme	-0.15	-0.08	-0.20	-0.08
Kârïi	-0.10	-0.04	-0.10	-0.04
Smilgas	0.02	0.02	-0.03	0.01
Zalmi	-0.12	-0.04	-0.11	-0.04

1.5 THE TRANSFORMATION OF THE LOCAL SYSTEMS.

In 1995 necessary transformation data was prepared for 23 towns. In all cases the main stage of transformation was definite transition from Pulkovo42 to LCS92 coordinate system, using united transformation base network (fig. 16). Defined in afore-cited sections transition was used for the transformation of local systems.

Since the transition of principle to the new Coordinate System had been provided, in this connection a meaning of G2 network have been changing. If before the transformation of triangulation the main task of G2 network had been to provide the control and to estimate the accuracy of transformation then at present next tasks are setting for G2 network:

1) to spread the united coordinate system LCS-92 to the whole of state territory (the standard error ellipsoid of any points must be equal or less than 25 mm relative to the reference points Riga;
2) to ensure the solutions of science problems (more precise definition to the geoid form and so on);
3) to be a base for the creation of networks of lower orders.

2. PRESENT

2.1. NATIONAL GPS NETWORK

In 1996 systematic work had been begun by Geodetic Network Division of Geodesy Department for the creation of uniform G2 network (the mean distance between points is 10-15 km). At the same time GPS measurements was implemented in the different G3 networks.
The points of G3 network have the diverse utilization: fotogrammetry control points, a base for small networks etc.

At the beginning of 1999 GPS networks of 2nd and 3rd orders have created on the 2/3 of the territory of Latvia (Figure 2).

Every project includes from 1 to 3 administrative districts.

As the information have been accumulating, separate projects of G2 network are readjusted in blocks using constantly supplemented covariance matrix. Each block includes 3-4 districts of Latvia.

2.2. EUVN'97

In period of 1994-1998 National Surveying Centre have taken a part only in one international GPS project: European Unified Vertical Network (EUVN'97) [3].
GPS observations had been accomplishing during May 21-29, 1997 on the 5 points (Figure 3):

- Riga - reference points of LCS-92;
- Skulte (LVO1) - Baltic Sea Level 93 tide gauge ;
- Liepaja (LVO2) and Ventspils (LVO3) - new GPS marker (tide gauge sites);
- Irbene (LVO4) - new GPS marker (astronomical point).

