Geodesy 2010

A strategic plan for Lantmäteriet's geodetic activities 2011 – 2020

Our vision

– is to be able to meet Swedish society's needs for a homogeneous, sustainable geodetic infrastructure and to guarantee its availability and use.

Preface

The Swedish government has given Lantmäteriet the national responsibility for co-ordinating geodata. This also includes responsibility for the national geodetic reference networks and for promoting the development of a homogeneous, national geodetic infrastructure. Geodesy is one of our key activities.

Geodata – data with some form of positional relationship – has become of increasing importance for the development of society. The national geodata strategy has been formulated to provide guidance to all parties in Sweden who are engaged in the establishment of a more efficient management and use of geodata. The present 10 year plan is one of several stages in the long-term task of creating a national infrastructure for geodata.

During the last decade we have witnessed, both in Sweden and internationally, a shift from traditional to space-based geodesy. Positioning is now a relatively simple and inexpensive process. In order to be able to take full advantage of technical opportunities, Lantmäteriet´s geodetic activities must keep abreast of technical developments.

The main focus of the activities of the Department of Geodesy should be on the establishment and maintenance of reliable geodetic and gravimetric reference networks to support a high level of accuracy in the determination of position and for making geodetic measurements of the dynamic Earth. These measurements also contribute to research concerning climatic change, natural catastrophes and other occurrences that have an impact on society.

Lantmäteriet's strategic plan for geodetic activities extends to the year 2020 and is in resonance with activities in the world around us. The plan is the successor to the earlier strategic plans, Geodesi 90 and Geodesi 2000, which have been successful in moving Swedish geodesy forward.

Stig Jönsson, Director General, Lantmäteriet

PRODUCTION: Lantmäteriet 2011
PHOTO AND MONTAGE:
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Lantmäteriet's geodetic activities

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. The Department of Geodesy, which is placed within the Land and Geographic Information Division, has a staff of 35 and a turnover of SEK 58 million (2010).

Our strengths

- Our staff, our knowledge base and our competence.
- We are at the forefront of and innovative in several R&D fields.
- Our solid reputation. We are considered to be independent, knowledgeable and trustworthy and act without profit motives.
- Our wide contact network in Sweden, the Nordic countries and internationally. Users provide us with their support and allow insight into their activities.

Our challenges

- To be able to continue to attract and recruit well-educated, competent staff.
- To be able to strengthen our external focus.
- To be able to meet the increasing needs of existing and new user groups.
- To be able to carry out the role as co-ordinator in a satisfactory way and to carry out an efficient technical monitoring despite not having our own production.

Important factors for our success include further development of co-operation with sister organisations, users, suppliers of instruments and training and educational institutions. It will also be necessary for us to contribute to the raising of the level of scientific competence in the field of geodesy.

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.

Our role as co-ordinator

The Swedish government has given Lantmäteriet responsibility for the national co-ordination of geo-data. 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 Geodesy Forum, for interested parties in the public sector.

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 Geodetic Commission (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.

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.

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.

A generation and technological shift

In the geodetic field, as in many other branches in Sweden, a major generation shift is taking place. Concurrently, a comprehensive shift in technology, based on positioning using satellite techniques and integrated technique solutions, is also in progress.

New staff will be recruited and new work routines will be introduced simultaneously and this will take place during a period which is characterised by a decreasing interest among young people for technical education.

Broad and expert knowledge is needed

There are issues of competence at different levels and they should be seen from several perspectives. To be able to maintain and develop the geodetic infrastructure there is a need for in-depth knowledge in many fields of geodesy.

Efficient survey activities require both broad and expert knowledge. Furthermore, there must be competent decision-makers and knowledgeable clients as well as competent executors.

The dissemination of technical information and methods requires both focused developers as well as able communicators. Users also need to have an opportunity to take part in further education courses. One particular challenge is the introduction of GNSS measuring methods in completely new branches.

