# Strategic Plan for Geodesy in Sweden

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## SUMMARY

Lantmäteriet (the Swedish Mapping, Cadastral and Land Registration Authority) has released a new 10-year-strategic plan for Geodesy that affects the whole country. This presentation will summarize the vision and goals for the period as well as the proposed actions for the coming years.

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## 1. LANTMÄTERIET'S GEODETIC ACTIVITIES

### 1.1 The role of the Department of Geodesy

Lantmäteriet's Department of Geodesy is the major player in the geodetic field in Sweden. In addition to the management of the Swedish reference networks, the Department also carries out comprehensive development, research and support activities including the operation and development of the SWEPOS™ reference network. Lantmäteriet is the co-ordinator in Sweden and also represents Swedish geodesy internationally**.** Our goals are to provide Swedish society and other users with

- Reference systems that are developed and managed in accordance with international praxis and which maintain, over time, a quality that satisfies user needs
- A geodetic infrastructure with both active and passive national networks that facilitates reliable access to our reference systems
- Measures to support an effective use of the geodetic infrastructure, for example in the form of method support and the provision of advice
- Geodetic observations and knowledge to back up development research and co-ordination, both nationally and internationally

### 1.2 Our role as co-ordinator

The Swedish government has given Lantmäteriet responsibility for the national co-ordination of geodata. For the Department of Geodesy this implies the role of co-ordinator in the geodetic field.

The development of the successful use of the geodetic infrastructure is the fruit of the co-operation between Lantmäteriet's experts and representatives for other central and local government authorities, private sector companies, colleges of higher education and the universities. In contrast to the situation in many other European countries, Sweden has launched both new reference systems and a national, active reference network, SWEPOS, for the benefit of all users. This has been possible without the need for regulatory legislation thanks to sound co-ordination and co-operation.

The role as co-ordinator will become even more important in the future as a consequence of, amongst other factors, the implementation of the Inspire directive, the goal of which is a common European infrastructure for geographic information. To achieve even better co-operation and co-ordination regarding geodetic issues, Lantmäteriet intends to supplement the SWEPOS reference group with a GeodesyForum, for interested parties in the public sector.

## 1.3 Our international role

Geodesy is a global science and its development is influenced by the world around us, which makes international co-operation very important. In Sweden, it is primarily Lantmäteriet and the technical universities that are currently contributing to international development.

Lantmäteriet's Department of Geodesy is engaged in extensive international co-operation. This is carried out directly through official channels, such as by representing Sweden in a number of international organisations. We also co-operate through professional contacts, often organised in professional societies and associations.

National and international reference networks are interdependent. The national networks represent the realisation of the international systems which, in turn, require observations from the national systems. This dependence has intensified during the last decade and development continues in a similar direction. The work is based on voluntary participation (own financing) by all of the involved organisations.

The international co-operation in which Lantmäteriet's Department of Geodesy is engaged will, therefore, increase during coming years and, to a great extent, will determine the direction of our activities. Our most important co-operating partners are the International Association of Geodesy (IAG) and its sub-groups in Europe. Currently, IAG's primary global project is the Global Geodetic Observing System (GGOS). There are also other global and regional organisations in which it is important to actively participate in order to be able to carry out effective geodetic activities in Sweden. Traditionally, co-operation between the Nordic countries has comprised co-ordination of field projects. The ambition is now to change the Nordic Commission for Geodesy (NKG) to be more of a platform on which it will be possible to co-ordinate our resources in several common projects as well as strengthening the role of the Nordic countries in European geodetic co-operation.

Through participation in overseas aid projects, Lantmäteriet also contribute to the development of geodetic activities in the recipient countries which, in turn, is a precondition for the success of the total project.

## 1.4 R&D activities

A large number of steps forward in development in several different technical fields will, most likely, lead to major and radical changes during the 2010s. In the geodetic field this development will be characterised by terms such as smaller, several, simpler, faster, more accurate, more flexible, cheaper and more highly integrated.