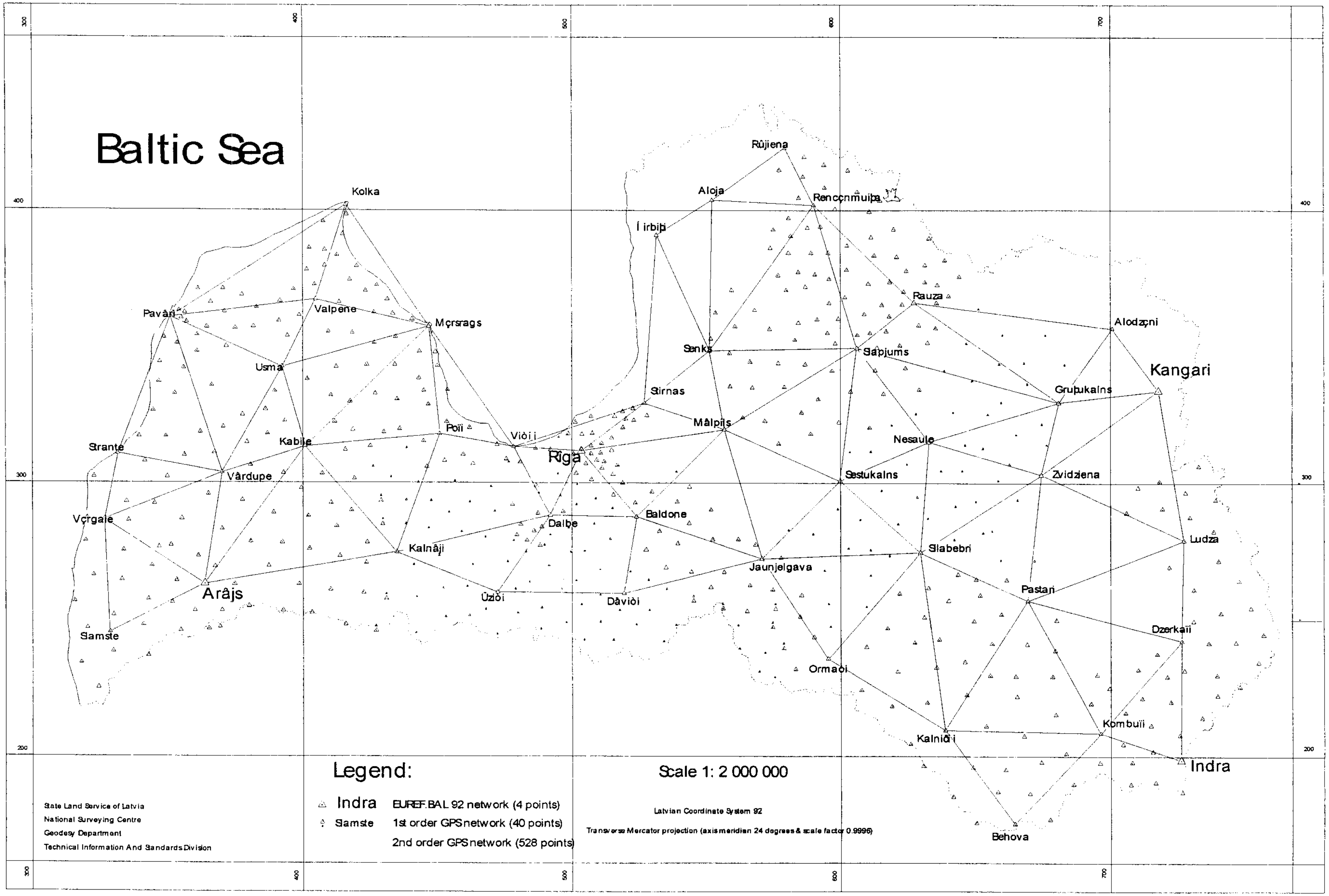


Figure 2. 1st and 2nd orders of GPS Network in Latvia, 1998.

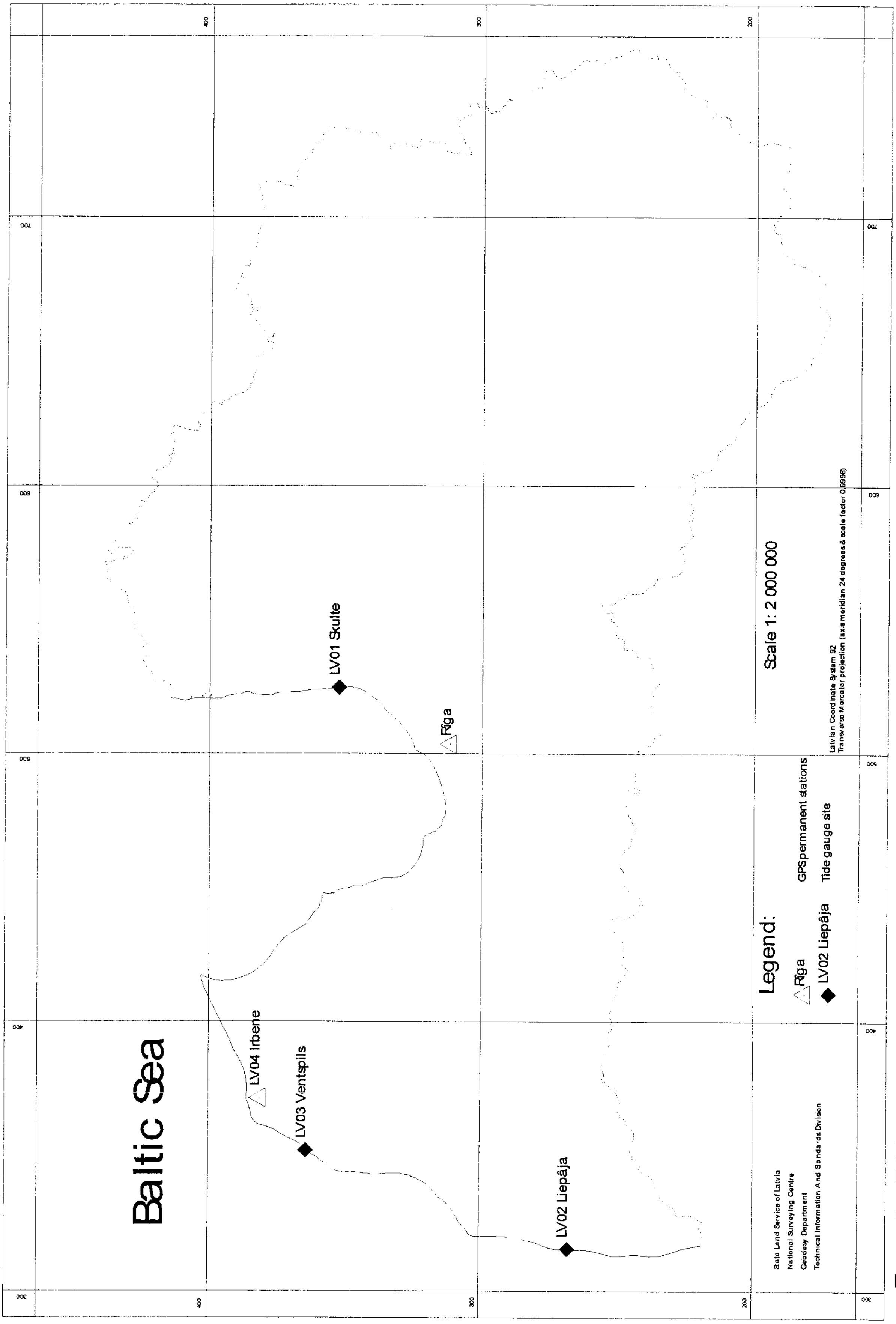


Figure 3. EUVN'97 points.