For the successful provision of competence there must be both interest and engagement in the branch — with Lantmäteriet as an active driving force.

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 statute s 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.

SWEPOS

A network of permanent reference stations for GNSS, its operations centre and examples of reference stations.

Geodetic activities in Sweden

In addition to Lantmäteriet's Department of Geodesy, geodetic activities in Sweden are also carried out by specialists at a number of municipalities and government authorities (primarily the Swedish Maritime Administration and the Swedish Transport Administration), private companies and colleges of higher education and the universities. Together, these bodies, each in its own specialist area, are engaged in creating a uniform and sustainable geodetic infrastructure and in bringing about an efficient use of it.

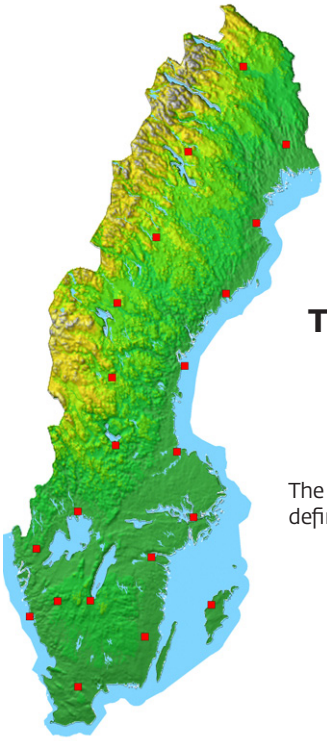
Geodesy's contributions to society

Geodesy makes a wide range of significant contributions to society, although few seem to be aware of their importance. Today, over 80% of all information on the Internet is geographically located i.e. it has a position in a geodetic reference system. At least 70% of all searches on Google also have a geographic location where the information is linked to a position, for example when environmental and climate issues such as variations in sea level over time are discussed or where the position of an observation needs to be accurately described.

Positions are linked to a digital map

A typical, everyday question from the general public, concerns positions shown on GPS instruments and how to link them to a digital map. At a professional level, a question can come, for example, from an excavator operator, whose machine is steered by a system that provides information about where and how deep he should excavate, and who wants to know more about how the system works. These are examples where there is a need for a system that provides accurate horizontal and vertical positions. Geodesy provides this information and very much more also.

The geodetic infrastructure is an important part of the Swedish emergency preparedness structure. The use of uniform co-ordinate and height systems ensures a correct exchange of data between different organisations in emergency and crisis situations.



SWEREF 99

The 21 fundamental stations defining SWEREF 99.

RH 2000

Levelling lines in the third precise levelling network, the base for RH 2000.

The Swedish realisations of the European geodetic reference systems

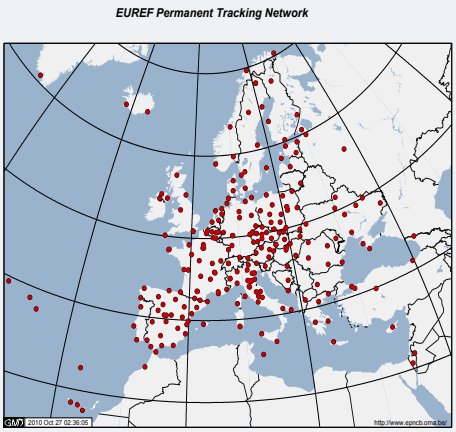
European reference systems

The three-dimensional reference system, ETRS89, is used throughout Europe. With the support of Euro-Geographics and the European Union, this reference system is a core component in all geographic and geodetic projects in Europe, both on national and international levels.

ETRS89 is managed by the International Association of Geodesy's sub-commission, EUREF, and is accessed via EPN (EUREF's permanent network), which is a research-steered network of continuously registering GNSS stations with known co-ordinates in ETRS89.

All contributions to EPN are voluntary although more than 100 European universities and National Mapping Authorities, including Lantmäteriet, participate.