We believe, for example, that with GNSS (the generic term for different satellite systems), the transition between a good signal and zero signal, when contact is lost for a limited time because of a physical obstruction, will take place fully automatically without loss of accuracy. We also believe that the measurement of heights using GNSS techniques will, to a large extent, have replaced classical levelling towards the end of the period 2011-2020. Generally speaking, GNSS is becoming a mass market and will become a natural component in most measuring systems. We also believe that geodesy's contribution to, for example, environmental and climate research will have become more self-evident and have increased.

Lantmäteriet's R&D activities are based on the management of reference systems and their use and sustainability over time as well as techniques and methods for determination of position.

In addition, research is carried out to varying extents at the Royal Institute of Technology (KTH), Chalmers University of Technology and at SP, The Technical Institute of Sweden. Close co-operation in research is an important facet of Lantmäteriet's national responsibility.

### 1.5 Advice and support

Depending on their specific requirements, persons and organisations that carry out practical survey work often require impartial and objective advice concerning choice of measuring techniques and how they should be used.

The successful transition to SWEREF 99 and RH 2000 in both the municipalities and government authorities has required a significant input of advice and support. The level of competence in the field survey sector in the municipalities has shown a tendency to decrease at the same time as the new techniques have provided great opportunities for simple and cheap solutions with the risk for uncertain results. Many new players have also appeared on the market.

We believe, therefore, that the need for advice and support, in different forms via different media, will be at least as great during the period up to 2020.

An example is the revision of the first version of the Handbook for Surveying and Mapping (HMK) in which different methods and accuracy requirements for surveying and mapping are described. The purpose of the handbook is to contribute to increased conformity and improved quality in surveying and mapping methods in Sweden.

Together with practical experience, R&D is a precondition for Lantmäteriet's ability to be able to be active in this field in the future.

## 2. OUR STRATEGIC DOCUMENT

We have developed a strategic plan for the period 2011-20 in which we describe what we believe will influence the development of geodesy and surveying in Sweden. Having this in mind, Lantmäteriet should then prepare the geodetic infrastructure to meet this development.

In this paper we try to present the content of the strategic document. We started the work by discussing a scenario for geodesy in Sweden by the year 2020. Having the scenario in mind, we then discussed and developed our role in the future as well as key activities to be achieved.

The strategic document is available in both English and Swedish and can be downloaded from Lantmäteriet's webpage www.lantmateriet.se.

## 3. SCENARIO

### 3.1 Reference systems and infrastructure

By the year 2020:

- There will be a seamless, unified geodetic infrastructure with homogeneous and globally adapted reference systems
- Development will have made it possible to reduce the uncertainty of real-time positioning by an order of magnitude (10 times smaller)
- There will be several satellite systems which will mean a decreased need for physically demarcated control points
- The density of the permanent stations will have been increased
- SWEREF 99 and RH 2000 will have been introduced in all municipalities and government authorities
- GNSS techniques will be used for all standards survey activities
- The accuracy of GNSS will be good enough for height measurements.

### 3.2 Users

By the year 2020:

- The geodetic infrastructure will have an increased and wider use
- Users will have access to Sweden's reference systems always, everywhere, with an ultra-rapid response – often without them being aware of it
- The complexity of building and construction work and measuring will have accelerated and everything will be handled three-dimensionally.

### 3.3 Geodesy's role and status

By the year 2020:

- Through its Department of Geodesy, Lantmäteriet will continue to play an active role in the maintenance and development of both the national and international geodetic infrastructure, including development of methods and standardisation
- The extent of Lantmäteriet's role as co-ordinator and advisor concerning positioning will have increased due, amongst other things, to EU-related activities such as Inspire and Galileo
- Geodesy will have a more prominent role in the field of geodynamics and as a science at the service of environmental and climate research
- Lantmäteriet will have been actively engaged in efforts to guarantee the availability of competence in the field of geodesy.