3. FUTURE: SUMMARY

3.1. NATIONAL GPS NETWORK.

In 1999 the uniform 2nd order GPS network will be created on the all state territory. After this the stage of total adjustment of G2 network and combined readjustment or G1 and G2 and comparative analysis will have been setting in.

3.2. GPS AND GEOID.

To this time the main task of different orders GPS networks has been to provide users with plane coordinates (X,Y) for the realization of the land reform. So approximately 15-20% of G1 and G2 networks points have physical heights of different orders determined by a base of United Precise Levelling Network (UPLN).
From 1999 it will be paying more attention to levelling network. All GPS points will be included in the levelling network.

REFERENCES

[1] J.Bikõe, K.Kukums, J.Lazdâns, A. Mazkalniòõ: *Coordinate systems, GPS activities and geoid determination in Latvia.* Reports of the Finnish Geodetic Institute, 95:4: **Coordinate systems, GPS activities and the geoid**. Helsinki,1995.

[2] V.Gremze, J.Lazdâns: *The transformation to State coordinate system LCS-92.* Technical University, Geodesy Institute. Rîga, 1995.

[3] *Report on the Results of the European Vertical Reference Network GPS Campaign 97 (EUVN'97).* Presented at the EUREF Symposium, June 10-12,1998. Bad Neuenahr-Ahrweiler, Germany.

0299

GPS APPLICATION AND DEVELOPMENT

IN POLAND - 1998

Polish Academy of Sciences

Committee on Space Research

CGSIC/IISC 7-th European Meeting

Gaevle, 3-4 December 1998

Scientific use of GPS for Geodesy and Geodynamics:

Permanent stations:

1. Borowa Góra - Institute of Geodesy and Cartography EUREF
2. Borowiec – Space Research Centre, PAS IGS/EUREF
3. Józefosław – Warsaw University of Technology IGS/EUREF
4. Lamkówko – Olsztyn Acad.of Agriculture &Technology IGS/EUREF
5. Wrocław – Academy of Agriculture EUREF

Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology continues to work as the

- **Regional Network Associate Analysis Center (RNAAC);**
- **EUREF Local Analysis Center - processes data from 16 European stations delivered on weekly basis to the CODE Center, Bern, Switzerland;**
- **CERGOP/EXTENDED SAGET Processing Center.**