The reliability of the network is based on redundancies and comprehensive guidelines guarantee quality from raw GNSS data to the stations' new coordinates. In addition to its key role for the maintenance of ETRS89, data from EPN can also be used for a broad spectrum of scientific applications such as detection of movements in the earth's crust (geodynamics), monitoring of sea level, space weather and numerical weather forecasts.



More than 200 EPN stations provide GNSS observations in real-time. The data is made available through local and regional data centres.

EVRS (the European height system) is also managed by EUREF. The system is based on data from national precision levelling networks and land uplift data in order to facilitate the exchange of height data within Europe.

Geodesy in climate research

What is the difference between weather and climate? The simplistic answer is: "climate is the average value of weather". More precisely, climate can be described as variations in the character of the weather during a longer period of time and over a wider area.

Geodesy can contribute to both weather forecasting and to climate research. Some of the impacts of human activity on climate include higher temperatures, the more rapid melting of glaciers and rising sea levels. Higher sea levels are "masked" by land uplift, a factor which must be determined and taken into account when making computations.

Water vapour sounds harmless but it is, in fact, one of the most powerful greenhouse gases. Water vapour is a problem when carrying out accurate GPS observations and it must be determined and corrected for. For weather forecasting and studies of climatic change, the gas is an important input parameter. In other words, what is unimportant on the one hand is valuable information on the other.

GNSS data from SWEPOS stations is used to continuously compute the water vapour content in the atmosphere. Lantmäteriet's Department of Geodesy co-operates in these fields with the Onsala Space Observatory of Chalmers University of Technology, the SP Technical Research Institute of Sweden and the Swedish Meteorological and Hydrological Institute (SMHI).

Many scenarios within climate research predict an increase in the number of extreme weather situations, such as storms and torrential rain. Preparedness includes, amongst other measures, carrying out risk analyses such as risk for flooding. These analyses require detailed geodetic and geographic basic information. Lantmäteriet has, therefore, begun the task of producing a new national terrain elevation model (NNH). Data is collected using airborne laser scanning and elevations in the model are referred to the RH 2000 height system.

Space geodesy and geodynamics

Lantmäteriet's geodetic activities mirror a strong and genuine interest for continuing and increasing co-operation with Onsala Space Observatory.

Onsala is the Swedish national facility for radio astronomy. The objective of the observatory is to provide world-class observing facilities for the Swedish and international astronomical communities. The Institution for Earth and Space Sciences at Chalmers University of Technology operates the observatory and activities are carried out on behalf of the Swedish Research Council.

There are two large radio telescopes at Onsala which are used for astronomical observations both as independent telescopes and together with radio telescopes in other parts of the world. The latest technique that is used is VLBI (very long baseline interferometry).

The VLBI technique is also used for geodetic observations, for example to study earth crust dynamics.

There is also other equipment for space geodesy at the observatory (for instance GPS/GLONASS receivers) and for gravimetry (superconducting gravimeter), which makes the facility a fundamental station of global significance which actively contributes to the continued development of geodesy.

Onsala Space Observatory.

As part of the research activities, measurements are made to determine movement in the earth's crust as well as earth rotation parameters as well as the amount of water vapour in the atmosphere, mainly with the help of GPS and VLBI.

Onsala is one of the radio astronomy observatories that have the longest history of measurement of movements in the earth's crust. Observations of global movement (plate tectonics) are of major significance for, amongst other purposes, the realisation of ITRS (the international reference system).

Observations of sea level

The Swedish Meteorological and Hydrological Institute's (SMHI) mareograph data is of great value for the management of the geodetic infrastructure.

Information concerning changes in sea level is, for example, necessary for Lantmäteriet to be able to determine land uplift.

The official Swedish network for measuring sea level comprises, at present, 23 stations with mareographs. SMHI has responsibility for the stations, as well as for data and the levelling of them.