## 4. THE GEODETIC INFRASTRUCTURE

The basis for a geodetic infrastructure comprises geodetic reference systems, including definitions, conventions and rules for their use. In Sweden these are SWEREF 99 and

RH 2000. The reference systems are realised in the form of reference networks, which can be passive or active.

A passive reference network consists of ground markers. RH 2000 is, for example, realised by a network of 50 000 points.

SWEPOS is an active reference network for use with GNSS measurements, which realises SWEREF 99 and distributes corrections for real-time measurements in SWEREF 99 and RH 2000.

Our systems for the provision of data and support for SWEPOS and the digital geodetic archive are part of the geodetic infrastructure. This infrastructure supports the infrastructures for road and railway communications, the provision of electricity power supplies and more. It is also a fundamental part of the technical infrastructure for geodata.

Our reference networks are not only connected to those of the other Nordic countries, they are also realisations of the European ETRS89 and EVRS reference systems. Lantmäteriet's activities including, amongst others, the supply of data and the analysis of geodetic data, are essential for the whole of the European geodetic infrastructure.

The globally important, fundamental station, the Onsala space observatory in western Sweden, is also part of the geodetic infrastructure as also are the Swedish Metrological and Hydrological Institute's mareographs.

Based on the geodetic infrastructure, different groups and organisations in Swedish society can capture their own positional data which then can be used, processed and analysed together. Today, several different areas are dependent on this infrastructure. These include:

- All types of measurements, positioning and navigation
- Mapping and hydrographical surveys
- Exchange, use and quality assurance of geodata
- The efficient use of modern measuring techniques such as GNSS
- The measurement of sea level and movements in the earth's crust
- Support for physical planning and a legally secure implementation of plans based on documented and, over time, reliable positional information
- Laws, ordinances, other statutes and legal decisions which contain co-ordinate information even where there is no reference to a geodetic reference system.

In order to guarantee its sustainability over time, management of the geodetic infrastructure includes both measurements to keep passive systems up to date and continuous measurements in the active network.

## 5. MEASURING WITH GNSS

GPS/GNSS techniques can now be used for practical positioning with centimetre accuracy and are on the way to replacing an ever increasing part of standard surveying methods. Examples of applications include large-scale surveys, cadastral surveys, steering of machines

in construction projects and agriculture, positioning different types of underground utilities and the collection of data for databases containing geodata.

During the years up to 2020, new satellite signals in the existing GPS and GLONASS systems will be taken into use, which will mean that these systems, by 2020, will each have signals on three frequencies.

When Galileo becomes operational we will have a new satellite system with three frequencies. Currently the system is planned to be operational with 16 satellites by 2014 and complete by 2016 – 2018, depending on the availability of financing. What will happen with the Chinese system, Compass, is at present difficult to predict.

### 5.1 Quicker and more reliable positioning

The introduction of new satellite systems will make satellite techniques even more usable for positioning in environments where free line of sight to the satellites is restricted, such as in urban environments with high rise buildings and in forest areas. The combination of new satellite systems and new satellite signals for GPS and GLONASS will make positioning quicker and more reliable.

It will take time before the new GNSS signals and new satellite systems can be used for general production measurements. There will be a need for comprehensive standardisation in order to achieve compatibility between different software and user terminals.

Different combinations of the, at least, nine available satellite signals will have differing characteristics from a users point of view. To be able to handle all of these new satellite signals, major development work is required for both software and hardware, both on the user terminal side and by those who provide positioning services such as SWEPOS.

The fact that Sweden, through the European Union, is part owner in the Galileo system calls for extra Swedish engagement in the formulation of specifications for the satellite system's performance and, above all, in the design of the services that will be provided.

### 5.2 Improved possibilities to make measurements

GNSS receivers, combined with MEMS techniques (microelectromechanical systems for inertial positioning), will enhance possibilities to make measurements with GNSS techniques without free line of sight to satellites and indoors.