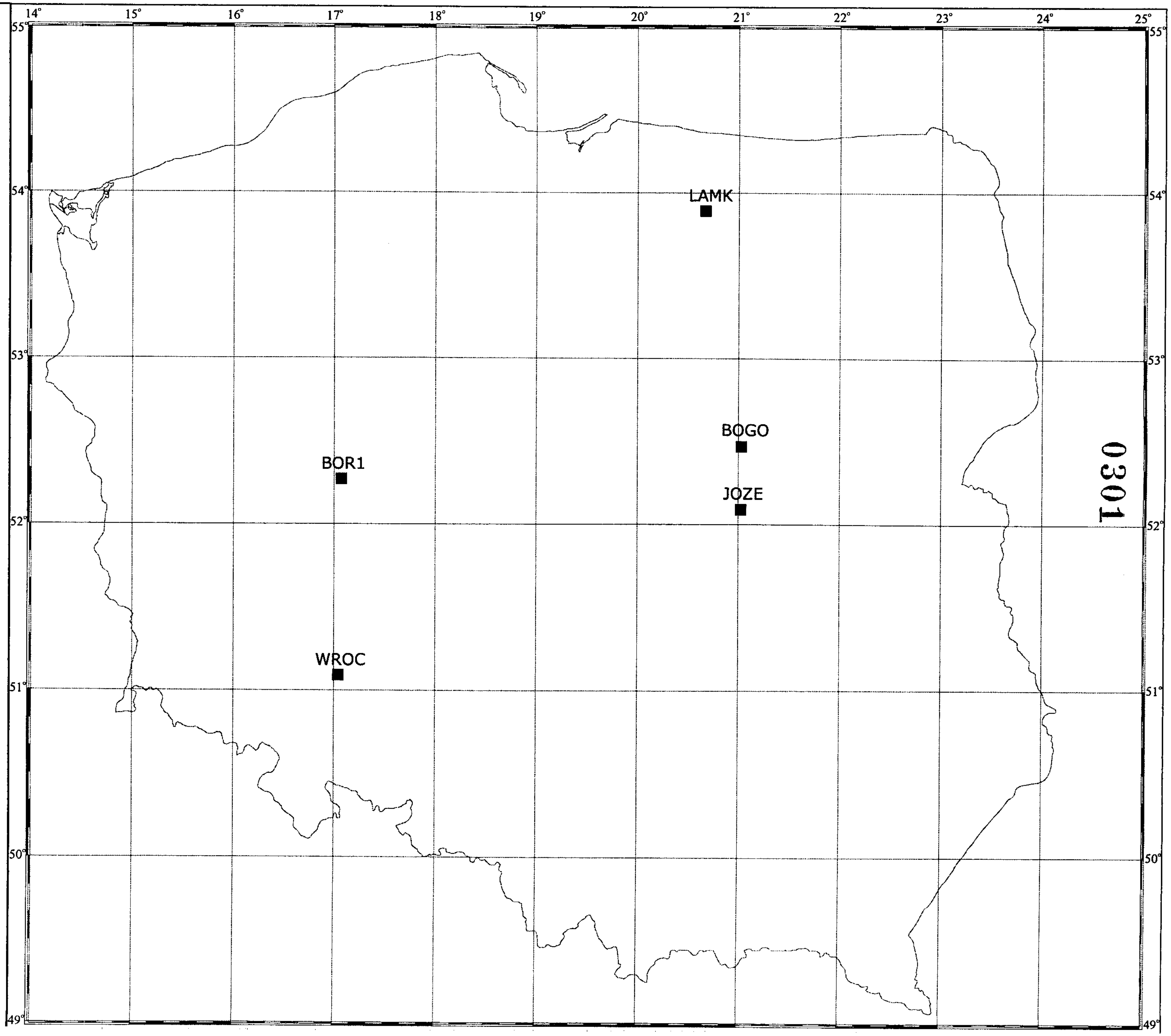
International GPS observation campaign EXTENDED SAGET done 27 June- 1 July 1998. About 30 European stations participated.

Borowiec Space Research Centre PAS station takes part in the International GLONASS Experiment (IGEX). The 3S Navigation R100-30T receiver operates continuously starting from the September 1. The main mission of this work is to test the time transfer methods by GPS and GLONASS.

POLAND

0 50 100
[km]

Permanent GPS stations in POLAND



LEGEND:

Permanent GPS Stations:

- ■ BOR1 Astrogeodynamical Observatory in Borowiec (SRC PAS)
- ■ BOGO Institute of Geodesy and Cartography (Observatory in Borowa Góra)
- ■ JOZE Institute of Geodesy and Geodetical Astronomy Observatory in Jozefoslaw (WUT)
- ■ LAMA Institute of Geodesy and Cartography Observatory in Lamkowko (Agriculture and Technical University in Olsztyn)
- ■ WROC Institute of Geodesy and Cartography (Agriculture and Technical University in Wroclaw)

Education and Information Activity:

1. **International Workshop on „Education in GPS Application to Geodesy and LIS/GIS" was organized in Grybów, by the Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology. Participants from 7 European countries took part in the workshop.**

2. **GPS Information Center continues its work of information and data dissemination by Internet and mailing. The web site address:** http://www.cbk.poznan.pl/~sextans/

3. **3-rd National Conference "Application of the satellite location systems GPS and GLONASS" was organised in Poznań, 28-30 Oct.1998, by the GPS Information Center. More than 130 participants attended, 30 papers were presented. Wide range of applications for static and mobile positioning and time transfer was discussed.**

4. **11-th International Conference on Navigation was held in Gdynia, 19-20 November 1998, with over 20 presentations discussing GPS application in maritime navigation.**

Instrument and Technology Development:

The market version of the L/N time transfer receiver was developed by the POLSPACE Ltd. laboratory. The receiver was designed and tested by BIPM, Paris, in collaboration with the Space Research Centre, Borowiec, Poland. It is based on the Motorola VP Oncore 8-channel GPS chip, combined with the high resolution time counter and PC. The dedicated software is the essential component of the receiver. Precision of the time transfer in common view mode is of the order of 1-2 ns.

Marine Navigation:

The DGPS system for coastal waters of southern Baltic is in routine operation and is systematically improved. Two stations:

Dziwnów = 54^0 01' N = 14^0 44' E

and Rozewie = 54^0 49 N = 18^0 20' E

are equipped with Leica reference stations and transmitters. RTCM messages are transmitted in LF/MF frequency band 24^h/day with the range over 100 km.