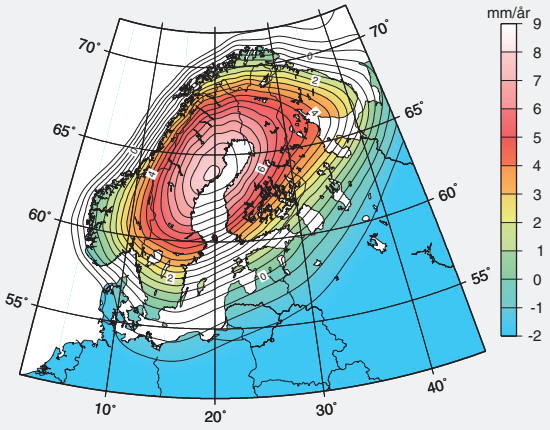
In the countries around the Baltic Sea there are several long, unbroken series of such measurements. The Swedish series is amongst the longest, unbroken time series in the world.

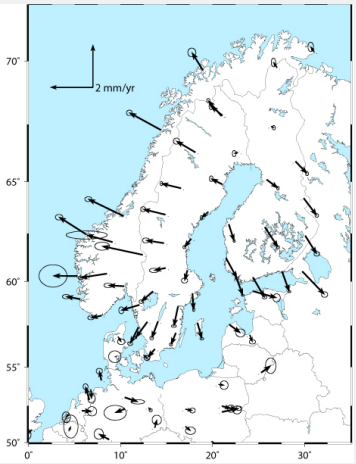
The Mareograph in Stockholm.

Earth dynamics

The Earth is not a rigid body but, instead, is continually changing due to the effects of external and internal forces. Continental drift and earthquakes are well known phenomena. In our part of the world we have land uplift as a result of the latest ice age. The crust of the Earth which was depressed by the weight of the kilometre-thick ice is now rising to reach a state of equilibrium.

Dynamic processes deform the Earth's crust which results in the relative positions of objects on the ground changing over time. In addition to its scientific value, the knowledge of these processes is of considerable value for the maintenance of our national reference systems. Land uplift has a maximum value of 10 mm per year in the vicinity of Umeå in northern Sweden, whereas the horizontal movements make Sweden approximately 1 mm wider per year. From having been stable during a long period of time, sea level began to slowly rise from the middle of the 1800s. At present, the changes in our area have been calculated to be around 2 mm per year.





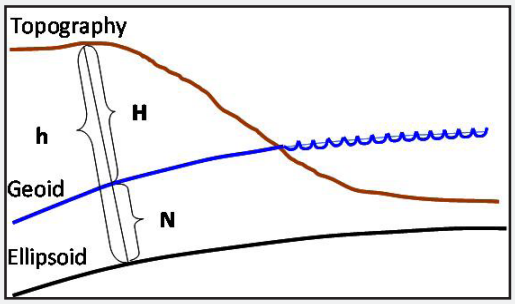
Measured horizontal movements at permanent reference stations in northern Europe.

A complicated process

The interaction between increases and decreases in the volume of ice in glaciers, land uplift/land sinking and changes in sea level is a complex process and is an area in which a great deal of research is being carried out. Land uplift in the Nordic countries is important in this context since it has been observed in long time series (>100 years) and because there is no significant, ongoing melting of glaciers in the area which could affect the equilibrium of the earth's crust. Furthermore, the volumes of melt water that run off the Scandinavian glaciers represent an extremely small part of the observed rise in sea level. We have, therefore, an international responsibility to provide researchers with the best possible geodetic observations - primarily GNSS observations at permanent reference stations as well as gravity changes.