The development of MEMS techniques for use in different fields, such as vehicle crash testing, indoor navigation and positioning of drilling equipment, is in progress. The development of equipment suitable for combination with professional GNSS measurements will require separate development work in the form of projects that are supported by Swedish research organisations such as Nutek.

Another important pre-requisite for an efficient use of satellite techniques by different user groups is that information regarding the present situation concerning technology and satellites is made directly available from source in the form of seminars and user-group meetings.

### 5.3 Lantmäteriet's role as a co-ordinator and instigator

If Sweden is to retain a leading position as a user of satellite techniques, Lantmäteriet must continue to actively promote and play a co-ordinating role concerning the development of the use of GNSS techniques.

Furthermore, Lantmäteriet should support the formulation of standards for positioning in different areas of application and maintain a continuous dialogue with various user-groups.

## 6. INFRASTRUCTURE FOR GNSS

At present, the National Infrastructure for GNSS measurements comprises the national network of permanent reference stations, SWEPOS, and local user-managed reference stations. In addition, there is the Swedish Maritime Administration's DGPS network, the satellite-based Starfix service from Fugro and the European support system, EGNOS.

SWEPOS is unique in a global perspective as it provides data for both measurements for production purposes in the form of precision navigation, large-scale mapping, steering of machinery and for scientific studies of movement in the Earth's crust.

### 6.1 Densification of the SWEPOS network would give immediate results

According to a customer survey, users would like to have a lower level of uncertainty in heights measurements made using GNSS. A densification of the SWEPOS network in Sweden, possibly with the co-operation of local groups, would have an immediate effect. When new satellite signals become usable for production measurements the uncertainty in height measurements will be further reduced.

At present, SWEPOS data is distributed by Lantmäteriet and Teracom via different channels. During the years up to 2020, it can be expected that additional European partners will participate in this distribution. With wider distributors, use all the use of SWEPOS data will increase.

### 6.2 Risk for local reference systems

Data from the national network of permanent reference stations should be supplied under conditions that make it more attractive for users than establishing their own reference stations. The use of local reference stations often results in a risk for "local dialects" of the national system. This would be a retrograde step now when all municipalities and government authorities and other owners of geodata have adopted SWEREF 99 and RH 2000.

### 6.3 Continues co-operation

Lantmäteriet should provide data in the form of raw data for further distribution by other bodies and as positioning services directly to end-users. Lantmäteriet should continue to participate in the existing form of co-operation with users, instrument suppliers, and Nordic sister organisations, colleges of higher education and the universities, in the operation and development of SWEPOS.

## 7. OUR PLANNED, MORE EXTENSIVE R&D PROGRAMMES FOR THE PERIOD UP TO 2020

We plan to:

- Continue to carry out R&D concerning theories and methods for geoid determination
- Extend our R&D activities concerning geophysics-based models for land uplift
- Further develop theories and methods for implementing deformation models in the maintenance of our reference systems
- Strengthen our R&D work concerning applied GNSS including, amongst other things, the impact of the availability of several satellite systems, in order to increase accessibility and decrease uncertainty in measurements
- Initiate R&D work concerning the integration of GNSS receivers with MEMS techniques
- Play an active role in the development of methods to utilise new techniques and use combinations of modern and traditional techniques, in a rational way
- Participate in R&D work concerning, for example space weather with the goal of achieving a lower level of uncertainty when making measurements using RTK network
- Contribute through active R&D to development of methods and norms for the quality marking of measuring systems and their reliability, in order to help users have control over their measuring processes
- Finance 1-2 doctoral candidates continuously. The GNSS research field will be given priority with a focus on applications and error sources
- Strive to have the sector responsibility for geodesy so that we, in a more active way, can stimulate and guide development by placing R&D assignments with colleges of higher education and the universities
- Participate in the development of Swedish GNSS competence
- Increase the number of projects that are carried out in co-operation with colleges of higher education, universities, sister organizations and others.