The geoid

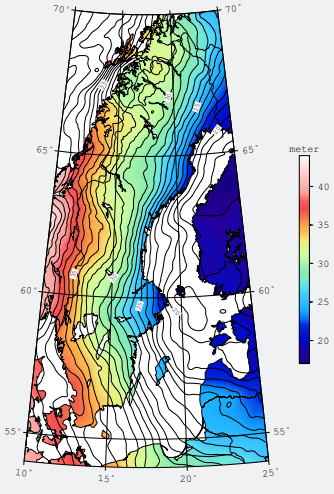
The geoid is the level surface in the Earth's gravity field that best approximates to mean sea level. A level surface is a closed surface everywhere at right angles to the direction of gravity (plumb line); an undisturbed water surface is part of a level surface. The geoid is the reference surface over which levelled heights (H) are measured as "heights above sea level".



The height of the geoid (N) relative to an elliptical Earth model varies by approximately +/- 100 m globally. The geoid is of fundamental importance for determining heights with GNSS in RH 2000. Changes in mean sea level affect the geoid, which is one reason for that the geoid also changes with time.

Geoid modelling

Geoid modelling requires measurements of gravity both globally and locally in Sweden with at least 5 km between points. The availability of greatly improved data has been significantly increased through satellite projects such as GOCE. Over sea areas and oceans, satellite altimetry is used. In addition, there is a need for, amongst other data, information concerning terrain elevation. The current Swedish geoid model, SWEN08, has an uncertainty of approximately 15 mm. The requirement is for a much better value, and our aim is to reach an uncertainty level of around 5 mm before 2020 at the latest. This will require going through and making additions to Lantmäteriet's archive containing gravimetric observations, improvement of the gravity reference system and development of theory and methods for computing geoid models.



Measuring with GNSS

GPS/GNSS techniques can now be used for practical positioning with centimetre accuracy and are on the way to replace 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.

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 user's of 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.

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.

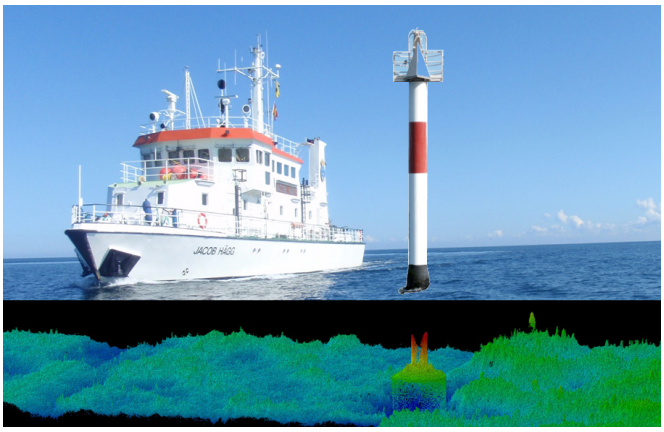
Another important pre-requisite for an efficient use of satellite techniques by different user groups is that information regarding the present situation concerning technology and satellites is made directly available from source in the form of seminars and user-group meetings.

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.

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.



Densification of the SWEPOS network would have 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, all the use of SWEPOS data will increase.

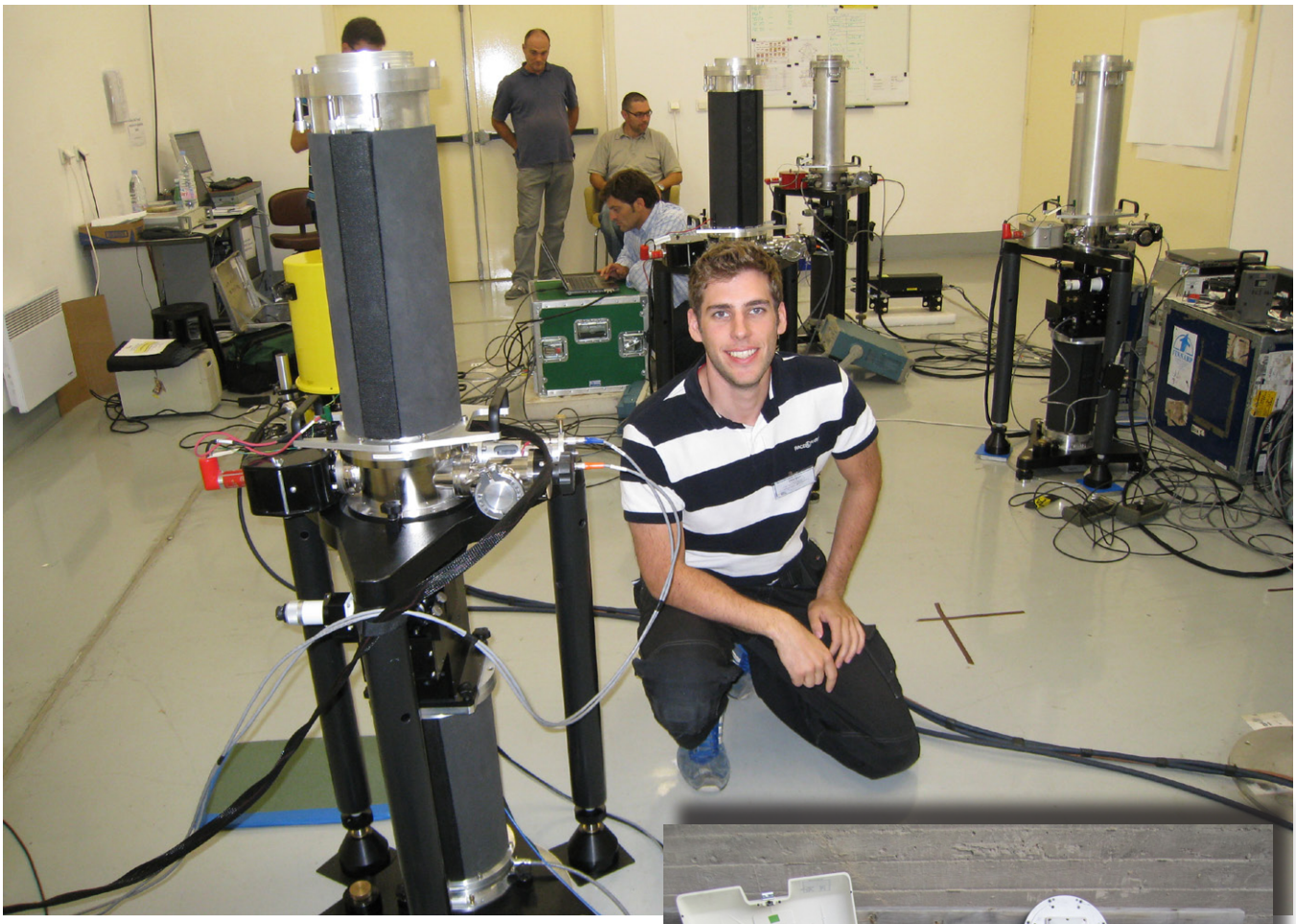
Risk for local reference systems

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.

Continued 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.

Our planned, more extensive R&D programmes for the period up to 2020



The Swedish absolute gravimeter being calibrated at the International Bureau of Weights and Measures in Paris in 2009.

An example of GPS equipment from the last 20 years.

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 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 the 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.

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 maintenance 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 an early introduction of modern GPS, GLONASS and Galileo in Sweden.
- Contribute to international geodetic co-operation by both supplying data and actively participating 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.