## 8. OUR KEY AREAS OF ACTIVITY

Lantmäteriet will continuously:

- Manage and keep the SWEREF 99 and RH 2000 geodetic reference systems updated
- Densify the SWEPOS network of reference stations, based on an approved plan, for ensuring accessibility and to increase the use of GNSS in real-time
- Carry out R&D work concerning the management of reference systems and their sustainability as well as the development of methods and techniques for positioning
- Actively follow-up and support development within both GNSS and other areas in the field of geodesy as well as being a driving force and leader

- Strive to promote the early introduction of modern GPS, GLONASS and Galileo in Sweden
- Contribute to international geodetic co-operation by both supplying data and actively participation in working groups
- Actively participate in and, where necessary, initiate standardisation activities in our area of activity
- Actively provide support and advice in our area of competence.

During 2011 we will place special focus on:

- The formulation of an overall plan for keeping reference networks up to date
- Ensuring that every SWEPOS station has at least two foundations for GNSS antennas, in orders to guarantee the consistency of time series and the development of SWEPOS services
- The introduction of the next generation of network RTK software
- Finalising the geodesy part of the new version of HMK and, thereafter, continually keeping the handbook up to date.

During 2012 we will place special focus on:

- Completing the preparatory work on the reference network in order to be able to receive signals from Galileo and modernised GPS/GLONASS
- Beginning measurement of relative gravity for supplementing and evaluating older measurements before they are used for determination of the geoid
- Making efforts, together with other interested parties, to develop combined measuring sensors based on GNSS and MEMS
- Formalising our role as co-ordinator in the geodesy field and gaining acceptance for a Geodesy Forum in Sweden.

During 2013 we will place special focus on:

- Continuing the measurement of gravity for determination of the geoid
- Carrying out a pilot project for measurements with Galileo.

By 2015 we will have:

- Guaranteed the use of GNSS in real-time with the measuring uncertainty reduced to the centimetre level both horizontally and vertically through a densification of SWEPOS
- Created a new three-dimensional model for post-glacial land uplift phenomenon
- Been actively engaged in ensuring that municipalities and government authorities have completed the transition to the new national SWEREF 99 and RH 2000 systems
- Defined and created a new gravity system, RG 000, and also established a new gravity network
- Measured relative gravity on approximately 4 000 points

- The possibility to utilise the results of implemented satellite projects, such as GOCE, for determination of the Earth's global gravity field
- Created a geoid model with an uncertainty of less than 10 mm
- Developed NKG's analysis centre so as to include all permanent reference stations in the Nordic countries.

By 2020 we will have:

- Guaranteed the long-term sustainability of seamless and unified reference systems, that satisfy user demands, through active management policies
- Created a geodetic infrastructure that gives users access to reference systems in real-time with an uncertainty of less than 1 cm
- Produced a geoid model for the whole of Sweden that has an uncertainty of less than 5 mm
- Ensured, through active participation that the European reference systems, ETRS89 and EVRS, still remain in use for technical applications.

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## BIOGRAPHICAL NOTES

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Mr Lilje is the Head of the Geodetic Research Department at Lantmäteriet (the Swedish mapping, cadastral and land registration authority). He graduated with a M.Sc. with emphasis on geodesy and photogrammetry from the Royal Institute of Technology (Stockholm, Sweden) in 1993. He has been working at Lantmäteriet since 1994, mainly at the Geodetic Research Department. He is also chair of FIG Commission 5 as well as chair of the FIG Working Group on "Reference Frames in Practice".

### Mr. Lars E Engberg

Mr Engberg obtained his masters degree from the Royal Institute of Technology in Stockholm 1973. He has been working as a lecturer in geodesy at the School of Surveying for many years. Between 1989 and 1996 he was at the City Surveying Department in Stockholm and responsible for the establishment of an improved reference network in Greater Stockholm. Since 1996 he is working at the Geodetic Research Department at Lantmäteriet. He was involved in a national project aiming to implement the new reference frame SWEREF 99 as a national standard as well as in INSPIRE data specifications. He is also engaged as an international adviser.

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