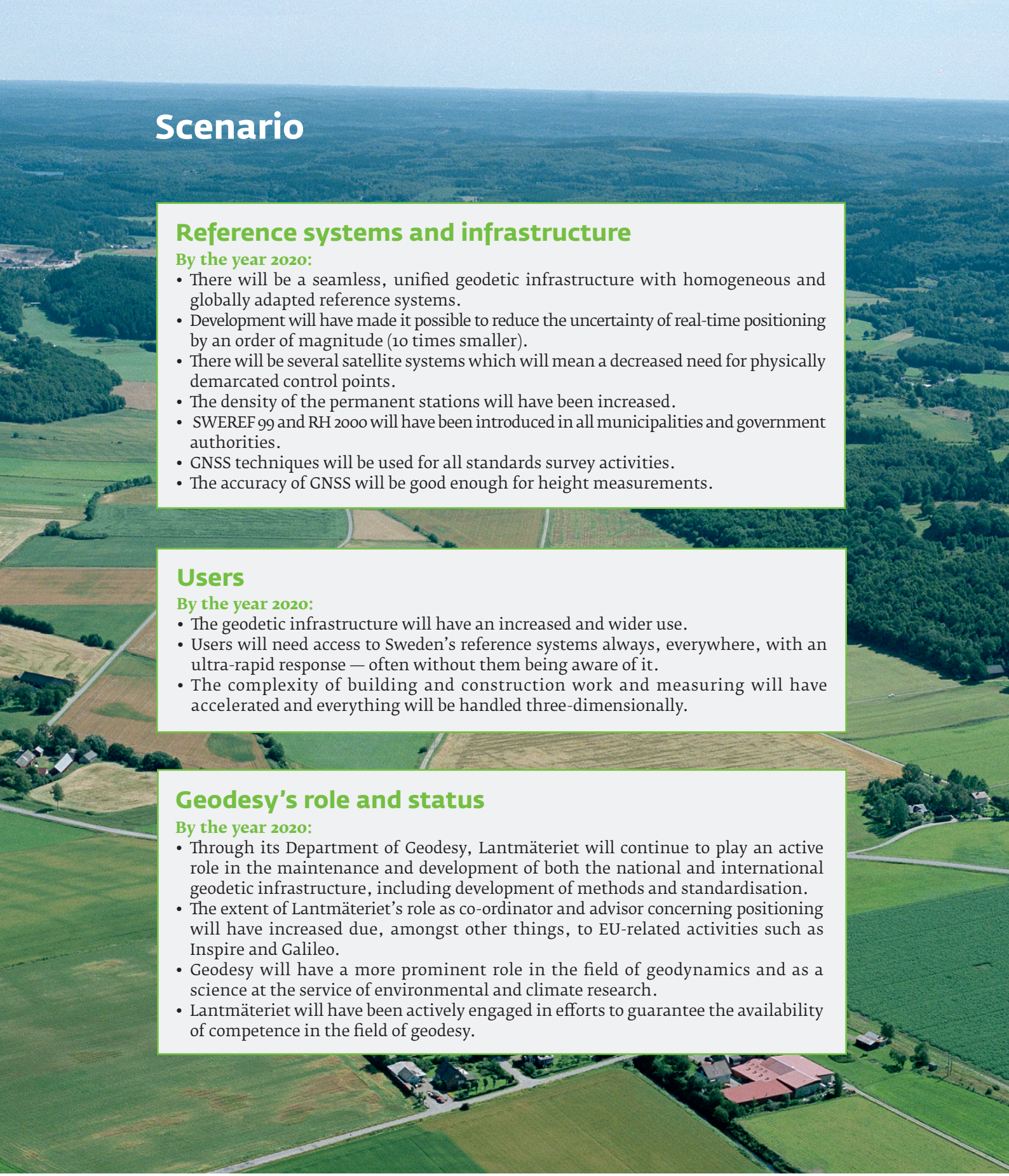
During 2011 we will place special focus on:
- The formulation of an overall plan for keeping reference networks up to date.
- Ensuring that every SWEPOS station has at least two foundations for GNSS antennas, in orders to guarantee the consistency of time series and the development of SWEPOS services.
- 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 permanent 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 the 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 2000, and also established a new gravity network.
- Measured gravity relatively on approximately 4 000 detail 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 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, ETRS 89 and EVRS, still remain in use for technical applications.



Scenario

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.

Users

By the year 2020:

- The geodetic infrastructure will have an increased and wider use.
- Users will need 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.

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.

LANTMÄTERIET

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